



# Improving Energy Resilience Of Buildings in New York City

**CLIENT** New York State Energy Research & Development Authority  
**TEAM** Brian Byrne, Shawn Cook, Chris Gallagher, Dwight Green, Laura Humphrey, Katrina Prutzman, Coury Revan, Josh Rosenfield, Shubhra Singhal, Cory Weissglass  
**EDITOR** Josh Rosenfield  
**ADVISOR** Susanne DesRoches

MASTER OF SCIENCE IN  
**Sustainability Management**  
THE EARTH INSTITUTE | COLUMBIA UNIVERSITY  
COLUMBIA UNIVERSITY | School of Continuing Education

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# 1 Executive Summary

Hurricane Sandy served as an alarming signal of the formidable risks that New York City faces from climate change. The last two and a half years have seen three of the 10 highest floods at the Battery since 1900 (Chen & Navarro, 2012) – and storm-related coastal flooding is very likely to increase as sea levels rise (New York City Panel on Climate Change, 2009). Indeed, shoreline areas in New York City will be inundated more frequently and other low-lying locations will be permanently submerged (New York State Sea Level Rise Task Force, 2010).

Given that many buildings store critical components of their energy systems in their basements and lower floors, the ability of New York City’s buildings to remain operational during and after flooding emergencies – not to mention blackouts and other power losses – is uncertain at best. Power losses during Hurricane Sandy caused the disruption of healthcare services and the dislocation of New York City’s residents and workers from their homes and businesses.

This report responds to a request from the New York State Energy Research and Development Authority (NYSERDA) to analyze strategies for improving the resilience of energy systems in New York City’s buildings against flooding, and to recommend best practice strategies that NYSERDA might support through its existing programs or through new programs. The report is intended to help NYSERDA begin defining a systematic approach to promoting energy resilience in New York City’s buildings, along with energy efficiency.

The analysis focuses on three types of large, high-occupancy buildings in New York City’s low-lying coastal areas: hospitals, multifamily buildings, and commercial buildings. The report draws on case studies, based practices, and interviews with expert practitioners in New York City to identify resilience strategies for building energy systems and provide details about them.

The resilience strategies have been analyzed in terms of technical feasibility, policy considerations, barriers and solutions associated with New York City and NYSERDA, and costs. The strategies are also evaluated for their potential to improve resilience in each of the three key building types. The building-specific analysis is important because in flooding emergencies the building types must perform distinct functions, which put different demands on energy systems.

As such, each building type has specific requirements for how resilient its energy systems must be against flooding. These requirements mean that certain strategies will be practical for certain buildings but not others. Moreover, no single strategy promises to meet all the resilience requirements of each building type. It is therefore recommended that certain resilience strategies be combined into holistic resilience approaches to meet each building type’s performance requirements.

Finally, based on an analysis of NYSERDA’s existing funding and technical support programs a series of recommendations is presented for how NYSERDA might integrate support for resilience into its program structure. The ultimate recommendation is that NYSERDA provide support for feasibility studies on resilience in order to gather additional information that might be used to form a case for integrating resilience measures in existing or new programs.

# 2 Climate Change, New York City, and Resilience

## Chapter Overview

- New York City is at risk of damaging storm surges because of its geography
- Climate change is increasing that risk and is projected to create greater risk in the future
- Floodwaters can cause damage to buildings' energy systems and disable their key functions
- Making energy systems resilient against flooding requires balancing multiple considerations

## CLIMATE CHANGE: LEARNING FROM SANDY, LOOKING TO THE FUTURE

This section provides a brief explanation of how the threat of flooding is increasing because of climate change. An understanding of the extent and likelihood of the threat of flooding in New York City can be helpful as a basis for developing recommendations of strategies to make buildings' energy systems more resilient against flooding, as well as possible incentives to building owners and landlords to implement the recommended strategies.

In October 2012, Hurricane Sandy, the widest storm ever to touch the Atlantic coast, struck New York City (Halverson & Rabenhorst, 2013). The storm destroyed 305,000 homes and 265,000 businesses in New York State and killed 43 people in New York City (Hond, 2012). Nearly 260,000 households were displaced following the storm and won approval for \$373 million in FEMA assistance (McKelvey, 2013).

Jones Lang LaSalle, a real estate service firm, estimates that 49 of 183 office buildings in Manhattan's downtown business district were closed because of mechanical failures, with half of those buildings running on temporary power one month later (Associated Press, 2012). Eight weeks after the storm, 11 percent of commercial office space in lower Manhattan was still closed (The Real Deal, 2012). Estimates of property losses from the storm range from \$25 billion to \$30 billion, and the total economic impact has been estimated at \$50 billion to \$75 billion (Herbst, Cassedy, Marks, Nikodem, & Shobowale, 2013).

Hurricane Sandy was only the latest signal that New York City is facing formidable risks from climate change, which include rising sea levels, increasingly frequent extreme weather events, and increases in annual precipitation. The year before, Tropical Storm Irene prompted city officials to order the evacuation of 370,000 people and to shut down the subway system (Navarro, 2012), and ultimately caused considerable flooding in the Rockaways and in Lower Manhattan (Chen & Navarro, 2012). The last two and a half years have seen three of the 10 highest floods at the Battery since 1900 (Chen & Navarro, 2012).

Trends in climate change as well as urban development in New York City suggest that certain sections of the city will increasingly come under threat. Projections developed by state- and city-appointed panels of researchers include the following:

**Under the consensus projection of a global temperature rise of 1-2 °C by 2100, the sea level around New York City is projected to rise three feet.**

- Powerful storms are highly likely to hit New York City's coastline, and the likelihood will increase over time (New York State Sea Level Rise Task Force, 2010)
- Sea level rise and coastal flooding from storm surge are already affecting New York City's coastline (New York State Sea Level Rise Task Force, 2010), and storm-related coastal flooding due to sea level rise is very likely to increase (New York City Panel on Climate Change, 2009)
  - Both 1-in-10 year floods and 1-in-100 year floods are projected to occur more frequently by the 2020s, with 1-in-10 year floods happening approximately once every 8 to 10 years and 1-in-100 year floods happening approximately once every 65 to 80 years (Horton, Gornitz, Bowman, & Blake, 2012)
- Low-lying locations along New York City's coastline will be permanently submerged, and other shoreline areas will be inundated more frequently (New York State Sea Level Rise Task Force, 2010).
  - Under the consensus projection of a global temperature rise of 1-2 °C by 2100, the sea level around New York City is projected to rise three feet (Gillis, 2010). This would put 1.7 percent of New York's existing real estate under water: some \$60 billion in property (Herbst, Cassidy, Marks, Nikodem, & Shobowale, 2013)
- Current investment and land-use planning practices by New York State and local governments across the state are encouraging development in areas at high risk of coastal flooding and erosion (New York State Sea Level Rise Task Force, 2010)

## MAPPING FLOOD VULNERABILITY IN NEW YORK CITY

Although current and projected conditions for flooding caused by storm surges pose threats to buildings and their energy systems, these threats vary considerably across New York City. Recommended strategies for making buildings' energy systems more resilient should primarily target the types of buildings that are concentrated in flood-prone and population-dense areas. This section identifies areas that are highly prone to flooding and the building types found there.

New York City has three coastal flood evacuation zones, ranked according to their potential for flooding from hurricanes of particular intensity. Evacuation Zone A comprises areas that are prone to flooding from any hurricane. Locations of interest in Evacuation Zone A include:

- Manhattan: Central and southern coastal areas (Figures 2-1 and 2-2)
- Queens: Western coast, Rockaway peninsula, Newtown Creek (Figures 2-1 and 2-4)
- Brooklyn: Northwestern and southern coastal areas (Figures 2-2 and 2-3)
- Staten Island: Western and eastern coastal areas

Analysis of the building stock and population density in these areas of interest suggests which building types should be priorities for improving energy system resilience. For example, the types of multifamily buildings found in more densely populated areas should be prioritized, since strategies to benefit those buildings will serve larger numbers of people. Based on this analysis, the following building types emerged as priorities for the design of energy resilience strategies:

- Multifamily – Large multifamily buildings with elevators emerged as a priority. Such buildings are concentrated in the Rockaway Peninsula, south Brooklyn, West Brooklyn, and Southeast Manhattan.
- Commercial/industrial – Commercial buildings are densely concentrated in lower Manhattan, followed by south Brooklyn. Buildings with the highest value at risk are located near the water in lower Manhattan and the Newtown Creek area in Queens.



- Healthcare – A number of hospitals are located in or near Evacuation Zone A on the Rockaway Peninsula, south Brooklyn, and southeast Manhattan. Eight hospitals are located in Evacuation Zone A in Manhattan, Staten Island, Rockaway Peninsula, and south Brooklyn, and several of these were flooded during Hurricane Sandy.

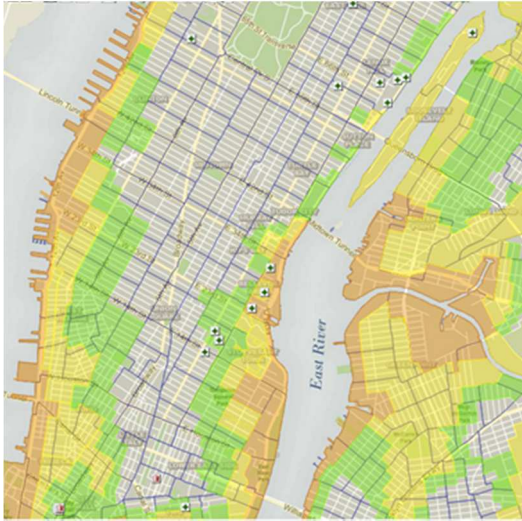


Figure 2-1: Central Manhattan, W. Queens, N. Brooklyn (Map source: NYC.gov)

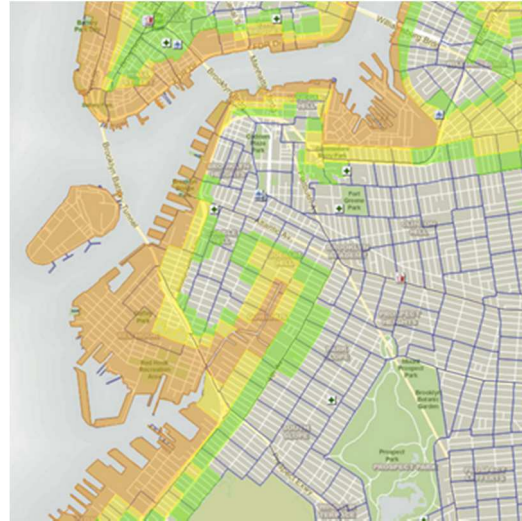


Figure 2-2: Lower Manhattan, Northwest Brooklyn (Map source: NYC.gov)

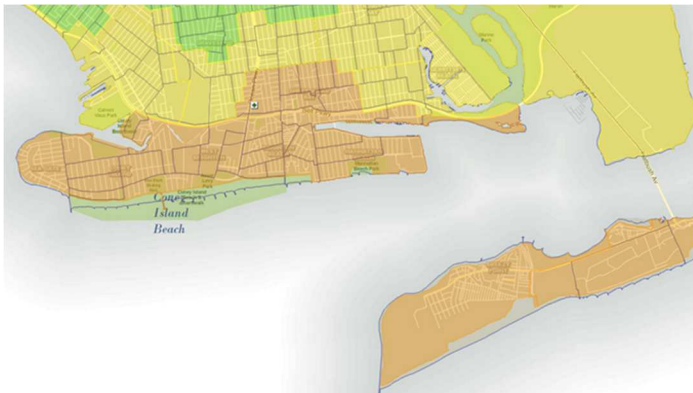
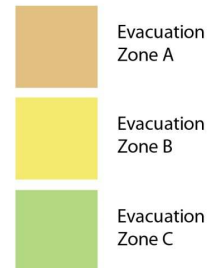


Figure 2-3:  
South Brooklyn  
(Map source:  
NYC.gov)



Figure 2-4:  
Rockaway  
Peninsula  
(Photo Source:  
NYC.gov)

#### LEGEND



## BUILDING ENERGY SYSTEMS: THEIR COMPONENTS AND THE EFFECTS OF FLOODING

### Components of building energy systems

Large buildings are reliant on two major energy systems: electrical and HVAC (heating, ventilation, cooling). The electrical system consists of all the equipment and wiring needed to distribute electricity throughout a building either from the grid or from onsite generation (such as a cogeneration plant). The HVAC includes furnaces, boilers, water heaters, air ducts compressors and heat pumps. These components are typically located in basements, sub-basements, or high floors or located outside buildings, as shown in the table below.

System	Component	Typical location in building
Electrical	Distribution system – Carries electricity from generation plant to building (Xcel Energy, 2009)	Basement or sub-basement
	Panels (fuse and circuit breaker boxes)	Basement or sub-basement
	Meters	Basement or sub-basement
	Switches (also referred to as switch gear)	Basement or sub-basement
	Outlets	Throughout building
	Backup electrical generator – Not a standard feature of a building electrical system but often found in large facilities requiring uninterrupted electricity supplies (Brown, P.E., 2005)	Basement, rooftop, or exterior
	Cogeneration plant – Not standard; can be found in large facilities or campuses like hospitals and increasingly in multifamily settings. Components include (C2ES, 2011): <ul style="list-style-type: none"> <li>• Gas turbine-generator</li> <li>• Heat recovery steam generator</li> <li>• Steam turbine-generator</li> <li>• Electrical interconnection</li> </ul>	Basement or sub-basement
HVAC	Air-Handling Unit – Conditions and circulates air; typically connected to duct work (Energy Star, 2013)	Indoors or on roof
	Boiler – Provides heat and/or hot water. Components include feed water pumps and controls (Northwest Energy Efficiency Alliance, 2013).	Basement or sub-basement
	Chiller – Provides cold water to air handling units. Components include (Trane, 2006): <ul style="list-style-type: none"> <li>• Compressor</li> <li>• Evaporator</li> <li>• Condenser</li> <li>• Reservoir</li> <li>• Cooling tower</li> <li>• Thermal expansion valve and stabilization assembly</li> <li>• Control panel</li> </ul>	Basement or sub-basement
	Pumps	Near boilers, chillers, and other equipment
Auxiliary equipment	Fuel tanks (for boilers or backup generators)	By code, must be located on lowest floor of building (New York City Department of Buildings, 2008)

## **The effects of flooding on building energy systems**

Major components of building energy systems are typically located in basements and sub-basements because these locations are not well-suited to rent or sell to tenants. Since these locations are typically below the building's Design Flood Elevation<sup>1</sup> (DFE), they are very vulnerable to flooding.

When inundated by floodwaters from storm surges, building energy systems can experience corrosion (from saline ocean water) and contamination (by waterborne pollutants), along with short-circuiting of electrical equipment (FEMA, 1999). Salt from seawater can be extremely corrosive, which can lead to shorts and expose people to the risk of electric shock. Salt can also lead to molding if the damage is not handled appropriately.

Appendix G of the New York City Building Code provides guidance on building design to protect energy systems that are located in the flood plain. This code applies to new construction and replacement of flood-damaged components in existing buildings. The code does not mandate compliance for elective improvements to existing buildings constructed prior to November 13, 1983, and relies heavily on ASCE 24 for best practices in design of building energy systems in a way that prevents damage from flooding (New York City Department of Buildings, 2005).

Because New York City's building stock is quite old, this report focuses on recommendations for improving existing buildings that may not be required or able to comply with the same building code requirements that apply to new buildings. Nevertheless, for existing buildings the mandates of Appendix G provide a valuable reference when considering the energy resiliency strategies presented and evaluated in this report.

## **The high cost of building failures in New York City**

High real estate values in New York City mean that building failures due to floods are especially costly. This section gives some indicative costs associated with energy system failures due to flooding for each building type.

According to the case studies in this report, commercial buildings affected by Hurricane Sandy were out of commission for periods ranging from several weeks to several months. The average rent rate is currently \$42 per square foot per month for a class A office space in lower Manhattan (NYC EDC, 2013). At that rate, closure of a 100,000 square foot building would result in lost revenue of \$350,000 per month, or \$80,769 per week. For building occupants, there can be additional economic costs, such as lost revenue for businesses and lost wages for employees.

Rent averages \$3,609 per month for a one-bedroom apartment of 700 square feet in the financial district (MNS, 2013). Closure of a 100,000 square foot apartment building would result in lost rent would be \$515,571 per month or \$128,892 per week. Building owners might also need to pay for temporary relocation expenses for their displaced tenants, at costs similar to the apartment rents. Tenants displaced by storms can also legally break their leases under "constructive evictions" leaving the building owner without a stream of income (Schneiderman, 2012) following the storm.

For hospitals, the costs associated with being shut down by flooding emergencies are significant. The New York City Health and Hospitals Corporation estimates that Hurricane Sandy caused \$810 million in property damage at eleven acute care hospitals, with much of this cost

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<sup>1</sup> The Design Flood Elevation is the Base Flood Elevation plus 1, 2, or 3 feet, depending on the building category or structure and the equipment in question (New York City Department of Buildings, 2005). The Base Flood Elevation is determined by statistical analysis for each floodplain area; it has a 1 percent chance of being exceeded in any given year (FEMA, 2009). Design Flood Elevations can also be set specifically for various areas; FEMA has issued Advisory Base Flood Elevations (ABFEs) for New York City based on findings from Superstorm Sandy (FEMA, 2013).



resulting from damage to electrical, water, heating, and communication systems (Herman, 2013). Lost revenue, pay for employees unable to work, and other costs are also substantial: NYU Langone estimated total costs from the storm at \$700 million to \$1 billion (Hartocollis, 2012).

## **RESILIENCE: INTERPRETING THE CONCEPT FOR BUILDING ENERGY SYSTEMS**

Various experts and institutions have proposed definitions for resilience, particularly resilience in the face of climate change. The definition proposed by the Rockefeller Foundation (Rodin, 2012) seems especially relevant in the context of building energy systems during floods:

Resilience means different things across a variety of disciplines, but all definitions are linked to the ability of a system, entity, community or person to withstand shocks while still maintaining its essential functions. Resilience also refers to an ability to recover quickly and effectively from catastrophe, and a capability of enduring greater stress.

The Stockholm Resilience Centre (2007) has also offered a definition that is worth noting for its additional emphasis on adaptation to new and foreseeable challenges: *Resilience is the capacity of a system to continually change and adapt yet remain within critical thresholds*. The adaptive properties of a system are of central importance to this report, which seeks to determine which modifications to building energy systems will be most useful for improving their resilience against flooding.

Beyond general definitions, it will be helpful to identify the features that make a system resilient and which features are pertinent to building energy systems during floods. The Rockefeller Foundation outlines five key features: the first three relate to dealing with a current disaster, the fourth is a near- and medium-term consideration, and the fifth has to do with planning for the next disaster (Rodin, 2012).

- Spare capacity, which ensures that there is a back-up or alternative available when a vital component of a system fails.
- Limited or “safe” failure, which prevents failures from rippling across systems.
- Rapid rebound, the capacity to re-establish function and avoid long-term disruptions.
- Flexibility, the ability to change, evolve, and adapt in the face of disaster.
- Constant learning, with robust feedback loops that sense and allow new solutions as conditions change.

These resilience features have been used to frame the definitions of building performance thresholds for the multifamily, commercial, and hospital buildings in the scope of this project. As discussed in the following chapter, special emphasis has been placed on those features that are especially critical to building and energy system performance during floods from storm surges.

# 3 Building Types and Their Energy Resilience Traits

## Chapter Overview

- Multifamily, commercial, and hospital buildings are described
- The functions of each building type are described and related to the energy systems that support these functions
- Resilience thresholds are defined for building performance: these represent the extent to which each building type must maintain its ordinary functions during flooding emergencies

## MULTIFAMILY BUILDINGS

For purposes of this report, research on multifamily buildings is focused on large elevator residences that contain 75 apartment units or more and are equal to or larger than 50,000 square feet. This scope means the analysis will consider mainly multifamily buildings with elevators within Evacuation Zone A. (Some buildings may have commercial uses in the lowest three floors, though their square footage will be primarily dedicated to residential use.) Research and recommendations in this report may apply to smaller multifamily buildings but these potential applications have not been considered explicitly.

### Building functions and energy system dependence

Multifamily buildings provide shelter to their residents. They also provide a site where residents can conduct essential tasks. Although the specific components and locations of energy systems in multifamily buildings vary, the residents of multifamily buildings rely on these energy systems for various functions.

Electricity distributed through room outlets is primarily used for household appliances. In some multifamily buildings, a majority of the air cooling function is provided by room-based air conditioning units powered by electricity from outlets (Urban Green Council, 2011). Such buildings do not rely on centralized ventilation and air conditioning equipment to perform the air cooling function and thus do not have such equipment that is exposed to flood risk. On the other hand, the use of electricity to provide air cooling means that electricity service must be maintained in order to support the air cooling function, particularly during warm months when air cooling is needed.

Boiler systems provide hot water year round and space heating during cool days to multifamily buildings and these are generally centralized.

### Resilience thresholds

If an evacuation is not required, multi-family buildings need to be able to act as shelters-in-place for residents on non-flooded floors for the duration of the storm event and recovery. For buildings that require a temporary evacuation during the storm event, such as an event like Hurricane Sandy, the energy systems will need to deliver basic services with minimal interruption (Urban Green Council, 2013). In both cases the primary or backup building utilities will need to provide critical comfort and safe environments to residents, including emergency lighting and water if not full services.

## COMMERCIAL BUILDINGS

Research on commercial buildings in this report focuses on buildings 100,000 square feet or larger. Within the flood zone, these buildings tend to be high-rise office buildings with elevators that may have retail operations in the lower three floors. The research and recommendations on high-rise office buildings may be relevant to smaller commercial buildings but these applications have not been evaluated.

### Building functions and energy system dependence

Commercial buildings can be fully evacuated and unoccupied during storm events, and their energy system equipment can be shut down.

Although the specific components and locations of energy systems in commercial buildings vary, the occupants of commercial buildings rely on these energy systems for various functions. Electricity distributed through outlets is primarily used for appliances. In commercial buildings, air cooling and ventilation functions are typically provided by centralized HVAC systems. Boilers provide heat and hot water to commercial buildings, and these are generally centralized.

### Resilience thresholds

As the NYC Building Resilience Task Force points out, the resilience efforts employed by commercial buildings are essentially business decisions taken by building owners (Urban Green Council, 2013). Since these buildings do not act as shelters or preserve human life during predicted storm events for which preparations are made, the energy systems can be fully or partially shut down until normal building activities have resumed.

Therefore, the primary goal for commercial buildings is to protect and preserve valuable energy system equipment so that regular services can be provided with minimal repair or replacement. In existing commercial buildings, operational strategies may play a larger role than structural in a building's resilience efforts (Urban Green Council, 2013). The present research focuses on structural resiliency solutions, but several operational strategies are presented for purposes of future consideration.

## HOSPITALS

Hospital buildings are used to provide healthcare activities. Often a diverse set of activities is conducted in the same building. NYU Langone Medical Center serves as a “center for clinical care, biomedical research and medical education” (NYU Langone Medical Center). Nursing homes provide supportive or palliative care for the elderly (New York State Department of Health, 2012).

### Building functions and energy system dependence

Typical functions of hospital facilities are listed below, as derived primarily from emergency plans published by two New York City hospitals and in a study of the effects of tropical storm Allison on a Houston hospital in 2001 (NYU Langone Medical Center, 2012) (NYU Langone Medical Center, 2013) (SUNY Downstate Medical Center, 2012) (Nates, 2004). Baseline services provided in nursing homes (New York State Department of Health, 2012) are also listed.

Hospital functions	Nursing home functions
Blood bank Central supply rooms Emergency room Food services High-tech testing (radiology, etc.) In-patient services Labs & research facilities Lounge and meeting places Obstetrics and gynecology services, including delivery and neonatal ICU Out-patient services Pharmacy Surgical services Urgent care clinic	Assistance and supervision of daily activities Diagnostic services Dietary services Lodging and housekeeping Medical services and equipment Nursing care Palliative care Pharmacy Physical therapy Recreational activities Social services

Two additional considerations should inform the analysis of possibilities for continuing hospital functions even in flood conditions or re-starting them shortly after a flood: which energy systems and sources a hospital depends upon, and how critical each of the hospital's function is. The basic energy systems and sources that support hospitals, and their key performance requirements, are given in the table below (U.S. Energy Information Administration, 2012) (Sacramento Municipal Utility District, 2013).

Energy system	Building functions supported
Electricity, including backup generation	Hospitals, nursing homes, and adult-care facilities use the roughly same amount of electricity around the clock, whereas commercial and multifamily buildings experience more variability in their energy consumption, according to when they are occupied (Levy, 2009).
HVAC	<u>Cooling and ventilation</u> – Humidity control is very important in areas such as surgical suites and intensive care units. Ventilation is essential for infection control and comfort, including elimination of pollutants and pathogens, and particular hospital rooms require certain numbers of air changes per hour. <u>Heating</u> – Hospitals tend to maintain indoor temperatures that are 2-8° F warmer than other buildings.
Boilers	Hot water

Some hospitals, including some in New York City that are prone to flood risks, rely on cogeneration plants to supply electricity, space heating, and hot water. Cogeneration plants will be explored further through the hospital case studies and the analysis of strategies.

### Resilience thresholds

Emergency and disaster management plans from New York City hospitals have been used as a guide to classifying hospitals' functions as one of the following: a vital function that must remain uninterrupted above all others in the event of emergencies; a function that should be maintained if only at reduced capacity; or a function that can be suspended to preserve the functioning of higher-order services (NYU Langone Medical Center, 2012) (SUNY Downstate Medical Center, 2012). The



table below synthesizes the list of hospital functions with the importance classification and the catalog of energy services to indicate which energy services must be maintained (or restored) to support functions.

Maintenance of function in emergency	Hospital function	Energy system dependence
Vital/uninterrupted	Blood bank	Electric
	Clinical labs	Electric, HVAC
	Communications	Electric
	Critical care units and obstetrics	Electric, HVAC
	Data centers	Electric, HVAC
	Emergency alarms and lighting (stairwells, exit lights, fire alarms, etc.)	Electric
	Emergency room	Electric, HVAC
	Food services	Gas, electric
	Morgue	Electric
	Nurse stations	Electric (lighting, strategic outlets)
	Pharmacy	Electric, HVAC
Limited	Elevators	Electric
	Lobby, other meeting areas	Electric (lighting only)
	Operating rooms (elective surgeries cancelled, only emergency surgeries)	Electric, HVAC
Shut down	Administrative services	None in emergency
	Central water cooling system	None in emergency
	Outpatient services	None in emergency

# 4 Case Studies of Energy Resilience in Floods

## Chapter Overview

- Case studies describe how specific buildings of each type performed during or after Hurricane Sandy and other flooding emergencies, and how building owners and landlords are preparing for future flooding emergencies
- Specific strategies for improving the resilience of buildings' energy systems are extracted from the case studies, categorized by type, and described

## MULTIFAMILY BUILDINGS

Multifamily buildings near the New York City waterfront were badly damaged by the extensive flooding from Superstorm Sandy. However, specifically describing the performance of multifamily buildings during flood emergencies, as well as the resilience strategies being implemented by owners and landlords, has proven challenging because building industry professionals typically treat details about buildings' as proprietary, confidential information.

Nevertheless, across the case studies that have been identified, a number of themes and trends are apparent:

- Some building owners and landlords have opted to make upgrades and renovations in order to become more resilient against future floods, while others contend that the improved resilience that might be gained from upgrades is not worth the revenue that would be lost by dedicating rentable floor space to energy system equipment.
- Particularly at the high end of the rental market, owners and landlords recognize that energy system resilience (and other types of flood resilience) is becoming a sought-after feature of all properties, especially new properties, after Hurricane Sandy.
- Multifamily buildings that have been recently built in or near Evacuation Zone A have been designed with consideration for rising sea levels and storm surges. Buildings with energy systems that were damaged by floods during Hurricane Sandy are actively seeking ways to elevate their systems to a higher floor.



Figure 4-1: Emergency generator at multifamily building (Photo source: Affordable Housing Institute)

150 Charles Street – The construction site for this luxury multifamily building in downtown Manhattan was partially flooded during Hurricane Sandy, prompting the developer to consider design features that would have allowed the building to stay open. After requesting recommendations from the building's architects, the developer decided to adopt all five of their recommendations: installing two natural-gas-powered generators on the roof to run the fire-alarm system, the emergency egress lighting, the elevators, and electrical and mechanical support

equipment; equipping each apartment with at least one electrical outlet connected to the generators; ordering five-foot-tall floodgates that can be assembled and installed to encircle the building in a matter of hours; poured concrete instead of cinder block for the basement walls; and sealing each basement mechanical room with watertight submarine-style doors. The efforts delayed the project by some six weeks and added as much as \$3 million to its cost (Satow, 2013).

560 West 24th Street – This new condominium building under way in Chelsea will include a waterproof “concrete superstructure” from the basement to the second floor that has 13-foot floodgates; waterproofed rooms with submarine-style doors to protect mechanical and electrical systems; and a generator and a pumping system run on natural gas. The floodgates are expected to cost \$100,000 (Satow, 2013).

Superior Ink – During Hurricane Sandy, this existing condominium and town-house development in the West Village experienced flooding in its lobby and basement, and some of the building’s mechanical systems were damaged by saltwater erosion. The residents were forced out of their apartments for more than 40 days and paid a \$1 million assessment in December 2012 so renovations could start immediately. The building is moving its electrical and mechanical systems to the second floor and is considering installing a generator (Satow, 2013).

Arverne By The Sea – This new master-planned development in the Rockaways is one of the largest multifamily development projects in New York City, comprising 2,300 units on 117 acres along 2 miles of waterfront. Several resilience features are part of the development’s design. Prior to construction, the developer elevated the site five feet using a half-million cubic yards of fill. Utilities were installed underground and the transformers are submersible. While grid power was lost during the storm, power was restored much more quickly than in other sections of the Rockaways. Gerry Ronski, the development’s project executive, said, “Even back in the planning phases, there was talk of global warming and rising sea levels and all that. We knew we’d have to engineer it specifically, and go above and beyond the building requirements, to make it hurricane-proof” (Kilgannon, 2012). The experience shows that development can occur along the waterfront, if it is done intelligently (Herbst, Cassedy, Marks, Nikodem, & Shobowale, 2013).

116 John Street – The boiler and backup generator at this 419-unit rental building near the South Street Seaport were on the roof of the building and thus escaped damage during Hurricane Sandy. However, the electrical switchgear that controlled many other systems was damaged by floodwater. The building landlord has said that moving the switchgear does not seem practical, considering that rentable space would have to be sacrificed (Satow, 2013).

88 Greenwich – This building’s basement was flooded by 3 million cubic feet of water and deemed uninhabitable by New York City’s Department of Buildings. Two months after Hurricane Sandy, the Department of Buildings approved the building to be occupied. Repair and resilience-improving efforts have continued, including the sealing of exterior cavities, the installation of additional sump pumps, and the elevation of equipment in the basement. The building has found creative ways to relocate electrical equipment to higher levels: an unused elevator shaft is being converted to electrical rooms at various levels without any loss of usable floor space. The building’s board is also considering relocating the boiler to the building’s 13th floor and installing a backup generator (Singhal, 2013).

Low-Income Housing Complex, Coney Island – The central boiler plant of this housing complex was completely inundated during Hurricane Sandy. Fortunately for these high-rise towers, the boiler plant had been located in its own two-story building between the towers. The complex is now looking to relocate the boiler plant to the roof of this shorter building (Zuluaga, 2013).

Large Multifamily Complex, Rockaways – The central boiler plant of this housing complex of approximately 1,500 units was similarly inundated during Hurricane Sandy. Due to the existing steam infrastructure in the complex and the centralized nature of the existing plant, relocation to the

roof or higher elevation is not feasible or cost effective. Instead the complex is elevating the system within its boiler room, which is lucky enough to have 20 foot ceilings. While this will make maintenance harder in the future, it will add a level of protection for the building. It is being recommended that the hot water capabilities be separated out to more efficient boilers that could be roof located (Zuluaga, 2013).

## COMMERCIAL BUILDINGS

Commercial buildings in downtown Manhattan, primarily office towers, were badly damaged by the extensive flooding caused by Hurricane Sandy. Many of their owners and landlords have opted to make major upgrades and renovations in order to become more resilient against future floods – although, as with multifamily buildings, owners and landlords and construction managers are reluctant to divulge too many details. Some patterns are evident across the case studies presented below. These patterns include:

- After Hurricane Sandy, many impacted high-rise buildings in or near Evacuation Zone A could not operate for weeks or months because of damage to flooded energy systems.
- Owners of commercial high-rise buildings that experienced flood damage to energy systems are pursuing opportunities to elevate those critical systems to higher floors of the building.
- Resilience strategies other than elevation, such as the installation of backup generators, are being pursued more selectively.



*Figure 4-2: Air tubes dry out lower levels of commercial building following Hurricane Sandy (Photo Source: Stamford Advocate)*

55 Water Street – The city’s largest office tower, with 3.8 million square feet on 53 stories, was hit hard by Hurricane Sandy. Although the building has 14 generators with a combined capacity of 11 MW, enough to power the entire building in a power outage, the storm surge flooded the fuel tanks and pumps, causing the building to remain closed for more than a month (Geiger, 2012). The building owners were allocated an open-ended budget to reopen the building as quickly as possible, with costs estimated at approximately \$100 million (Cuozzo, 2012). To make the building’s energy systems more resilient, the utility points of entry will be moved from the basement to the third floor of the building (Cuozzo, 2012), and the fuel oil tanks on the lowest floor are being dry-floodproofed with a watertight room enclosure (Frank, 2013). Critical mechanical and electrical equipment is located the 14th floor, well above the DFE (Cuozzo, 2012).

199 Water Street – After being flooded with 8 million gallons of water on the ground level, this 35 story building reopened on December 5, 2012. Some building systems will remain in the basement, but floodgates will be installed between the exterior columns. Four new electrical switchboards will be installed in an upper level of the building, using several thousand square feet of revenue-generating floor area. Other utilities, such as telecom equipment, are also being moved up to the fourth floor. The cost of damage from the storm is estimated at \$50 million, including cleaning, repairs, and a renovation of the lobby (Hughes, 2013).

110 Wall Street – This building has a history of flood damage, including a severe flood from a storm in the 1990s. All leases were cancelled under a constructive eviction in response to Hurricane Sandy. The building owner perceives this situation as an “opportunity catalyst” for a gut



renovation and a possible conversion to residential use, for which the building is well-suited thanks to its small floor plates. Redevelopment plans for the building include the installation of energy systems on a high floor. Many buildings in the financial district have been converted to residential use, such as 75 Wall Street and 95 Wall Street (Geiger, 2012).

**80 Pine** – The owners of this 41-story office building spent approximately \$35 million to move the electrical switchboards and other equipment to the top level of an on-site parking garage, where they sit 20 feet above sea level, or 8 feet above the high mark of Hurricane Sandy's floodwaters. The relocation required the elimination of 70 parking spaces out of 180 (Hughes, 2013).

**200 West Street** – The Goldman Sachs building at this address reportedly sustained little damage after using sandbags and barricades as protection against four feet of floodwater (Herbst, Cassidy, Marks, Nikodem, & Shobowale, 2013). Employees were able to return to work shortly after Hurricane Sandy, and the firm maintained its operations (Slavin, 2012).

**120 Wall Street** – In response to Hurricane Sandy, the landlord Silverstein Properties is securing portable diesel generators and brought in a fuel tanker to keep them supplied with fuel, under guard by security workers. Critical infrastructure will be moved to higher floors in the 600,000 square foot, 34-story skyscraper (Associated Press, 2012).

**60 Wall Street** – This building used 100,000 gallons of fuel to power its backup generator following Hurricane Sandy. Building staff were able to restore grid power quickly by drying the electrical gear, reconditioning it, and testing it so they could pass an inspection quickly. The high voltage gear was ready to energize when the utility crews showed up. Steam service remained out of commission for longer than electricity, and the building staff procured a temporary boiler to get back into the building (Herbst, Cassidy, Marks, Nikodem, & Shobowale, 2013).

## HOSPITALS

Across the case studies on hospitals and flooding that have been identified and documented below, a number of noteworthy patterns and trends related to energy systems can be discerned:

- Nearly across the board, hospitals that have experienced flooding in recent years have announced plans to move key components of their energy systems out of their basements and to a height that is considered safely above projected floodwaters, as well as plans to build floodwalls and other barriers against flooding.
- Many hospitals, having been disabled by flooding and forced to maintain reduced levels of healthcare service for weeks or months after the flooding event, have made it their first priority to restore full service, before taking on the energy system resilience measures they have announced.
- Relocating energy systems in existing buildings to upper floors, out of the way of projected floodwaters, is costly.

Hospital officials quoted in the case studies and interviewed by the project team nearly all agree on the need to move key energy system components higher in the building and the cost of undertaking this work suggests that NYSEERDA's programs for funding resilience improvements to hospital energy systems will be most effective and valuable if they are aimed at supporting improvements that hospitals have already planned and committed to.

### New York City hospitals

Case studies on the experiences of New York City's hospitals during Hurricane Sandy illustrate the damage done by flooding and the resilience-improving plans set out by hospital officials (Evans, 2012) (Abramson & Redlener, 2012) (Redlener & Reilly, 2012).

Bellevue Hospital Center – Emergency generators on the 13th floor were disabled when floodwater filled the hospital’s basement and disabled electricity to the fuel pumps and switches. Generators continued to operate with fuel hauled up stairs by employees and the U.S. National Guard. The CEO of the New York City Health and Hospitals Corp., which owns Bellevue, said remediation plans would relocate electrical switches, fuel pumps and other critical infrastructure, such as power distribution, water and communication systems, that were vulnerable to flood damage. However, the system’s first priority is reopening the hospital (Evans, 2012).



*Figure 4-3: Evacuation of patients from Bellevue Hospital (Photo Source: NY Daily News)*

Manhattan VA Medical Center – Overflow from the East River filled the subbasement of the hospital and rose higher than five feet in the basement, destroying the hospital’s electrical equipment and fire-safety system (Evans, 2012). The hospital had resumed its outpatient services as of May 2, 2013 and expected to restore emergency and in-patient services by the end of May 2013 (VA NY Harbor Healthcare System, 2013). The director of the VA New York Harbor Health Care System, which operates the hospital, said, “Whatever can be moved up will be moved up,” including electrical switch gear, medical gases, and vacuums. Pre-storm plans to build a flood wall may need to be revised and raised (Evans, 2012).

NYU Langone – Floodwaters from the East River filled the basement of the medical center, disabled the building’s emergency power systems, and forced the evacuation of more than 300 patients during a 13-hour period of darkness, wind, and rain. Medical research projects were shut down and medical school classes disrupted. Total costs from the storm were estimated at \$700 million to \$1 billion, counting cleanup, rebuilding, lost revenue, interrupted research projects, and salaries for employees who could not work. Emergency power systems failed not because the generators were damaged – all but one of the generators is on a high floor – but the fuel tanks are kept in the basement. When liquid sensors on the fuel tanks sensed the floodwater, they shut down the fuel pumps feeding the generators (Hartocollis, 2012).



*Figure 4-4: Evacuation of patients from NYU Langone during Hurricane Sandy (Photo Source: LA Times)*

Long Beach (NY) Medical Center – The storm surge surmounted a 3-foot concrete barrier and flooded the facility’s basement with 10 feet of water. Essential electrical and boiler equipment were destroyed, and groundwater continued seeping into a subbasement and basement rooms holding mechanical equipment for more than four weeks after the storm. The hospital’s CEO said that an emergency generator would be moved out of the basement, and possibly the boiler as well. “Getting everything out of the basement would be ideal,” said Mark Healey, director of facilities and engineering for the center (Evans, 2012).

Coney Island Hospital (Brooklyn) – This hospital, also owned by the New York City Health and Hospitals Corp., lost utility power during the storm and pre-emptively shut off the backup generator to prevent damage from advancing floodwater. Generators will be raised and electrical switch gear, which distributes power and water supply pumps, will be relocated from the basement.

Remediation plans won't be finalized until immediate repairs are made and the hospital reopens (Evans, 2012).

Columbia University Medical Center – The medical center was unaffected by flooding from Hurricane Sandy because of its location in Washington Heights. The building that houses the School of Public Health was threatened most because its lower levels are 10 stories below the center's other buildings. All buildings on campus have backup generators that supply 80-100% of the needed power supply to the buildings. They are also designed to connect to portable commercial generators (large systems on tractor trailers) that can be connected directly to a building's electrical system. The portable generators could be continuously refueled by tank trucks parked next to the trailers. The hospital is also considering the installation of conversion kits to allow its steam generators to run on fuel oil or natural gas. Because natural gas is delivered under pressure and does not need to be pumped to generators, gas-fed generators can continue to operate if the fuel pumps are disabled by flooding (Thompson, 2013).

### **Cogeneration in NYC hospitals**

NYU Langone – NYU Langone is building a new energy generation plant including an 8-megawatt cogeneration plant with standby boilers and a 7.5-megawatt emergency power plant to feed Tisch Hospital in case of a grid power outage (NYU Langone Medical Center, 2012).

New York Presbyterian Hospital – This facility has a cogeneration plant that generates 100 percent of the hospital's base electrical load and two-thirds of its peak electrical load, thereby allowing the hospital to purchase 80 percent less grid electricity than without the plant. The cogeneration plant provides a 100 percent redundant power source for inpatient areas. The plan promises to save the hospital some \$5 million each year (Levy, 2009).

### **Hospitals outside New York City**

Case studies about hospitals outside New York City that have experienced flooding and extreme weather events provide additional instructive examples.

California hospital system – A system of 157 hospital buildings in California is pursuing an energy efficiency program in order to become more resilient against rolling blackouts. A consultant working on the project explained the rationale for this program thusly: "Hospitals use tons of electricity. Whatever they can do to reduce their strain on the grid can help prevent blackouts. Less demand from the grid, less strain on the grid, they won't crash as quickly." (Falco, 2013)

New Orleans – Two New Orleans hospitals, Charity Hospital and Lindy Boggs Medical Center, lost their emergency power because back-up generators were located in the lowest levels of the hospital. Tulane University Hospital, across the street from Charity Hospital, maintained its emergency power because its generators were above street level. Researchers investigating this situation concluded, "Hospitals should do whatever they can to minimize their reliance on city power and water supplies when disaster strikes." This means having enough backup generation capacity to power all essential equipment, including at least one elevator in buildings with multiple floors. Emergency generators should be "located out of harm's way" (Arendt & Hess, 2007).

Clara Barton Hospital Center, Kansas – Following a devastating tornado in 2004, the hospital installed a new emergency generator with enough capacity to power the entire building. The new generator for the hospital is located outside the building, mounted on a concrete slab that is adjacent to an exterior wall and provided with a lockable steel shell. To ensure its reliability during an emergency, the generator is tested every Monday by the hospital's maintenance staff (FEMA, 2004).

Columbus Regional Hospital, Indiana – In June 2008, record flooding from nearby Haw Creek filled the basement and up to six inches on the first floor of Columbus Regional Hospital

destroying the laboratory, pharmacy, pneumatic tube system, electrical, air handlers, IT center, radiology equipment, medical records, and food service facility housed in the hospital's basement (Flooded Hospital Shortens a Long Road Back, 2009). The hospital has constructed a 2,400-foot flood wall system that FEMA has recognized as a best practice in flood mitigation design (Fish, 2012).

Texas Medical Center, Houston – After experiencing flood damage from Hurricane Allison, this Texas hospital considered 112 measures to prevent future disasters and implemented some of them. Some were intended to prevent water from reaching the hospital, and others were aimed at limiting damage from inevitable water breaches. Electrical vaults and backup generators were elevated from basements to floors above flood level, as were important facilities such as research labs. Existing buildings were equipped with flood gates, and new buildings were built surrounded by berms. Underground tunnels were outfitted with submarine doors. Changes to the hospital cost \$756 million, paid by FEMA; millions more were spent on public works (Geller, 2012).



# 5 Resilience Strategies for Building Energy Systems

## Chapter Overview

- Strategies for improving the resilience of building energy systems are described and analyzed in terms of technical feasibility, policy considerations, local barriers and solutions, and costs and benefits
- Strategies are analyzed with regard to existing buildings that might undergo retrofits to improve resilience, not new construction
- Findings about each strategy that are unique to particular building types are also documented
- A summary comparison of all the strategies is presented at the conclusion of the chapter; strategies are assessed and ranked independently from one another

This section describes the predominant strategies for improving the resilience of buildings' energy systems, as identified in the case studies presented above. These resilience strategies are not specific to particular building types and are thus described in generic terms. The resilience strategies are grouped into four categories: floodproofing, elevation, on-site and backup generation, and pro-resilience energy efficiency.

The suitability of the resilience strategies for different buildings will vary considerably, owing to variations in policies and code requirements, technical feasibility, and especially costs and benefits for particular building types. Analysis of the suitability of resilience strategies for particular buildings is also presented.

## FLOODPROOFING STRATEGIES

Floodproofing refers to measures taken to make a building resistant to damage from flood waters, by making the building impervious to floodwater or installing materials that will not be damaged by floodwaters. Various floodproofing approaches exist (WBDG, 2013).

- Dry floodproofing involves the use of sealants, coatings, and equipment to enclose building areas and equipment so they are watertight and, importantly, can withstand the pressure of floodwaters. Dry floodproofing includes strategies such as enclosure (of areas and equipment inside a building) and the sealing of building exteriors.
- Wet floodproofing involves the design and construction of building features that allows for water to penetrate and escape a building, and the use of materials that will not be damaged by flooding

The strategies described and analyzed below are all dry floodproofing strategies, for only dry floodproofing protects energy system components that are located below the DFE. Since each of these strategies addresses a distinct aspect of water entry, serious consideration should be given to implementing them in tandem. Wet floodproofing primarily concerns the protection of the building itself rather than its contents. Since energy systems are the focus of this report, wet floodproofing is outside of the scope.

### Building watertight enclosures

Watertight enclosures constructed to house energy system components can be effective for isolating energy systems from floodwaters, as long as the enclosures are watertight and their entryways use watertight doors and hatches. Watertight walls are generally used when construction of pedestals or elevation is not feasible such as in the case of existing facilities (FEMA, 1999).

Equipment located below the Design Flood Elevation (DFE) in a flood evacuation zone can be enclosed within watertight walls that extend above the DFE to reduce the likelihood of water reaching the equipment (FEMA, 2007). The top of the walls must be at or above the DFE to reduce the likelihood of water getting to components (Safety, 2012). Such walls must also be strong enough to withstand the hydrostatic load of any floodwater that penetrates the building (FEMA, 2012). If the DFE is low enough, a low wall or curb can be constructed without a closure panel (FEMA, 1999).

A watertight enclosure should also be designed with allowances for drainage to prevent water from damaging the equipment located inside, should floodwater rise above the walls. A typical enclosure might include a check valve that will permit water to leave the enclosure and also prevent water from entering (FEMA, 1999).

Floodproofing enclosures should be designed as “passive protection” systems. Passive protection designs reduce human involvement during emergencies, thereby lessening safety risks. Under normal use, the utility should be protected from floodwater and accessible for maintenance. Finally the design should consider offset distances from the equipment. Energy system equipment requiring adequate air flow should not be enclosed by walls in order to prevent improper operation of the unit or safety problems (FEMA, 2012).

**Technical feasibility:** Floodwater exceeding the predicted height of low barriers or shields can result in the loss of energy system equipment. This alternative should only be considered if relocating equipment is deemed impossible (FEMA, 2012). Dry floodproofing using watertight walls is generally used when construction of platforms or pedestals is not feasible (for example, a water heater or other piece of equipment may be too tall to be elevated above the DFE and fit on a given floor). For flood protection of HVAC system equipment in new buildings, elevation of equipment above the DFE, e.g. using pedestals, generally provides a simpler and more cost-effective solution than watertight walls (FEMA, 1999). For this reason, the use of enclosures to protect energy systems should be considered a secondary option rather than a best practice.

**Policy considerations:** Appendix G of New York City’s building code provides guidance for the design of dry-floodproofed enclosures in nonresidential buildings in accordance with ASCE 24 (New York City Department of Buildings, 2005). Flood-damaged buildings are required to comply with Appendix G, but Appendix G is also noted as offering “best” practice for elective floodproofing measures. ASCE 24, a standard for floodproof design and construction developed by the American Society of Civil Engineers, specifies the minimum height and other design features for floodproofing structures (American Society of Civil Engineers, 2010). ASCE 24 specifies that the minimum height for dry flood proofing for Category III in A-Zones should be Base Flood Elevation plus one foot. Category III buildings are characterized as buildings and other structures that represent a substantial hazard to human life in the event of failure including, but not limited to:

- Buildings and other structures where more than 300 people congregate in one area



*Figure 5-1: Submarine type doors installed at Texas Medical Center after severe flooding from Tropical Storm Allison (Photo Source: Times Free Press)*

- Buildings and other structures with elementary school, secondary school or day care facilities with an occupant load greater than 250
- Buildings and other structures with an occupant load greater than 500 for colleges or adult education facilities
- Health care facilities with an occupant load of 50 or more resident patients but not having surgery or emergency treatment facilities

NYC-specific barriers and solutions: While not necessarily considered a best practice, enclosures may be a good option for many buildings in New York City given that space and financial constraints create high financial costs for other strategies, especially elevation.

Cost considerations: The costs of building a watertight enclosure are estimated at \$17 to \$20 per square foot of enclosed space (Homewyse, 2013). Avoided costs will vary greatly depending on the type and size of the energy system requiring enclosure.

### Sealing cavities in the exterior of a building

Sealing exterior cavities is another noteworthy strategy for making a building's energy systems more resilient against flooding. Sealing cavities involves injecting grout, under pressure, into cracks, voids, and joints in concrete substrates, and is intended to help stop the flow of water, including floodwater, into the building. This method can be used in new or existing buildings with concrete, brick, stone, and masonry foundations (Lakshmi Construction Chemicals).

Utility points of entry must also be sealed in order to prevent water from penetrating a building. Several technologies are widely used to seal utility points of entry, including foam sealant, polysulphide sealant, and link seals. These methods can be used in all building types with utility penetration points through concrete, brick, stone, and masonry foundations (Thunderline Modular Seal, 2013).

Technical feasibility: Grout injection and the sealing of utility points of entry are proven, commonly practiced techniques. Grout injection alone is unlikely to prevent floodwaters from entering a building and thus needs to be supplemented with other flood resilience strategies.

Policy considerations: No policy considerations exist that would prevent the implementation of this strategy.

NYC-specific barriers and solutions: Exterior cavities can be sealed in virtually any building; the necessary materials are widely available; and sealing techniques are widely practiced. This strategy is recommended as a first step to consider in improving resistance to water intrusion for New York City's aging building stock.

Cost considerations: Specific costs to implement this strategy will vary greatly according to the condition of the building and the number of penetrations in the exterior wall. Link seals typically range in price from \$90 to \$310 per penetration, depending on the diameter of the pipe to be sealed (Hyer, 2013).

### Sump pumps

Sump pumps are an essential feature of flood-protected buildings. They provide a means of eliminating floodwater from buildings and preventing damage should other floodproofing strategies fail. Sump pumps are useful to protect against infiltration of floodwaters through cracks and small openings. Submersible sump pumps are useful for controlled dewatering after floodwaters recede (FEMA, 2012).

Most sump pumps are triggered automatically using a float activator arm or a pressure sensor. Manually operated pumps are also available. Pedestal sump pumps use open motors, supported on a pipe column with the pump at its base. Submersible sump pumps, which have

watertight motors directly connected to the pump casing and installed at the bottom of the sump, are preferred because they operate even if submerged by floodwaters. Many sump pump systems are equipped with a battery-powered backup sump pump as a failsafe in case the primary sump pump stops working (FEMA, 2012).

**Technical feasibility:** Sump pumps are proven, commonly used equipment. However, sump pumps alone are not likely to be capable of keeping floodwaters from damaging equipment in a flooded building. Sump pumps typically need to be installed in buildings which have other flood-resilience strategies in place, usually starting with sealing cavities in the exterior of a building.

**NYC-specific barriers and solutions:** One challenge with installing sump pumps in densely built areas like Evacuation Zone A is identifying a proper location for the pump so that it can move water far enough from the building that it will not re-enter easily.

**Cost considerations:** Specific costs to implement this strategy will vary according to the size of the building and the anticipated volume of floodwaters, as determined by the volume of the building's interior located below the DFE. A typical submersible pump setup can cost as little as \$5000-\$7000 depending on the pump size, flow rate, and height to which water must be pumped (Hyer, 2013).

## ELEVATION STRATEGIES

One obvious and widely practiced strategy for protecting energy system components (and other building contents) during floods is to elevate them above the DFE. In fact, New York City's building code makes a limited form of elevation mandatory: newly constructed buildings are required to be built without basements (Cohen, 2013). Different elevation strategies exist. Equipment can be elevated within a room by placing it upon pedestals that safely hold the equipment above the DFE. Alternatively, equipment can be moved to a different room or location on a higher floor of a building or even the building's rooftop. This strategy, however, can be costly, in that it can require valuable space on upper floors to be devoted to equipment, as outlined in Chapter 2. It can also necessitate expensive work to re-engineer and reconfigure energy systems. This section explores elevation strategies in further detail.

### Elevation of equipment within a room

Some energy systems and components that are prone to damage from floodwater can be elevated above the DFE within the room where the equipment is already kept. The strategy can be applied to all energy systems and components that are not submersible or are legally required to be installed in a location that is prone to flooding. Raising systems and components to the minimum level above the DFE may not be adequate for the life of the building, since the DFE may be raised in response to rising sea levels or climate change projections (New York City Department of City Planning, 2011) (Hughes, 2013).

**Technical feasibility:** This strategy is proven and often implemented as a resiliency solution for energy systems; construction companies and engineers are actively working to relocate energy systems from the existing room to higher location above the DFE within the same room. Some buildings are applying this strategy, or have done so, in the aftermath of Hurricane Sandy (Bomke, 2013).

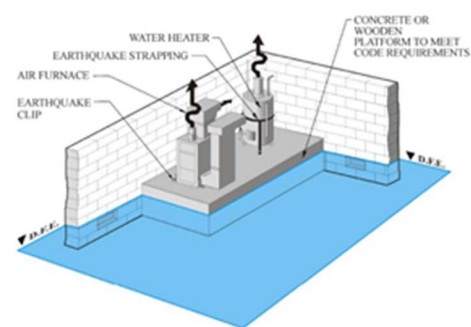


Figure 5-2: Elevation of building systems above DFE (Image Source: FEMA)



Policy considerations: Beyond policies that exist for typical energy systems, there are no policies that are different for merely moving the systems within the current space.

NYC-specific barriers and solutions: In New York City, rooms where energy system components are kept tend to be small and well filled with equipment. Existing rooms may therefore lack space above the DFE in which equipment can be elevated. In addition, New York City building codes mandate that fuel storage tanks be kept and secured at the lowest level within a building and thus cannot be elevated within a room or elsewhere (New York City Department of Buildings, 2008).

Cost considerations: Based on case studies mentioned in this report, this strategy can cost millions of dollars, although actual costs will be specific to each building. The financial benefits of implementing this strategy are of two kinds: rents (or revenue, in the case of hospitals) that are not lost if buildings remain operational during and after flooding emergencies, and rent premiums that might be charged to tenants because of the promise that buildings can remain operational due to their greater flood resilience.

### **Elevation of equipment to a higher floor**

This strategy involves elevating energy systems from the basement or other room below the DFE to a higher floor within the building or to the rooftop so they are no longer vulnerable to damage from floodwaters. The strategy can be applied to any energy system components that are not submersible or not required by building codes to be located on lower floors.

Technical feasibility: This strategy is proven and has often been implemented as a long-term resilience solution for energy systems (Bomke, 2013). Several of the building case studies in the previous chapter refer to the application of this strategy. Because this strategy is successful for long term resiliency, many new buildings are being designed with energy systems on higher floors or rooftops instead of the basement (Scheib, D'Angelo, Guenther, & Villacara, 2013).

Implementing this strategy in existing buildings will require building owners to deal with significant technical and engineering implications that are specific to their individual buildings. For example, the interworking of the system throughout the building may need to be redistributed, and duct sizes may need to be changed for air systems to change direction. Moreover, moving energy system components to the roof could require the rooftop to be reinforced, which may not be possible.

Raising electric service points to the third or fourth floor above grade would necessitate extensive internal rewiring within the building, so that switchgear is above ground rather than below grade (Bomke, 2013). For buildings with steam heat systems, in particular single-pipe systems, relocating heating equipment to the roof or any floor above the third or fourth floor would require a large-scale re-engineering of the heating system throughout the building (Corbett, 2013). This challenge arises because steam heating systems rely on the natural tendency of steam to rise and are difficult to configure so that steam can be forced downwards from the roof or a high floor.

Policy considerations: Zoning laws regulate a building's area and height by means of the calculated floor area ratio (FAR). The FAR is the principal calculation determining the allowable size of buildings: the ratio of total building floor area to the area of its zoning lot. Each zoning district has an FAR which, when multiplied by the lot area of the zoning lot, produces the maximum amount of floor area allowable on that zoning lot. For example, on a 10,000 square foot zoning lot

**Because elevation of energy systems enhances their resilience for the long term, some new buildings are being designed with energy systems on higher floors or rooftops rather than in basements.**

in a district with a maximum FAR of 1.0, the floor area on the zoning lot cannot exceed 10,000 square feet (NYCDCP, 2013). Areas in the building below grade – where building energy systems are mainly stored now – are not counted against the FAR. Building owners will be reluctant to use valuable area on the upper floors of their buildings (e.g. the area allowed by the applicable FAR) to house energy system components, which presents a major obstacle to the widespread practice of elevating energy systems to higher floors.

Public policy must change in order to resolve this conundrum. One option is for city officials to modify FAR restrictions to encourage building owners to relocate building services that would typically be located below grade. Maximum floor areas could be adjusted in cases where critical equipment that was originally placed outside the FAR-determined floor area and is moved into the FAR-determined floor area, such that the amount of space given to the relocated equipment be added back to the property as additional buildable area (Frank, 2013).

NYC-specific barriers and solutions: Given the high price of real estate in New York City, particularly within Evacuation Zone A, this strategy could be challenging to implement. Building owners may be unwilling to sacrifice income-producing floor space in their buildings, if the financial payoff from elevating equipment is uncertain. Additionally, the high up-front cost of elevating certain systems, such as HVAC systems, means that building owners are very unlikely to undertake this strategy without some financial support or incentive (Paciorek, 2013).

Cost considerations: Based on case studies mentioned in this report, this strategy can cost millions of dollars; costs are unknown and are specific to each building. Even though elevating equipment to higher floors represents a very effective protective measure, the strategy will not be cost-effective in every building. As noted above, energy system components that are relocated to a higher floor or a rooftop will occupy space that might otherwise produce income for the building owner, and the costs of moving the components and supporting systems (e.g. pipes, wiring) can be high (Glick, 2013). The financial benefits of implementing this strategy are of two kinds: rents (or revenue, in the case of hospitals) that are not lost if buildings remain operational during and after flooding emergencies, and rent premiums that might be charged to tenants because of the promise that buildings can remain operational due to their greater flood resilience. Depending on the particular conditions that exist for a building, the costs of elevating equipment and lost revenues could exceed the financial benefits from implementing the strategy (Zuluaga, 2013).

### **Elevation of hot water boiler**

Buildings use a wide variety of system designs and components to produce hot water and heat. Some buildings rely on a single system to make hot water for plumbing and heating; other buildings have separate systems. A building can make its heating and hot water service more efficient and resilient by installing separate systems and placing the heating components, such as a steam boiler, at a low level in the building while the hydronic (hot water) boiler is placed on a high floor or the roof, well out of reach of damaging floodwaters (Zuluaga, 2013). Using a separate hot water system allows a building to upgrade to high-efficiency condensing boilers (ASHRAE, 2011); condensing boilers are estimated to be 10% more efficient than conventional boilers (Che, 2004). Steam boilers are often impractical to elevate to higher floors due to the size and weight of these systems in addition to the significant engineering challenge of pumping steam downward.

Further energy savings can be realized if the building shuts down its heating system during warm months, when building heat is unnecessary (U.S. Department of Energy, 2011). This approach can provide a further measure of system resilience as well. During Hurricane Sandy, the heating system of a large multi-family complex in the Rockaways was destroyed by floodwaters. But some of this damage could have been mitigated had the system been fully shut down prior to the storm, to

prevent electrical shorts, and the expensive burner components removed from the boiler room (Zuluaga, 2013).

Technical feasibility: This is a well-proven strategy that would protect a building's hot water system from floods. It could be applied in any building that cannot relocate its heating equipment to higher elevations. In addition, high-efficiency condensing boilers are commonplace and widely recommended (ASHRAE, 2011). Ordinary maintenance routines can be used with elevated hot water boilers. Fuel pumps or a natural gas delivery system would need to be floodproofed or the boiler would have to be fed by an ancillary fuel source in order to operate in flood conditions.

Policy considerations: There are no policy barriers to this strategy, which has been implemented widely.

NYC-specific barriers and solutions: This strategy is uniquely appropriate for large multifamily buildings in New York City due to the predominance of steam boiler systems in this building population. Since this strategy would improve a building's energy efficiency, in multifamily buildings it could be implemented under NYSEERDA's Multi-Family Performance Program, as one of the measures that help the building achieve 15% reduction, or the Existing Facilities Program. However, the strategy is only eligible for these programs if the boiler fuel is natural gas.

Cost considerations: While the exact cost of placing a new boiler on a building's roof will depend on the building's size and hot water needs, one source estimated that implementation of this strategy, including new equipment costs, could be as low as \$70,000 (Glick, 2013). Condensing boilers typically last for 20 to 25 years (New York State Homes and Community Renewal, 2011).

### Installation of a secondary electrical panel

The most effective flood-resistant design of electrical systems in new and substantially improved buildings in flood-prone areas is elevation of all electrical components to levels at or above the DFE. If raising electrical equipment above the DFE is not practical within the electrical room, then secondary electrical equipment can be located on a floor above the DFE. This strategy is particularly effective for an electrical subpanel that can serve limited electrical needs from a backup generator. Installing a separate emergency electrical system, powered by a backup generator feeding a set of transfer switches and emergency subpanels that are also located above the DFE zone, will provide additional resilience for a building.

Technical feasibility: While installing a new electrical panel is relatively straightforward, integrating it into the building's system is more involved than what would appear on the surface. The electrical system can include wiring, transformers, switchboards, meters, circuit breakers, raceways, receptacles, and switches. The installation of this equipment as an integrated system is specific to each building, and can be time-consuming. Relocation of an electrical subpanel should be combined with floodproofing of the main panel or backup generation for optimal effectiveness (FEMA, 1999).

Policy considerations: No known policies would prevent the implementation of this strategy. The National Electric Code, which New York City follows, provides guidance on electrical system location, wiring, and emergency power requirements and should be consulted before installing any new panels (NFPA, 2008).

NYC-specific barriers and solutions: New York City's aging building stock is conducive to the implementation of this strategy, for electrical panels can be relocated as they are due for replacement.

Cost considerations: The cost to install an electrical panel on an elevated floor will be influenced significantly by the size of the building and the configuration of the electrical system. The function of the new panel, and whether it operates an independent emergency electrical circuit or is

integrated with the normal building system, will also affect the cost of implementation because specific switches and control circuits are required for either setup (Yuksel & Trotta, 2013).

## ON-SITE POWER GENERATION STRATEGIES

Certain buildings and multi-building complexes in New York City, such as healthcare facilities, rely on some sort of on-site system to generate electricity or heat or both, thereby reducing their dependence on electricity and heat from public utilities. Like energy systems that are connected to the power grid or district steam, on-site power generation systems are prone to disruption and failure when floods occur. This section explores strategies for improving the flood resilience of two types of power generation system: combined heat and power (CHP) systems, also known as cogeneration systems, and photovoltaic solar arrays.

### Black start capabilities for combined heat and power systems

NYSERDA has completed a wealth of technical and NYC-specific policy research on the implementation of CHP (NYSERDA, 2013). This research has largely focused on the ability of CHP systems to improve the energy efficiency of buildings under normal operating conditions and has not, to the writers' knowledge, explored the possibilities for using CHP systems to provide power and heat during grid interruptions. In fact, CHP systems can provide power and heat to buildings even when grid failures occur. During and after Hurricane Sandy, many buildings equipped with CHP systems continued using electric power and heat due to the uninterrupted supply of natural gas (Revkin, 2012).

Using CHP systems to power and heat buildings during grid power interruptions requires that these systems be configured for resilience. The U.S. EPA recommends three capabilities to enhance resilience: (1) uninterrupted supplies of natural gas or other fuels, (2) the ability to disconnect from the power grid; and (3) support of emergency power loads rather than general building loads.

Assuming that these capabilities are in place, the EPA recommends that "black start" capability be added to new and existing CHPs systems in order to make them operable during a blackout (U.S. Environmental Protection Agency Combined Heat and Power Partnership, 2007). A black start system consists of batteries and inverters that provide the electricity to operate a CHP system until grid power is restored (U.S. Environmental Protection Agency Combined Heat and Power Partnership, 2007). Without a black start system, a CHP system cannot run during a blackout.

**Technical feasibility:** CHP is a widely used technology, as indicated in the descriptions in the previous chapter. It is particularly common in healthcare: more than 200 hospitals in the U.S. use CHP systems (U.S. Department of Energy, 2011). Although both the EPA and NYSERDA recommend black start systems for all CHP installations, a number of factors indicate that black start systems may be unreliable sources of backup power for all building types within the flood zone.

First, in New York City buildings, CHP systems are commonly located in basements (Glick, 2013) (Vardakas, 2013). Installing CHP systems on buildings' roofs is challenging for technical

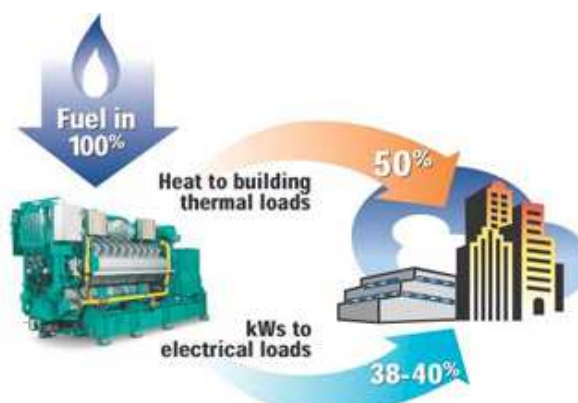


Figure 5-3: Cogeneration (Diagram Source: Integrated Power Systems International, Inc.)



reasons as well as costs (Vardakas, 2013). Rooftop CHP units are more difficult to maintain and must be housed within a structure for protection. In addition, CHP systems function best when located near electric panels, which are usually in the basement or sub-basement (Glick, 2013).

If floodwater inundates a CHP system, it cannot be used until the entire system is serviced. Because CHP systems are modular, cleaning a CHP system's components and replacing electrical panels will generally enable the system to work again. But until the system is serviced, it is inoperable, whether or not it has black start capabilities (Glick, 2013).

An additional limitation pertains to CHP systems in multifamily and commercial buildings. CHP systems need to be designed to balance the production of electricity and heat. Since space heating needs change dramatically with the seasons and multifamily and commercial tenants generally pay for their own electricity, CHP systems are built to cover the electric needs of common areas and hot water needs of multifamily and commercial buildings, which are consistent year round (Glick, 2013) (Vardakas, 2013). As a result, CHP systems in multifamily settings are sized to cover only a portion of the electric and heating load. For example, a multifamily building with a 500 kW base load might be outfitted with a 75kW CHP system (Vardakas, 2013). In blackout conditions, then, the multifamily building's CHP system alone would be unable to support the building's base load, making it somewhat less useful as a backup system during grid power failures. Hospitals have high and steady electric and hot water needs and are not divided into tenant spaces, so they are not subject to the same limitations as multifamily and commercial buildings.

Policy considerations: No known policies or codes would prevent the implementation of black start systems for CHP installations.

NYC-specific barriers and solutions: Numerous facilities in New York have CHP systems, and the technology has proven effective at providing heat and power during grid failures. For example, the Montefiore Medical System in the Bronx has a CHP system with total electrical capacity of 10 MW, which provides all the electric and thermal needs of the medical center. During the 2003 Northeast blackout, Montefiore was reportedly the only hospital in New York City able to continue normal operations (NYSERDA, 2009). Meanwhile, other CHP systems located in the flood zone experienced outages after inundation with flood water (Glick, 2013). NYSERDA administered a CHP grant program that concluded in 2012.

Cost considerations: Adding black start capability to a CHP system can increase the overall project cost by about 50% (Vardakas, 2013). Locating the entire system on the roof, to prevent it from being inundated by floodwaters, could more than double the cost of the system (Vardakas, 2013). Other estimates suggest that adding black start capabilities to a CHP system can cost \$1,000 to \$2,000 per kW (Glick, 2013). In multifamily and commercial buildings with limited thermal loads, black start-equipped CHP systems would also likely need to be supplemented by backup generators in order to meet emergency-level electric power requirements, making them less cost-effective.

### Solar power systems

Solar installations can reduce a building's demand for electricity from the grid as well as support buildings as a backup energy source during emergency situations. The NYC Office of Emergency Management has identified that "small utility-interactive PV systems with battery backup increase the effectiveness of disaster-resistant buildings and ultimately support communities to meet distributed generation needs" (CH2MHill, 2009, p. 8). Solar energy was used following Hurricane Sandy to meet basic energy needs. The Solar Sandy Project established 17 10kW mobile PV arrays to provide power for lighting, heating food, and charging electronics. Though the Solar Sandy Project did not help individual buildings, a number of 10kW mobile PV arrays could power a building or even a cell phone tower (Tweed, 2012).



Solar PV installations are widely deployed in the US, where more than 300,000 installations exist, with total operating capacity of 7,221 MW (GTM Research, 2012). Many manufacturers offer PV panels, system design, and installation support services within the US, and specifically in NYC.

Technical feasibility: To be used as a reliable source of backup generation, PV systems need to be installed with a battery component to store energy for use during periods when solar energy is not available to the system (Kling, 2013) (Zuluaga, 2013) (CH2MHill, 2009). Moreover, it is unlikely that a building would be able to feed all of its backup power needs from a rooftop PV system due to limited sizing capacity in NYC and solar intermittency issues, but solar could be packaged together with other back up feeds, such as CHP, to support the building (Zuluaga, 2013). Sizing is highly dependent on the buildings needs so it is difficult to generalize how much power would be required (Kling, 2013). One expert suggested that a large multi-family building would want to look into a 25kW installation since that would have the capability to run an elevator (Zuluaga, 2013).

Like black start CHP systems, solar PV systems must be able to be disconnected from the power grid to function during a grid power outage, a capability known as “islanding”. The types of inverters and other capabilities needed to disconnect a solar PV system from the grid means that it is easiest for backup capabilities to be incorporated in the design phase; retrofitting an existing system can be difficult. However, most inverters now do have an off-grid mode, which is acceptable to use as long as the inverter is UL-listed (Kling, 2013).

Policy considerations: No policy measures or building codes prohibit the use of solar PV systems under normal operating conditions. The following passage describes restrictions, specific to New York City, on the use of solar PV systems during grid failures.

NYC-specific barriers and solutions: PV installations are becoming more common in New York City. As of June 2012, there is 11.5 MW of solar capacity installed within the five boroughs with annual production of over 15 million kWh (City University of New York, 2012). Notably, half of the solar installations in New York City, equivalent to approximately 5 MW of electricity, are within areas flooded during Hurricane Sandy (Kling, 2013).

In New York City, grid-connected solar PV systems are required to be fully shut down during a wider grid failure (City University of New York, 2013) but Con Edison will allow a system to run if it can be isolated (Con Edison, 2013). SIR/IEEE 1547 standards allow islanding, but this capability has not been widely implemented and remains relatively expensive. No policy incentives for islanding are available (Kling, 2013). In order to implement islanding, this capability would have to be designed into the system prior to installation, and the service arrangement with Con Edison would have to follow the utility’s guidelines for inverter-distributed generation.

Cost considerations: Costs of solar PV systems range between \$0.30-0.50/w for “daylight emergency power” that provides a very limited amount of power during the day (1 outlet), or for an inverter that is capable of on- and off-grid operation, with or without a battery that can power a fan or water pump or more outlets (City University of New York, 2013). Per-watt costs range from \$0.30 to several dollars, for grid-connected PV systems with off-grid capabilities (e.g. batteries) (City University of New York, 2013).

## **BACKUP POWER GENERATION STRATEGIES**

As described in the case studies in the preceding chapter, permanent backup systems for generating electricity can support some building functions during periods when grid power is unavailable. Installing such systems thus represents one category of strategies for improving the resilience of buildings’ energy systems during flooding emergencies. However, the pitfalls associated with backup generation are evident: as New York City experienced after Hurricane Sandy, region-wide fuel shortages caused many buildings with diesel-powered generators to run out of fuel

(Ventre, 2012). Among buildings with backup generators, those with enough fuel to last a week to ten days performed well. Buildings with smaller fuel stores had difficulty supplying their generators through the grid power outage following the storm. Some have responded by revising their procedures for supplying fuel oil and increasing fuel storage capacity (Calvano, 2013).

The National Energy Technology Laboratory asserts that buildings and electric utilities alike would benefit by having backup generation systems integrated with a building's normal operations, not just their emergency operations. The laboratory sees an additional possibility for backup generation systems to act as distributed generation capacity during non-blackout conditions, thereby reducing peak energy demand on the utility and, potentially, lowering a building's energy costs (Zheng, 2008). A 2007 study estimated that New York City is home to approximately 1320 MW of backup generation capacity (Gilmore & Lave, 2007). This approach to energy management across a grid is known as *demand response* and is described more fully in the Appendix to this report.

The New York Independent System Operator (NYISO), the nonprofit agency responsible for maintaining the reliability of the bulk electric grid, incentivizes large energy users to reduce their electrical load during periods of peak demand by taking part in demand response programs (DRPs). Facilities can reduce their usage of grid power by either shutting down unnecessary loads or by shifting their load to an on-site generator when called upon by the utility (NYISO, 2010). Participation in such programs can offset some of the capital investment and maintenance cost associated with backup generation systems, particularly if the systems are run for more than 2000 hours per year (Gilmore & Lave, 2007). Only sources such as traditional backup generators or fuel cell systems are appropriate for demand response programs as they can be dispatched on demand. By providing incentives to increase participation in DRPs, NYSERDA can widen the utilization of backup generation and improve the energy resilience of the city's building stock.

### Backup generators

Traditional backup generators combust natural gas or liquid fuels, such as diesel and propane, to generate electricity. A standby generator is a back-up electrical system that operates automatically. Within seconds of a grid power outage, an automatic transfer switch senses the power loss, signals the generator to start, and transfers the electrical load to the generator. The standby generator begins supplying power to the circuits. After utility power returns, the automatic transfer switch transfers the electrical load back to the utility and signals the standby generator to shut off. Most backup generators run on diesel fuel or natural gas (Hickey, 2002).

**After Superstorm Sandy, region-wide fuel shortages caused many buildings with diesel-powered generators to run out of fuel.**

Automatic standby generator systems may be required by building codes for critical safety systems such as elevators in high-rise buildings, fire protection systems, standby lighting, or medical and life support equipment. Residential standby generators are increasingly common (Hickey, 2002).

Technical feasibility: Backup generators are a proven technology that has been implemented in many buildings and is prevalent in healthcare facilities. A number of the healthcare case studies presented in this report noted the use of backup generators to keep buildings supplied with electricity following Hurricane Sandy.

Though crucial to resilience, backup generators are generally considered outside of normal building operations. They have been found to fail 20-30% of the time because of maintenance lapses (Koerth-Baker, 2012). In order for a standby generator to improve the resilience of building energy systems, its fuel tanks, pumps, and electrical switchgears must remain operational during a storm.

Furthermore, traditional backup generators are not designed to run on a routine basis, so the fuels and designs need to be reassessed to reduce pollution and noise and increase reliability.

Biodiesel could play a role in this regard, for it burns more cleanly than other liquid fuels and can be used in existing diesel systems (Barrett, 2004). Carbon monoxide emissions from generators pose health risks to users and others nearby (Miller, 2012) (Ventre, 2012).

Should fuel supplies run low, deliveries must be made to keep the generator running. Distribution networks for liquid fuels were revealed to be highly vulnerable during and after Hurricane Sandy (Ventre, 2012).

Policy considerations: NYC Fire Department regulations require that fuel tanks feeding a generator are located in the basement of a property. The city's building code allows natural gas fired generators to be placed on a building's roof (Geiger, 2012). The Joint Commission, an accreditation organization for the healthcare industry requires hospitals to only use diesel powered backup systems in order to be eligible to receive federal funding. Unless changed, this policy poses a barrier towards the adoption of natural gas fired backup generators in hospitals (Paternoster, 2013).

NYC-specific barriers and solutions: To support DRPs, NYSERDA's FlexTech program shares the costs to develop peak-load curtailment plans (PLCPs), and the Existing Facilities Program (EFP) offers capital incentives to offset a portion of the technology costs required to participate in DRP. These offsets include the cost of automation equipment and new on-site generators (NYSERDA, 2012). To protect its investments and improve the flood resilience of facilities, NYSERDA could require the implementation of additional floodproofing measures as a qualifying condition of FlexTech and EFP applicants seeking funding for backup systems.

Cost considerations: The cost of backup generators varies according to the capacity needed to power a building. A 40-story multifamily building in New York City installed a 275 kW diesel generator at an approximate cost of \$300,000, with enough capacity to power the building's elevators, hallway lighting, and emergency services and successfully ran the generator during and after Hurricane Sandy (Lyons, 2013). Larger generator systems capable of powering commercial buildings with sensitive data can be much more expensive, at \$2 million or more (Yuksel & Trotta, 2013).

## Fuel cells

Fuel cells can be used to provide a backup source of electricity, generated on site using natural gas without dependence on the electric grid. Fuel cells operate silently with far fewer toxic emissions than combustion engines and are relatively compact, making them suitable for use within hospitals and residential buildings (Fuel Cell Today, 2013). When waste heat is captured in a CHP configuration, fuel cells can convert more than 80% of the fuel energy to usable energy (U.S. Department of Energy, 2012) and can provide both heat and cooling through absorptive chilling.

Compared to the electric grid, natural gas delivery in New York City has been very reliable, which allows fuel cells to power buildings when the electric grid fails (Hughes, 2013). Elevation of fuel cell equipment above the floodplain will benefit from the low emission and noise characteristics of fuel cell operation. With heat recovery, fuel cells convert natural gas to energy more efficiently than gas-fired CHP. Fuel cells don't have moving parts, making their maintenance simpler (Fuel Cell Today, 2013).

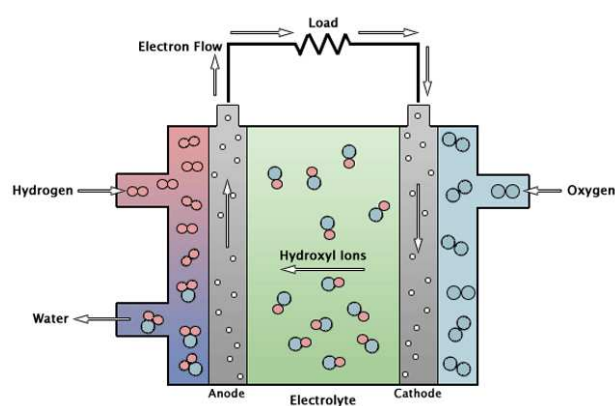


Figure 5-4: Fuel Cell (Photo Source: Inhabitat)

Fuel cells have been installed by the U.S. military and large companies like Microsoft, Apple, and eBay (Miller, 2012) (Pentland, 2012). Some healthcare facilities have installed fuel cells to meet some of their energy needs. For example, St. Helena Hospital, a 181-bed community hospital located in Napa Valley, Calif., recently installed a PureCell (UTC) system to provide 60 percent of the hospital's electricity needs and 50 percent of its space heating and domestic hot water requirements (Ferenc, 2012). Kaiser Permanente deployed four megawatts of solid oxide fuel cells from Bloom Energy that power seven facilities in California (Kaiser Permanente, 2011).

Technical feasibility: Reliability and cost are the primary concerns associated with this relatively new technology: while the reliability of fuel cells has improved over time, the technology has a short track record and its reliability has not been convincingly demonstrated (National Fuel Cell Research Center, 2009). Nevertheless, the use of fuel cells in stationary applications has been steadily increasing every year since 2008, particularly in the United States and Korea (Fuel Cell Today, 2012). As of 2012, the U.S. market for stationary fuel cell applications are split among three major suppliers and three technologies: Bloom Energy, UTC Power (now called ClearEdge Power in 2013), and FuelCell Energy (Fuel Cell Today, 2012). Other vendors include Ballard Power Systems, Plug Power, and Panasonic, as well as many startups (Gigaom, 2010).

Policy considerations: No known policies or codes prohibit the use of fuel cell systems.

NYC-specific barriers and solutions: Installing fuel cell systems in city settings can be challenging because of their size and weight. However, their low emissions provide an advantage, enabling buildings to generate power on site without violating ambient air quality standards. NYSERDA offers a Fuel Cell Rebate Performance Incentive that can provide up to \$1 million for systems larger than 25kW (DSIR, 2013).

Cost considerations: The upfront capital required to purchase and install a fuel cell system can vary significantly depending on the size of the system: \$2 to \$2.5 million will purchase a 400kW UTC unit (Ferenc, 2012), while four 200kW UTC Power PAFC fuel cells with four rotary UPS systems will cost approximately \$4 million (U.S. Department of Energy, 2010). UTC's best-in-industry fuel cell stack life is rated at 10 years (Burger, 2012). Power purchase agreements can be used to eliminate capital expenditures costs and maintenance costs. The New York City office building Four Times Square uses two on-site fuel cells to generate 3 million kWh per year (Oak Ridge National Laboratory).

## ENERGY EFFICIENCY STRATEGIES

Although energy efficiency strategies might not improve resilience on their own, such strategies can reinforce dedicated resilience strategies by allowing a building's energy systems to operate with less input, thus making it possible to run critical systems from smaller backup generation capacity, or for a longer duration. Thermal improvements in existing buildings can be used to keep a building habitable and functional even when its full operations have been curtailed. The ability of a building to maintain critical life-support conditions for its occupants even if energy services are down for extended periods is generally known as passive survivability (Wilson, 2005).

Although energy efficiency strategies can be applied to most building types, for purposes of improving flood resilience, they are most practical to consider as options for multifamily buildings which may need to operate as shelters in place following a flood event. Energy efficiency strategies may also be useful for improving the resilience of hospitals although hospitals tend to be well-equipped with backup or onsite generation capacity. Energy efficiency strategies are least useful for improving the resilience of commercial buildings, since these buildings will not generally be operated when critical energy systems are down.



Building designs that promote efficiency and resilience that have been recommended by sustainability conscious designers for years are now getting increased attention for incorporation into NYC buildings following Hurricane Sandy (Shepherd, 2013). An integrated energy efficiency plan that uses proven design, construction, and passive strategies can create multiple resilience benefits, including enhanced building comfort and temperature control during periods when energy systems cannot be operated and reduced overall energy loads that can be supported more readily by backup generation systems. Efficiency strategies are generally widely available, relatively low cost, and provide minimal protection during a flood event.

### **Room fans**

Box, oscillating, or ceiling fans can improve interior comfort at temperatures outside of the typical ASHRAE recommended zones in buildings at a reasonable cost (Santamouris, Pavlou, Synnefa, Niachou, & Kolokotsa, 2007). Fans draw much less electricity than air conditioners, making it more feasible to operate them from backup generation systems. Additionally, building owners can control fans using a central switch. In blackout conditions, if a building is able to produce or utilize a small amount of electricity, permanently installed fans could be powered from a backup generation system and activated by the building owner to manage the building temperature.

### **Cool roofs**

The use of light and reflective colors on roofs can decrease the surface temperature of the roof, and subsequently the heat that is transferred into the building (Santamouris, Pavlou, Synnefa, Niachou, & Kolokotsa, 2007). This technique can reduce the surface temperature of the roof by as much as 16 degrees, reducing the cooling load required for the building during the summer months. Cool roofs are an effective strategy being employed to help reduce the heat island effect in cities (Shepherd, 2013).

### **Managing the infiltration of outside air**

Some energy efficiency strategies are only effective in certain climates and with certain building traits. Minimizing the infiltration of outside air is one such strategy that is appropriate for the colder climate of New York City (New York City Department of Buildings, 2010). The strategy involves improving window insulation and air sealing. In summer months, when temperatures rise, natural ventilation can be enabled with operable windows that allow cooler nighttime air into the building (Grondzik, Kwok, Stein, & Reynolds, 2010). New York City design firms are seeing an increased interest for operable windows following Hurricane Sandy (Shepherd, 2013).

### **Window glazing**

The thermal performance of windows can be improved with multiple glazing layers, low-conductivity gases (such as argon) sealed between glazing layers, low-emissivity coatings on one or more glazing surfaces, and use of low conductivity framing materials such as extruded fiberglass. When implemented properly, glazing that reflects or absorbs a large fraction of the incident solar radiation can penetration of solar heat by up to 75 percent. Windows with improved thermal characteristics are a particularly attractive strategy to consider if a building is already planning on replacing windows. To optimize performance and keep costs low, south-facing windows should be prioritized for glazing treatments (Jakob & Madlener, 2004).

### **Insulation of buildings and ductwork**

Insulation can be inexpensive and effective for maintaining a comfortable indoor environment. Recent research in the United States has demonstrated that leaks in ducts for



distributing air for heating and cooling can increase energy requirements for these systems by 20 to 40 percent (Metz, Davidson, Bosch, Dave, & Meyer, 2007), while more tightly sealed HVAC ducts can be more efficient. Sealing technologies, include fine particles that can be sprayed into the duct system to seal small leaks, are a low cost and simple means of reducing leaks in existing buildings. Sealing air distribution systems can also improve air quality in a building.

### Hybrid ventilation management

Hybrid ventilation strategies combine mechanical and natural ventilation techniques, providing greater benefits than ventilation strategies in isolation. These include night ventilation and earth-to-air heat exchangers (Santamouris, Pavlou, Synnefa, Niachou, & Kolokotsa, 2007) in addition to simple insulation strategies for room air conditioners (Urban Green Building Resiliency Task Force, 2013) and the building's ventilation system (Rosenzweig, et al., 2011). Hybrid ventilation strategies may be especially valuable in high-rise commercial buildings where ventilation and cooling can account for more than 50 percent of a building's energy requirements (Heiselberg, 2000). Hybrid ventilation systems have been tested with much success for multifamily buildings in urban areas and, in comparison with natural ventilation, offer the added benefit of improved indoor air quality.

### OPERATIONAL STRATEGIES

The preceding analysis focuses on structural improvements to existing buildings. However, other strategies for improving the resilience of buildings' energy systems are more operational in nature. While this report does not explore these strategies in depth due to scope limitations and time constraints, they are summarized below for the reference and consideration of certain building owners who might find them valuable. NYSERDA may wish to investigate the following operational strategies further.

- Sandbags and barricades – As described in the case for 200 West Street, this strategy was effective at protecting the building from four feet of flood water during Hurricane Sandy.
- Flushing the electrical system – When a building has been flooded with salty or brackish water, the electrical systems can be flushed with freshwater and inspected to determine if any of the wiring needs to be replaced. All components must also be dried thoroughly with heaters and fans (Smith, 2012).
- Removing burner starter – Research on the heating system suggested that the system could be completely shut down to prevent electrical shorts and expensive burner components removed from the boiler room prior to a flood in order to minimize damage and replacement costs (Zuluaga, 2013).

## SUMMARY OF STRATEGIES

In evaluating and comparing strategies for improving buildings' energy resilience against flooding, four criteria make up the analytical framework: technical feasibility, range of applications, cost to implement, and avoided cost. Each criterion addresses key considerations that building owners must confront when determining how to make their buildings' energy systems more resilient. The four criteria and their underlying considerations are as follows.

Technical Feasibility – This criterion considers the availability, maturity, and reliability of the technology and operating procedures that a strategy depends on. Strategies that rely on proven and widely available technologies and operating procedures are rated more highly than strategies that rely on emerging technologies and more experimental procedures.




Range of Applications – This criterion refers to the variety of buildings that could consider utilizing the strategy. Policy considerations and NYC-specific barriers and solutions, two aspects of each strategy that were explored in the previous chapter, are taken into account when assessing how readily the strategy might be applied to different buildings. Strategies that can be readily applied to a wide range of building types are rated more highly than strategies that only work in buildings that have particular traits, such as limiting load constraints and practical limitations on how space can be repurposed.

Cost to Implement – The precise cost of implementing a strategy can only be calculated with regard to a particular building and its specifications. Nevertheless, ranges of expected costs have been provided in the strategy descriptions in this chapter. Using these ranges as a guide, the approximate upfront capital cost to implement a strategy can be compared against the approximate upfront cost of other strategies. Additional determinants that contribute to the total cost to implement a strategy, such as the anticipated renovation needed to accommodate the strategy, were also taken into account. Strategies having lower capital costs are rated more highly than strategies that involve greater capital expenditures.





































































Avoided Cost – This criterion refers to the expected costs that a building owner can increase his chances of avoiding, during and after a flood event, by implementing a given strategy. As with Cost to Implement, this criterion will depend on a number of factors, including the typical use of a building, the value of the assets it contains, and the flood elevation of the building. However, avoided costs can be estimated for each strategy with regard to particular buildings based on case studies and research identified in previous chapters. Components of avoided costs include avoided losses of building revenue (by maintaining building functions during a flood event and by minimizing recovery time after a flood event) and avoided capital costs (by preventing damage to energy systems and building infrastructure). A strategy that allows a building to avoid most or all costs by keeping the energy systems fully functional during a storm event, eliminating building downtime after the event, and fully protecting energy system components will be rated most highly.

The first table on the following page provides descriptions of the ratings as they relate to each of the criteria described above. The second table summarizes the ratings that were applied to each of the strategies analyzed in the report. Based on the analysis presented in this chapter, each strategy was rated separately.

### Strategy rating key

Criterion / Sub-consideration		High 	Medium 	Low 
<i>Technical feasibility</i>		Well-known and available	Available; may require customization	Emerging or limited availability
<i>Range of applications</i>		Easy for all buildings	Applicable to some buildings	Highly site-specific, typically requires changes to building infrastructure
<i>Cost to implement</i>	Building renovation required	None	Minor	Major
	Customization	None	Some design may be required	Custom design required
<i>Avoided cost</i>	Equipment protection	Full, high value equipment	Partial, potential for damage	Light, low equipment value
	System downtime	Minimal to none	Some downtime possible	Downtime likely
	Functionality during flood	Full	Limited, emergency services only	Minimal to none

### Strategy comparison table

Category	Strategy	Technical feasibility	Range of applications	Cost to implement (1)	Avoided cost
Floodproofing	Watertight enclosures				
	Sealing exterior cavities				
	Sump pump				
Elevation	Equipment within a room				
	Equipment to a higher floor				
	Hot water boiler elevation				
	Secondary electrical panel				
Backup generation	CHP - black start				
	Standby/backup generators				
	Solar as a backup system				
	Fuel cells				
Efficiency	Room fans				
	Cool roofs				
	Managing outside air				
	Window glazing				
	Insulation				
	Hybrid ventilation				

1. Relative cost to implement strategy, compared to other strategies in the same category

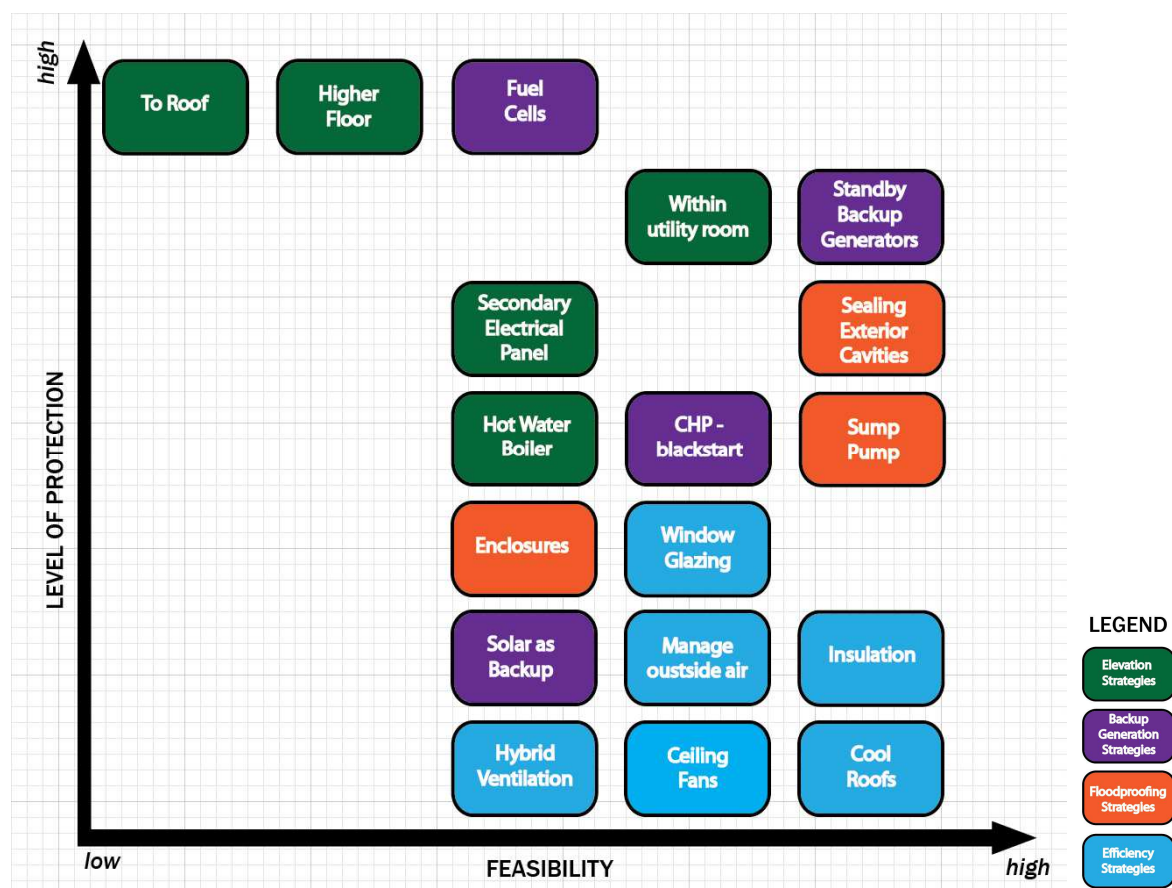
## COMPARING SOLUTIONS FOR EACH BUILDING TYPE

The diagrams in this section provide a graphical representation of the strategy rankings for each building type, based on the analysis documented in the preceding tables. The x-axis expresses the combination of Technical Feasibility and Range of Applications (from the criteria described above), and the y-axis expresses the level of protection that the resilience strategy can provide, in terms of Avoided Cost. Locations close to the origin represent less favorable strategies; locations farther from the origin represent more favorable strategies.

The diagrams are intended to help building owners understand, in general, the tradeoffs associated with certain strategies. Building owners should thoroughly evaluate resilience strategies for a given building in order to develop an effective approach, rather than relying on the diagrams to make decisions.

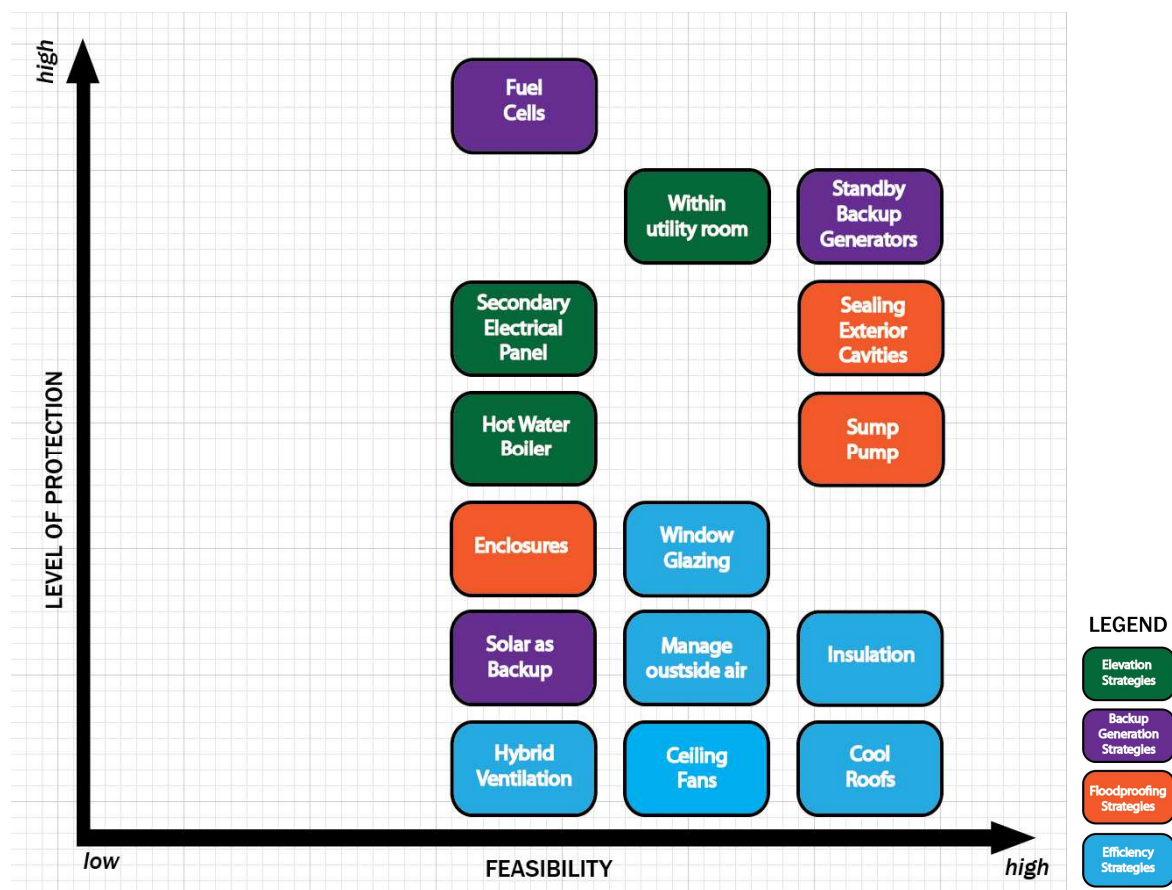
## Evaluating Solutions: All Buildings

The first chart plots all the strategies onto a chart with regard to all buildings. The ideal strategy for a given building will offer high feasibility with a high level of protection, while delivering the necessary level of performance. Because no single strategy can provide maximum resilience for a building's energy systems at a reasonable cost, most buildings will need to apply a combination of strategies in order to attain a high level of resilience at a reasonable cost. Such a holistic approach to strategy selection will encompass a combination of strategies for floodproofing, elevation, backup generation, and energy efficiency. The following diagrams give a clearer indication about which strategies are practical for each of the three building types considered in this report.



## Evaluating Solutions: Multifamily

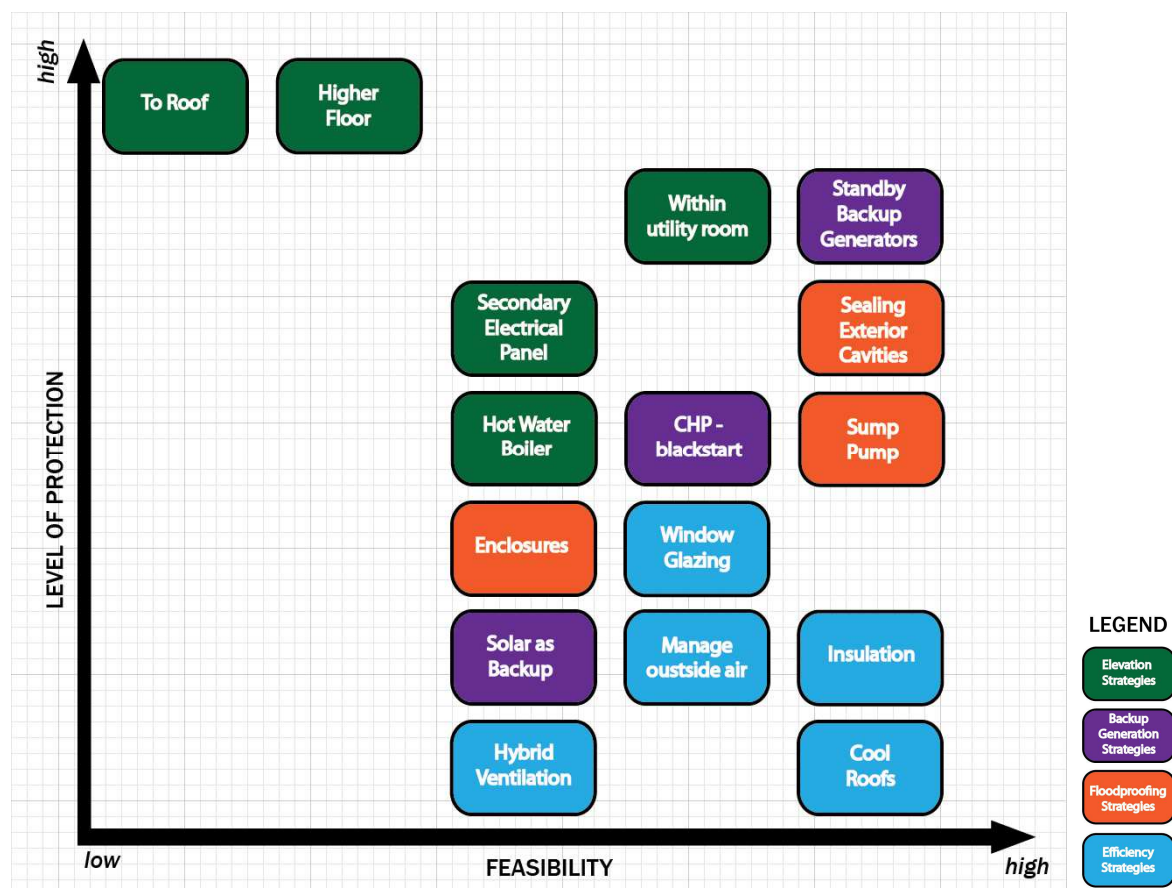
Fewer resilience strategies are recommended for multifamily properties, since they can operate with limited functionality during a flooding emergency and therefore require less energy system performance. The primary function for a multifamily building is to allow its residents to shelter in place while maintaining an adequate level of thermal comfort and minimal energy services. Strategies that rank highest for protection and feasibility include sealing exterior cavities, installing sump pumps, elevating the water boiler to the roof, elevating equipment above the DFE, and implementing thermal and efficiency improvements. Elevating systems to higher floors within the building may not be practical for many buildings because the systems would reduce the rentable/salable space on those floors. CHP systems equipped with black start capabilities might not be practical for multifamily buildings because these systems are sized to cover only a portion of the building's electric and heating load when applied to a multifamily setting.





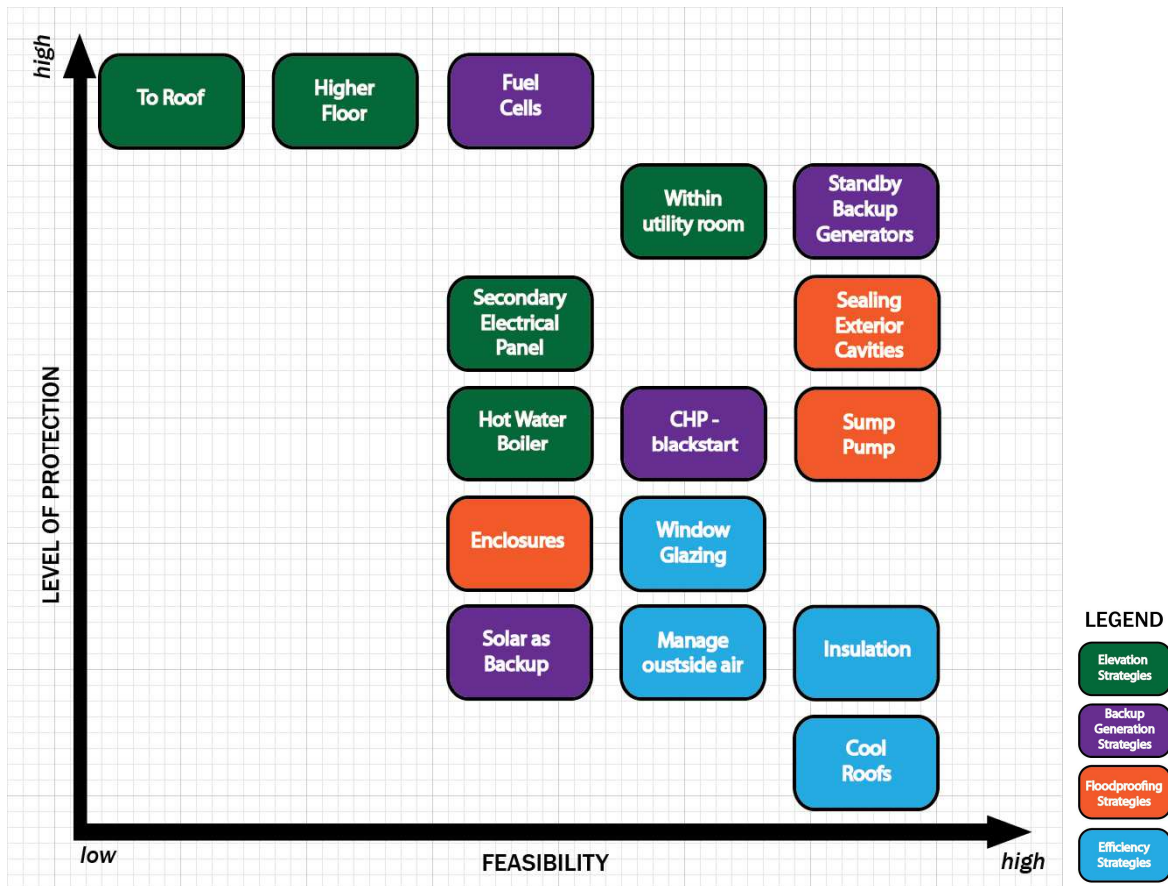
## Evaluating Solutions: Commercial

For commercial buildings, profitability is likely to be a more important consideration than maximizing building function. The recommendations of resilience strategies for commercial buildings are geared to allow the buildings to protect valuable energy system equipment and for normal energy services to be restored with minimal repairs or replacement of equipment. Elevating systems to higher floors or rooftops offers high protection but low feasibility. Strategies that are feasible and provide high protection include sealing exterior cavities, installing sump pumps, and elevating equipment in utility rooms and above the DFE. The decision to use support backup generation is dependent upon the value of avoided downtime. Businesses that value continuous operation highly should use backup generators. Maintaining thermal comfort during and after a flooding event is not a priority because full evacuation of the building is expected. Thus, the installation of ceiling fans is not included on the chart.



## Evaluating Solutions: Hospitals

A large number of strategies are applicable to hospitals, due to the high level of resilience they need to achieve in order to sustain performance during and after floods. Hospitals will benefit from implementing multiple strategies. High-feasibility, high-protection strategies include sealing exterior cavities, installing sump pumps, elevating equipment well above the DFE, and installing backup generators. Energy efficiency strategies are noteworthy for their high feasibility but offer limited protection. Hybrid ventilation and ceiling fans are not applicable to healthcare facilities because of the strict air quality standards specific ventilation control requirements they must fulfill.



# 6 Recommendations and Conclusions

Given the wide variety of designs, construction methods, locations, and primary functions of buildings in New York City, no single resilience strategy emerged as a universally applicable best practice under the criteria described in this report. However, as explained in Chapter 5, many strategies provide increased resilience for a building's energy systems when they are applied together, such that multiple-strategy combinations aligned to the specific needs of particular buildings will represent best practice approaches. The table below presents the strategy combinations that can offer the most improvement in energy system resilience for each of the three major building types.

Each building will have unique design, construction, and operational considerations that inform the possibilities for improving resilience. As a result, holistic approaches will vary in their specifications even among buildings of the same type. In most buildings, energy systems can be made more resilient by applying a combination of strategies, from all four categories, that is tailored to its operational goals, its infrastructure characteristics, and the needs of its owners, managers, and occupants.

Building Type	Resilience Goals	Recommended Combination of Strategies
Multifamily	<ul style="list-style-type: none"> <li>• Protect equipment from damage</li> <li>• Maintain survivable interior temperatures</li> <li>• Provide minimal electricity service</li> </ul>	<ul style="list-style-type: none"> <li>• Seal exterior cavities</li> <li>• Install sump pumps</li> <li>• Elevate the water boiler to the roof</li> <li>• Elevate equipment within the utility room and above the DFE where possible</li> <li>• Implement thermal and efficiency improvements to improve habitable conditions during an outage</li> <li>• Provide backup generation for basic services that will allow for a base load of critical services to allow the building to remain habitable for tenants after storm waters recede</li> </ul>
Commercial	<ul style="list-style-type: none"> <li>• Protect equipment from damage</li> </ul>	<ul style="list-style-type: none"> <li>• Seal exterior cavities</li> <li>• Install sump pumps</li> <li>• Elevate equipment within the utility room and above the DFE where possible</li> <li>• Optionally, provide backup generation for basic services</li> </ul>
Hospitals	<ul style="list-style-type: none"> <li>• Remain fully functional through flood emergency</li> <li>• Provide additional services and care</li> </ul>	<ul style="list-style-type: none"> <li>• Seal exterior cavities</li> <li>• Install sump pumps</li> <li>• Elevate all equipment well above the DFE</li> <li>• Provide full functionality through backup generation</li> </ul>

In addition to these strategies, all buildings can benefit from energy efficiency improvements that provide greater levels of interior comfort and allow lower-capacity backup generation equipment to be used. Buildings that choose to employ backup capability may benefit even in non-storm events through the use of peak load shaving or demand response capabilities in agreements with local utilities. (Further information about demand response programs is in the Appendix.)

## INTEGRATING RESILIENCE STRATEGIES WITH NYSERDA'S PROGRAMS

A holistic approach to resilient, efficient energy management can be supported by many of NYSERDA's existing and proposed programs. Many of the strategies identified in this report are already supported through existing NYSERDA programs, and other programs could be updated to provide incentives or impose requirements for the implementation of resilience measures. This section presents an overview of recommendations for integrating resilience strategies with NYSERDA's programs.

### Primary recommendation: Feasibility studies

The primary programmatic recommendation for NYSERDA is to support feasibility studies of how individual buildings can improve the resilience of their energy systems. Such studies might be supported through existing or new programs, as explained here:

- Multifamily buildings – NYSERDA could introduce a program similar to FlexTech that funds resilience studies for individual buildings. The study protocol would specify consideration of each building's flood risk and operational goals as well as its construction and design features.
- Commercial and hospital buildings – NYSERDA could provision a resilience category under its FlexTech program, again specifying consideration of each building's flood risk, operational goals, and construction and design features.

It is recommended that the feasibility study begin with an assessment of elevation strategies, in order to establish the foundation for other strategies. Floodproofing strategies should be evaluated next, followed by backup power generation strategies. This analytical sequence will enable each feasibility study to produce a holistic set of strategies for improving the resilience of a building's energy system. Below is a more complete description of this potential framework for evaluating each strategy under the recommended feasibility study approach.

Elevation strategies should be considered first, for they provide the best protection of energy system equipment in a flood event. Feasibility studies should consider the costs and feasibility for a specific building.

Floodproofing strategies can next be assessed as measures to complement the elevation strategies that appear to offer the most utility for the building. The table below shows how complementary floodproofing strategies can be matched with preferred elevation strategies for a building.

Preferred elevation strategy	Complementary floodproofing strategy
Elevate equipment to a higher floor	Supplemental floodproofing is not necessary
Elevate equipment within the utility room	Supplement with sealing strategies, sump pumps, and equipment enclosures. Enclosures can be for individual pieces of equipment, or for the entire room. Partial flood walls may prove ineffective here, since the equipment will be partially elevated

Preferred elevation strategy	Complementary floodproofing strategy
No elevation is possible	Mandatory implementation of sealing strategies, sump pumps, and consideration of equipment enclosures. Enclosures can be for individual equipment, the entire room, or partial flood walls. Consider elevation of hot water boiler for multifamily and hospitals Consider providing a secondary electrical panel on a higher floor for emergency service

Backup generation can be considered in tandem with elevation, if some degree of energy system function is determined to be necessary for a building. If backup generation is applicable to the building, the following considerations should be used to evaluate options.

- First, the emergency level of energy system performance should be determined
  - Hospitals in Evacuation Zone A are strongly recommended to have enough backup generation capacity to power all their functions, and even additional functions
  - Multifamily buildings should consider supporting limited energy loads
  - Commercial buildings should determine the necessary level of backup generation capacity according to the business needs of the building owner and tenants
- The specifications of the backup generation system can then be determined
  - Critical building functions that need backup generation must be prioritized
  - Energy loads for critical functions must be sized, taking into account opportunities for efficiency improvements based on NYSERDA's expertise
  - An appropriate generation technology should be selected
  - The system should be sized and designed with respect to the recommended elevation and floodproofing strategies for the building

Energy efficiency strategies are generally relatively easy to implement and allow for improved energy system performance under normal conditions and during flood events. Energy efficient buildings can also use lower-capacity energy systems for normal operations and backup generation. The following efficiency strategies are recommended to tie the building studies with existing NYSERDA programs such as the Multifamily Performance Program (MPP) and Existing Facilities Program (EFP).

- Couple recommended efficiency strategies with existing efficiency programs
- Require Zone A buildings to complete a resilience study prior to obtaining support for efficiency projects or implementation of resilience strategies

General considerations are presented below for the design of feasibility studies and the integration of study results with NYSERDA's existing programs.

- Commission qualified and certified assessors in flood resilience strategy analysis; build on current network for efficiency
- Include flood protection level of the strategy being evaluated, and DFE required of the building based on Appendix G of the building code
- Feasibility studies would provide NYSERDA with a body of information about what resilience strategies are practical to implement given different building characteristics and operational goals
- Collect and maintain a database of building studies to gain insight into typical costs and feasibility
- Cost data will inform economic considerations that underlie incentive programs



The existing framework of the MPP and EFP programs is not entirely compatible with making resilience a priority. Because the feasibility of each strategy will vary from one building to another, establishing across-the-board requirements, pre-qualification strategies, or performance-based incentives is impractical for resilience strategies.

Nevertheless, a holistic approach to resilient, efficient energy management can be supported by many of NYSERDA's existing and proposed programs. Many of the strategies identified in this report are already supported through existing NYSERDA programs. For example, backup generation is incentivized through NYSERDA's DRP efforts. NYSERDA already has grant programs in place that support the adoption of CHP and fuel cells systems. Other programs could be updated to provide incentives or impose requirements for the implementation of resilience measures.

## CONCLUDING REMARKS

The strategies described and analyzed in this report are intended to give NYSERDA an initial indication of options for supporting improvements to the resilience of buildings' energy systems against future flooding events. As with any set of preliminary recommendations, this will serve primarily as guidance for future study rather than as a definitive prescription about where to commit support and organizational effort. Indeed, the main recommendation of this report is not to direct support toward any particular resilience strategy, but instead to support resilience studies by individual property owners, in order to give NYSERDA a broader set of facts on which to build a case for integrating resilience in existing programs or creating new programs specifically to support resilience improvements. This will allow NYSERDA to advance its ambitious aim of helping to safeguard New York City's buildings against the adverse effects of climate change.

# Appendix

## DEMAND RESPONSE PROGRAMS

This section provides an expanded description of demand response programs. Demand response programs are described outside the context of strategies that NYSERDA might consider implementing since they need to be administered by electric utilities but are nevertheless worth mentioning in case NYSERDA has the opportunity to introduce the idea.

The National Energy Technology Laboratory (Zheng, 2008) has suggested that both buildings and electric utilities would benefit by having backup generation systems integrated in to a building's normal operations. Backup generation systems would thereby function as distributed generation capacity during non-blackout conditions, reducing peak demand on the utility and, potentially, lowering a building's energy costs. This is already starting to occur in the commercial and healthcare sectors (Zheng, 2008). Yet traditional systems are not designed to run on a regular basis, so the fuels and designs need to be reassessed to reduce pollution and noise, and increase reliability.

Demand response programs can reinforce the resilience that backup generators provide. As noted earlier in this report, maintenance lapses are faulted in the high rate of emergency generation failure. Currently neither NYISO nor Con Edison are involved in the maintenance and regular testing of participating demand response generators. However, an example of such involvement can be found in Portland General Electric, a utility in Oregon, which has implemented a dispatchable standby generation (DSG) program that directly improves the resilience of backup generators in context of a demand response program.

PGE's DSG program is a funding and technical assistance program that provides incentives for buildings to install and maintain backup generators, so that the utility can draw power from the generators during periods when the utility is unable to meet peak demand. In exchange for up to 400 hours of access per year, PGE will assist its customers by significantly lowering upfront costs of new or upgraded backup generators and will pay for parallel switchgear to allow for seamless transfers between grid and backup generators. Regular maintenance, fuel costs, and remote monitoring are managed and entirely paid for by PGE (Portland General Electric, 2013). Depending on the size of backup systems, this program saves buildings \$20,000 to \$30,000 of maintenance and fuel costs per year (Barney, 2013). Through the DSG program, PGE is expected to have amassed 125 megawatts of generation capacity (Northwest Power and Conservation Council, 2010).

Two Oregon healthcare facilities have benefited from PGE's program. Providence Newberg Medical Center received funding from the utility to increase the capacity of its two emergency generators, to 750 kW each, and have installed upgraded transfer switches and switchgear. The output from these generators is sufficient to power about 3,000 homes (Matt, 2011). Kaiser Permanente Westside Medical Center also receives funding from PGE to maintain its backup generators in return for allowing PGE to draw power from them during peak demand periods (Oregonlive.com, 2011).

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Interviewee	Title	Organization/Company
Barney, Bruce	Project Manager, Dispatchable Standby Generation Program	Portland General Electric
Bomke, David	Executive Director	New York Energy Consumers Council
Bose, Satyajit	Lecturer in Discipline	Columbia University
Calvano, Michael	Superintendent for Construction	Schulman Industries
Cohen, Richard	Vice President, Facilities Operations	NYU Langone Medical Center
Corbett, Valerie	Founder	IntelliGreen Partners LLC
Culp, Charles	Associate Director	Energy Systems Laboratory
Falco, Greg	Manager, Sustainability and Intelligent Infrastructure	Accenture
Frank, Scott	Partner	Jarros Baum & Bolles
Gilford, David	Associate Director	NYC Economic Development Corporation
Glick, Jeffrey	Vice President of Sales	Tecogen
Kelly, Thomas	Energy & Sustainability Manager	Montefiore Medical Center
Kling, Alison	NYC Solar Coordinator	City University of New York
Lyons, Chris	Sales Executive	Genserve Inc.
Mateo, Danielle	UTC Fuel Cells	Clean Edge Power
Mejia, Diana	Associate Director, Capital Project Management	Columbia University Medical Center
Norris, Davidson	Principal	Carpenter Norris Consultants
Paciorek, Sukanya	Vice President, Corporate Sustainability	Vornado Realty Trust
Paternoster, Frank	Facility Manager	Memorial Sloan Kettering
Pearlman, Jeff	MPP Contractor	Bright Power
Shepherd, Ben	Associate Director	Atelier Ten
Strawn, David	Vice President	Schully, Strawn & Associates
Thompson, Jim	Executive Director	Columbia University Medical Center
Trotta, Brendan	Construction Manager	Turner Construction
Vardakas, Lee	President	Aegis Energy Services
Yuksel, Sevince	Construction Manager	Turner Construction
Zuluaga, Marc	Vice President	Steven Winter Associates

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