PHOTO: OLD COLONY IN SOUTH BOSTON, NEW ECOLOGY INC.

Resilient Design Brief

A Guide for Massachusetts Housing Owners and Developers

October 1, 2022

15 Court Square, Suite 420, Boston, MA 02108   Phone: 617-557-1700   www.newecology.org

EXECUTIVE SUMMARY

By using publicly available design tools, development teams can effectively evaluate heat and flooding risks to potential properties through the year 2070. With these tools, teams can then apply resilience strategies to minimize risks to both residents and to the property. Advanced, free to use tools are also available to evaluate the opportunity for renewable power and backup battery systems. Renewable energy and backup systems can reduce costs during normal operations, and can potentially support a space of refuge for residents during an emergency. Creating as space of refuge for residents as well as having an emergency preparedness plan will help to support residents during an emergency.

This resilient design brief is intended for use by property managers, developers, and those participating in affordable housing design or renovation. The tools presented below are designed to help aid in evaluation of resilience needs at a given location in Massachusetts, and the analysis is limited to publicly available tools designed to evaluate extreme heat risk and risk from flooding from sea-level rise/storm surge. Some locations may have specific concerns that are not addressed by these tools, and each location should be evaluated by the professionals on each project team. New Ecology is available to provide resilience assessments of properties as a service, please reach out to Info@newecology.org for more information on resilience assessments.

Risk Evaluation Tools

The following report is focused on new construction projects and reviews no-cost, publicly available tools that can be used to evaluate extreme heat and flooding risks at locations in Massachusetts. These tools can be used during planning stages to better understand risks to residents and infrastructure, and help speed recovery after an emergency or extreme event. Design standards from DHCD's CHARM project and other sources can be used to reduce those risks during development planning or property renovations. Tools evaluated include financial tools for analyzing renewable energy and backup battery options, both of which are now supported by Inflation Reduction Act funding. Finally, resilience hubs can be spaces for residents to build community and connections during normal operations, and can be areas of refuge during emergencies. A guide to planning for resilience hubs is reviewed below. Together these tools can help developers to make choices in allocating resources and creating resilient properties for residents today and well into the future.

Example Resilience Assessment

A resilience assessment is presented for a potential development at 170 Cottage Street in Chelsea, MA. Using publicly available tools, the example evaluation shows potential considerations for review by the development team during early planning stages. Mitigation strategies using resilient design standards are also presented, with the intent that if these considerations are included early in the design process they may be done at little or no additional cost, and can result in cost savings in the medium and long term.

TABLE OF CONTENTS

INTRODUCTION

As communities in Massachusetts adapt to the pressures from a changing climate, tools and materials are available to help better understand and reduce risks to residents. While risks from extreme heat as well as flooding from sea level rise are expected to increase, these risks can be anticipated and new properties have the opportunity to incorporate resilient design methods, systems, and spaces of refuge into design.

This *Resilient Design Brief* is intended to help property managers and developers to understand risk factors, plan for them, and include design elements and features in order to reduce risks to residents. The report is tailored for new construction projects, aiming to improve risk identification and mitigation capacities during design development, and focuses on two common New England building typologies: a common multifamily typology known as 5 over 1 podium buildings as well as row houses/town homes. The report reviews tools and strategies to measure and mitigate risk, and presents an example case showing the practical application of these tools.

Design Tools Summary

The following design tools and materials are reviewed in this *Resilient New Construction Design Brief:*

- ***Climate Resilience Design Standards Tool (RMAT)***
- ***NOAA National Hurricane Center Storm Surge Risk Maps***
- ***With FEMA flood maps as a secondary resource***
- ***REopt: Renewable Energy Integration & Optimization***
- ***CHARM (Climate Hazard Adaptation and Resiliency Masterplan) Resources***
- ***Urban Sustainability Directors Network (USDN) – Guide to Developing Resilience Hubs***
- ***NEI Emergency Preparedness Plan***

The ***Climate Resilience Design Standards Tool (RMAT)*** tool evaluates heat and flooding risk at properties in Massachusetts, and includes forward looking projections through 2070. The RMAT team is adding features and data to the tool as of 2022. The ***NOAA National Hurricane Center Storm Surge Risks Maps*** resource is available to evaluate storm surge inundation during a hurricane. This tool is not able to zoom in on a precise location, but can provide area data. FEMA maps can be used as well, but a team may consider supplementing these maps with other resources. NREL's ***REopt: Renewable Energy Integration & Optimization*** tool can make both resilience and financial projections for renewable energy systems, including those coupled with backup batteries. The system reports are on output and financial costs/benefits are more detailed when the team has detailed information for systems expected to be installed, but can use default values as well. ***DHCD CHARM*** Resources are targeted at typical Massachusetts building typologies and include both graphical and written resources on how to improve resilience in properties. While these resources are mainly targeted at existing properties, the construction specification sections can be used for new construction projects. ***USDN's Resilience Hub Development Guidance*** lays out a process to develop community resilience as well as resilient spaces for use during emergencies. The guide lays out a process for a team to work through to create an effective community resilience space. ***NEI's Emergency Preparedness Plan*** (included as an appendix) provides community staff with straightforward resources to implement procedures and protocols for a comprehensive emergency response.

Defining Risks

As weather patterns change, residents will be exposed to more severe and more frequent risks. In order to prepare new buildings to support residents who live there, we will define the risks that this report will address. The State Hazard Mitigation and Climate Adaption plan describes numerous environment hazards that may impact Massachusetts's people, buildings, and infrastructure. However, the risks investigated in this report are those especially relevant to Greater Boston Area, as identified in the city's vulnerability assessment.[1]

- **Heat Risk** – According to the CDC, "Extreme heat is defined as summertime temperatures that are much hotter and/or more humid than average. Because some places are hotter than others, this depends on what's considered average for a particular location at that time of year."[2] Excessive heat risk is concerning because excessively hot days can often lead to power disruptions as energy use spikes in the area. Power disruptions are a severe danger to vulnerable residents who may not be able to cope with the adverse climate conditions. Situations where the body is not able to cool itself and residents are unable to relocate to conditioned areas can lead to serious heat related illnesses.

---

[1] Executive Office of Energy and Environmental Affairs, 2020, *Climate Ready Boston*, https://www.mass.gov/doc/boston-climate-ready-boston.

[2] "Extreme Heat," *Centers for Disease Control and Prevention*, https://www.cdc.gov/disasters/extremeheat/index.html

- **Sea Level Rise** – According to NASA, sea level rise is caused primarily by two factors related to global warming: the added water from melting ice sheets and glaciers, and the expansion of seawater as it warms.[3] Per NOAA's 2022 report, sea level rise for Northeast United States waters is expected to be between +1.97 and +6.89 feet by the year 2100.[4] With 30% of the population living in coastal areas, there is a real risk to residents from rising water levels.
- **Storm Surge** – The National Hurricane Center states- "Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides. This rise in water level can cause extreme flooding in coastal areas particularly when storm surge coincides with normal high tide, resulting in storm tides reaching up to 20 feet or more in some cases."[5] When coupled with Sea Level Rise, some properties are at risk where there may seem to be no immediate threat. The Climate Resilience Design Standards Tool and NOAA Storm Surge Risk Maps can be helpful in diagnosing such cases.
- **Extreme Precipitation** – Per the EPA, extreme/heavy precipitation "refers to instances during which the amount of rain or snow experienced in a location substantially exceeds what is normal."[6] These magnitude of these events is increasing in the Northeast,[7] and the excessive rainfall can cause serious flooding when urban drainage is insufficient due to impervious hardscapes or when increased runoff overflows the capacity of rivers and their banks.

---

[3] "Vital Signs," *Nasa Global Climate Change*, https://climate.nasa.gov/vital-signs/sea-level/

[4] NOAA, *et al.*, 2022, *2022 Sea Level Rise Technical Report*, https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report-sections.html

[5] "Storm Surge Overview," *National Hurricane Center*, https://www.nhc.noaa.gov/surge/#:~:text=Storm%20surge%20is%20an%20abnormal,surge%20and%20the%20astronomical%20tide.

[6] "Climate Change Indicators: Heavy Precipitation," *EPA*, https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation

[7] Executive Office of Energy and Environmental Affairs, 2020, *Climate Ready Boston*, https://www.mass.gov/doc/boston-climate-ready-boston.

Who is at Risk?

- **Elderly Residents** – Older residents may have trouble adapting to higher temperatures, and may face challenges in relocating during an emergency.
- **Young Residents** – Infants and children will need help from others during extreme heat events in order to keep cool and hydrated. During emergencies, infants and children will need support with relocation and having adequate supplies on hand.
- **Residents with limited mobility** – Residents with limited mobility may face challenges relocating to cooling centers or spaces of refuge during emergencies.
- **Residents who have communication challenges** – Residents with communications challenges may need support including provision for communication in other languages or using supportive means during emergencies or when needing to relocate.
- **Residents with medical conditions, or those needing refrigerated supplies** – Some residents may need access to electricity to support health conditions, and/or to refrigerate supplies. Provisions for backup power or a space of refuge with backup power can help support during emergencies.
- **Unemployed or underemployed residents** – Unemployed or underemployed residents may need support with mobility during emergencies, and may need support during times of recovery.
- **Unhoused populations** – Unhoused populations may not have access to a space of refuge during an emergency, and may need access to additional supportive services.

DESIGN TOOLS

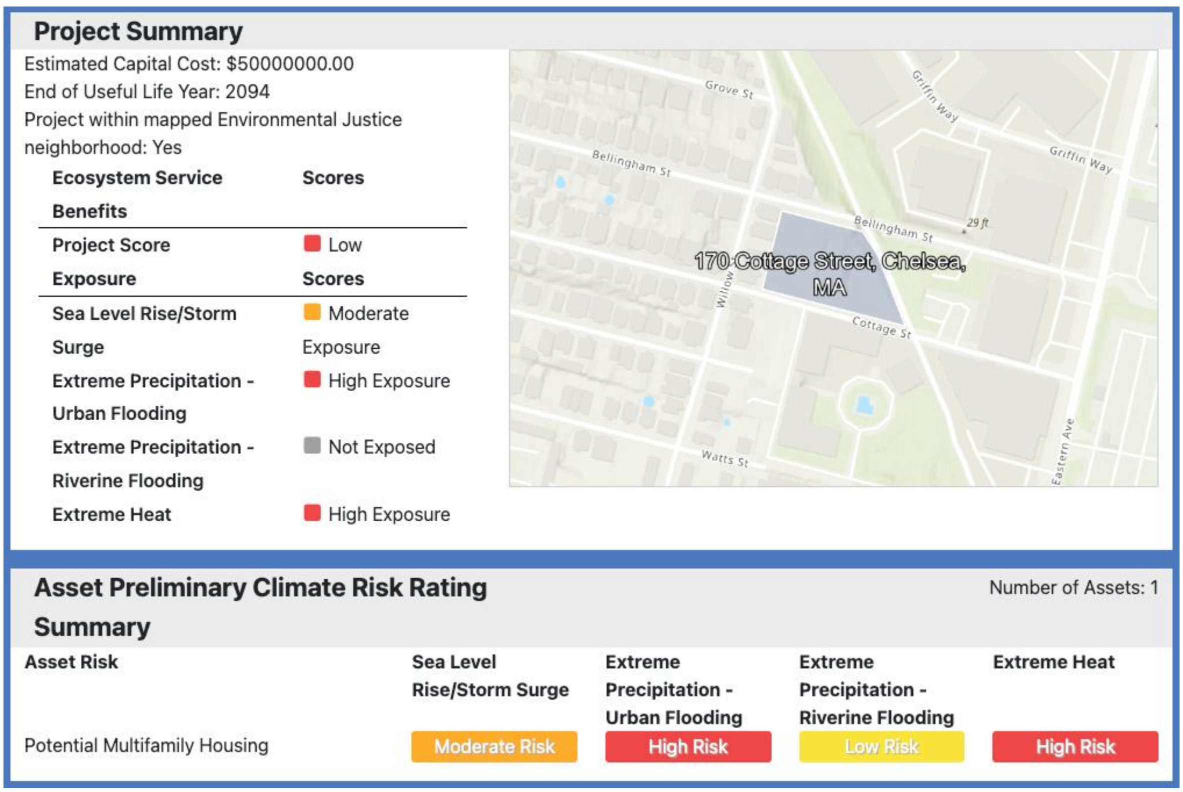
Understanding a property's climate risk profile, identifying valuable techniques to mitigate exposure, and exploring the feasibility of these techniques are all critical to effectively design for resilience. The resources assembled in this section provide developers and property managers a kit of different tools to assist them in this process.

Climate Resilience Design Standards Tool (RMAT)

- **Tool Purpose:** To evaluate extreme heat and flood risk at Massachusetts addresses. The tool draws on powerful resources, including a very comprehensive flood risk model the Mass. Coastal Flood Risk Model (MC-FRM).

- **Tool URL/Web Address:**
  https://resilientma.mass.gov/rmat_home/designstandards/
- **Tool Creator:** Resilient MA Action Team (RMAT)
- **Estimated Time for Analysis:** 2-3 hours.
- **Considerations:** Create a user account. Some patience is necessary for site navigation for the initial uses. The tool continues to evolve and improve. Having a preliminary understanding of the development project scope, including first cost, can be useful.

Image 1. Climate Resilience Design Standards Tool Typical Report



Project Summary

Estimated Capital Cost: $50000000.00
End of Useful Life Year: 2094
Project within mapped Environmental Justice neighborhood: Yes

Ecosystem Service Benefits	Scores
Project Score	Low

Exposure	Scores
Sea Level Rise/Storm Surge	Moderate Exposure
Extreme Precipitation - Urban Flooding	High Exposure
Extreme Precipitation - Riverine Flooding	Not Exposed
Extreme Heat	High Exposure

Asset Preliminary Climate Risk Rating Summary

Number of Assets: 1

Asset Risk	Sea Level Rise/Storm Surge	Extreme Precipitation - Urban Flooding	Extreme Precipitation - Riverine Flooding	Extreme Heat
Potential Multifamily Housing	Moderate Risk	High Risk	Low Risk	High Risk

Tool Summary

The Climate Resilience Design Standards Tool can be used to assess vulnerability to flooding and extreme heat exposure with only a few hours' time commitment. The initial report generated by the tool (Image 1) clearly shows the estimated risks from:

- Sea-Level Rise/Storm Surge
- Extreme precipitation as a cause of urban flooding
- Extreme precipitation as a cause of riverine flooding
- Extreme heat

Reporting includes both summary "Exposure Scores" using the categories: Not Exposed, Low Exposure, Moderate Exposure, or High Exposure. Each risk factor is also developed in detail, going beyond the summary analysis. Example summary risks are presented below, and a more comprehensive explanation of risks is presented in the later example resilience assessment.

Maintained by the Resilient MA Action team (RMAT) this tool draws from the Mass. Coastal Flood Risk Model (MC-FRM) and therefore has access to some of the most up to date flood maps available. For projects subject to flooding risk, the outputs of this tool will help a team identify risks in detail. The tools accessible as a general summary of risks for the categories shown in bullets above, but it also allows for a deeper analysis of risk, as needed.

Heat Risk Analysis

The Project Exposure score presents a summary analysis of the risks faced by a project, with classifications ranging from not exposed through high exposure. Below in Image 2 is a case where there is high exposure to extreme heat over the lifetime of the project, and explanation of why the project is classified that way. This information can be used to plan heat risk mitigation into a project at the start, from cool roofs, to shading from vegetation and up to a cooling space of refuge with backup power and on-site refrigeration.

Image 2. Project Scoring Rationale – Exposure Score and Explanation for Extreme Heat Risk

Extreme Heat

This project received a "High Exposure" because of the following:

- 30+ days increase in days over 90 deg. F within project's useful life
- Not located within 100 ft of existing water body
- Increased impervious area
- Existing impervious area of the project site is between 10% and 50%
- No tree removal

Flood Risk Analysis

The Project Exposure score presents a summary analysis of the three types of flood related risks at a given project as well: Sea Level Rise/Storm Surge, Extreme Precipitation - Urban Flooding, and Extreme Precipitation - Riverine Flooding and the explanation for the exposure classification for each (Image 3).

Image 3. Project Scoring Rationale – Exposure Score and Explanation for Flood Risk by Category

Sea Level Rise/Storm Surge

This project received a "Moderate Exposure" because of the following:

- Exposed to the 1% annual coastal flood event as early as 2030
- Located within the 0.1% annual coastal flood event within the project's useful life
- Not located within the predicted mean high water shoreline by 2030

Extreme Precipitation - Urban Flooding

This project received a "High Exposure" because of the following:

- Increased impervious area
- Maximum annual daily rainfall exceeds 10 inches within the overall project's useful life
- No historic flooding at project site
- Existing impervious area of the project site is between 10% and 50%

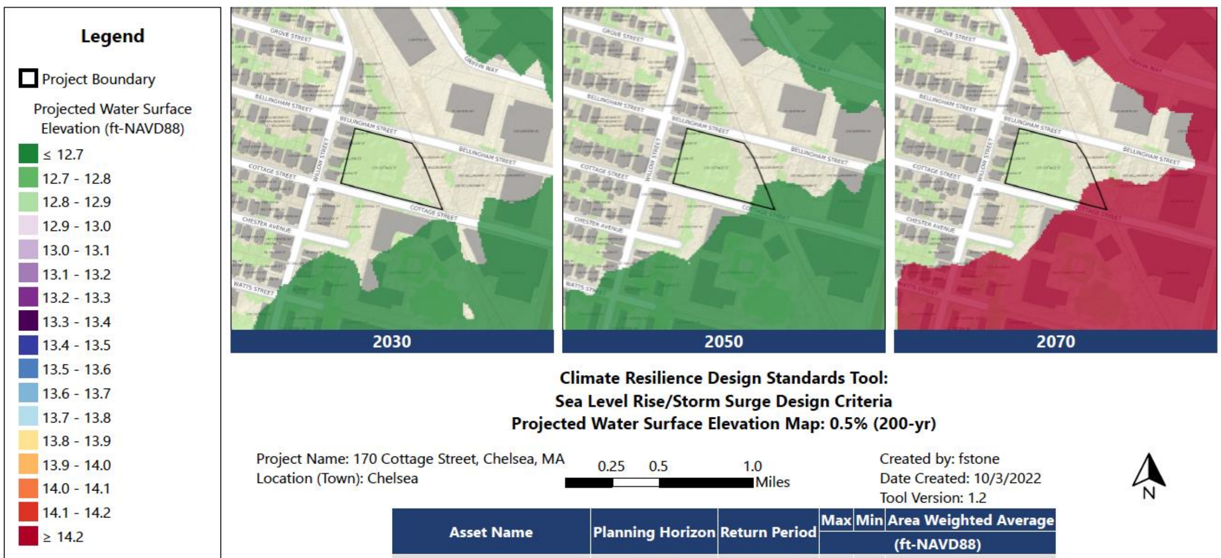
Extreme Precipitation - Riverine Flooding

This project received a "Not Exposed" because of the following:

- No historic riverine flooding at project site
- The project is not within a mapped FEMA floodplain [outside of the Massachusetts Coast Flood Risk Model (MC-FRM)]
- Project is more than 500ft from a waterbody
- Project is not likely susceptible to riverine erosion

In addition to the summaries of risks, the tool output includes maps showing flood risk over time. Image 4 below is an example map which shows the 0.5% annual flood chance due to Sea Level Rise/Storm Surge at 20-year intervals from 2030 through 2070. This can be used to plan for any flood risk or flood barrier needed at a site.

Image 4. Climate Resilience Design Standards Tool Typical Report



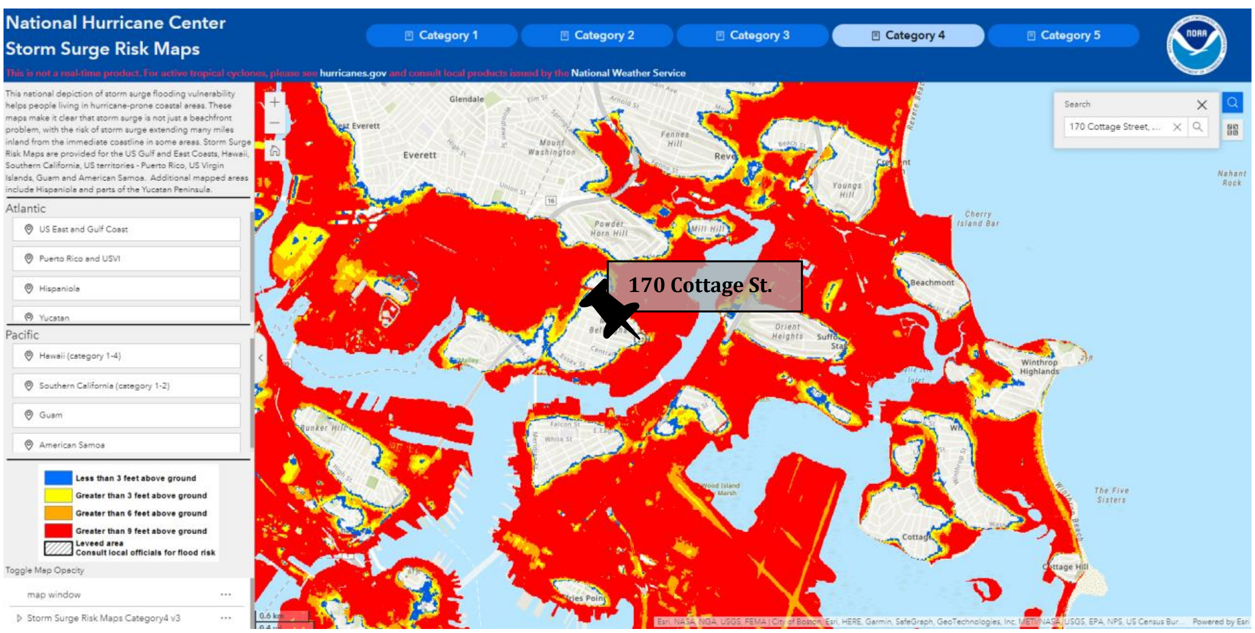
Asset Name	Planning Horizon	Return Period	Max	Min	Area Weighted Average
			(ft-NAVD88)		
Potential Multifamily Housing	2030	0.5% (200-yr)	N/A	N/A	N/A
	2050	0.5% (200-yr)	12.7	12.7	12.7
	2070	0.5% (200-yr)	14.2	14.2	14.2

To apply the information once the risks are known, user should consult a tool like the CHARM resources identified below in order to mitigate the risk or to adapt the property to sustain residents through that potential hazard.

National Storm Surge Risk Maps Interactive Viewer

- **Tool Purpose:** To quickly evaluate potential storm surge inundation associated with Category 1, 2, 3, 4 and 5 hurricanes.
- **Tool URL/web address:** https://experience.arcgis.com/experience/203f772571cb48b1b8b50fdcc3272e2c
- **Tool Creator:** National Oceanic and Atmospheric Administration (NOAA)
- **Estimated Time for Analysis:** 15-30 minutes.
- **Considerations:** No account creation required. Can search specific addresses, but must zoom out until the selected risk map appears. Maximum zoom level is not granular enough to identify individual property boundaries.

Image 5. Category 4 Hurricane Risk Map, Maximum Zoom, 170 Cottage St, Chelsea, MA



Tool Summary

The online interface can be used to gauge a location's vulnerability to hurricane storm surge. The dynamic platform allows users to interact with risk maps for each incremental increase in hurricane severity. Users can find a specific address using the top right search box and then cycle through the maps for different categories of storms to visually investigate inundation zones and storm surge depth. Image 5 above displays how the tool can be used to search an address in north Boston and display the Category 4 hurricane risk map. Easy zooming and panning of the map also enable users to quickly move to different areas and to gain a broad understand of inundation patterns.

Available Geographies

U.S. Gulf and East Coasts, Hawaii, Southern California, U.S. territories - Puerto Rico, U.S. Virgin Islands, Guam, and American Samoa

Output

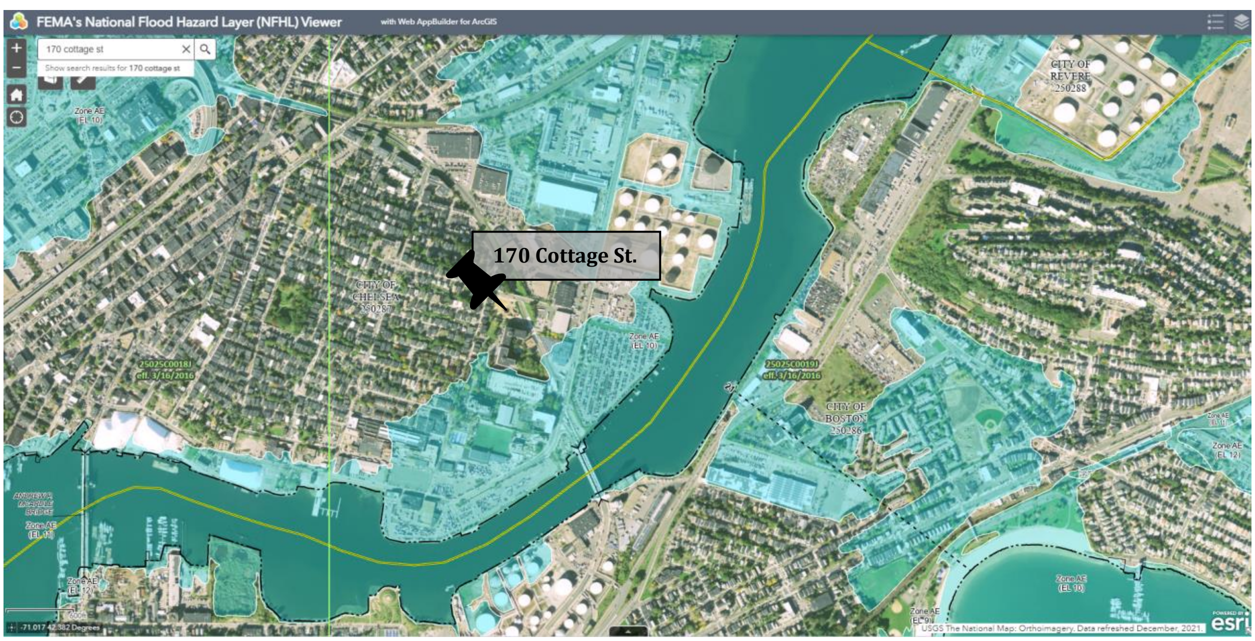
After locating an address with the search box, users must zoom out slowly until the risk map reappears. Through this process, one can roughly place a property of interest in the context of the storm surge maps. When viewing the risk map, the four different colors represent the gradient of storm surge exposure for a specific category of storm events. The legend in the left panel shows exposure is displayed as potential depth of storm surge above ground level at that location. We recommend estimating and recording the potential storm surge depth at your property during a Category 1 hurricane, and for each increasingly severe category of storms.

Applying the Information The key to using this tool is understanding that no single Category 4 Hurricane event would create 100% of the inundation shown in Image 5. NOAA created the storm surge risk map in Image 5 by simulating thousands of Category 4 Hurricanes making landfall at 5 to 10-mile intervals along the coast for every iteration of different trajectories, speeds, widths, and tide levels. Storm surge depth was estimated for each hurricane using the SLOSH methodology and then the simulated outputs for each C4 hurricane were combined and overlaid. From this combination, a single layer composed of approximately 9m by 9m grid cells was extracted that depicts the maximum storm surge depth for that cell based on all the underlying hurricane simulations (Image 5). Therefore, the storm surge depths displayed in the risk maps are interpreted as potential inundation in a near worst-case scenario – "If a Category 4 storm hit just right, how deep could the storm surge potentially get for my area."

FEMA's National Flood Hazard Layer (NFHL) Viewer

- **Tool Purpose:** To evaluate flooding vulnerability of a property using the Flood Insurance Rate Map (FIRM) risk zones.
- **Tool URL/web address:** https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd
- **Tool Creator:** Federal Emergency Management Agency (FEMA)
- **Estimated Time for Analysis:** 30 minutes – 1 hour
- **Considerations:** No account creation required. Can search specific addresses. Interpretation of zones may not be intuitive. Tool is based on historical data, not future projections.

Image 6. NFHL Viewer Screenshot, Chelsea, MA



Tool Summary

The online tool can be used to access flood risk exposure for specific addresses and areas using FEMA's Flood Insurance Rate Maps (FIRMs). The map viewer allows users to quickly locate properties (shown in Image 6), and dynamic panning and zooming helps to develop a comprehensive understanding of flood patterns. With the tool, one can identify:

- What FEMA flood hazard zone a property lies within.
- The BFE (Base Flood Elevation) or flood depth (available for certain zones).

Available Geographies

Near complete coverage of US states and territories.

Map Output

The online tool provides two potential forms of output. After locating an address with the upper left search bar, users can simply left click anywhere near the property and download a graphic of its respective FIRM Panel as shown in Image 7 (users may need to cycle though pop-up windows using the left and right arrows on the pop-up). One can also use the "NFHL Print Tool" located below the search bar to create a more refined, standard flood map with a legend and scale. The tool prompts user to drop on a pin on the location on interest and then select a size from FIRMETTE (Image 8) and a full FIRM Panel.

Understanding Map Output

If a property is in area that is at high to moderate risk of flooding, the zone will be shaded and labeled. Any zones that begin with the letters A or V are defined as "Special Flood Hazard Zones." These are the highest risk flooding zones and in communities that participate in the National Flood Insurance Program, all properties are required to buy flood insurance and adhere to certain floodplain management regulation. Zones B and any Zone X that is orange-shaded represent moderate risk, while Zones C, D, and X (clear/unshaded) represent minimal or uncertain risk. These moderate to low risk zones are not required to buy flood insurance or adhere to the floodplain regulations. Detailed definitions of the zones can be found in Appendix 1: FEMA Flood Zones.

Below the flood zones label on the map, users can find either the BFE ("El 10" in Image B) or flood depth (usually labeled "Depth X Feet"). A common misinterpretation of this map is to assume "El 10" is the elevation of the property of interest. Instead, BFE refers to the height of surface water above sea level that results from a 1% flood. By comparing the BFE to the elevation of a property, one can estimate flood depth for a 1% storm.

Image 7. FIRM Panel Graphic

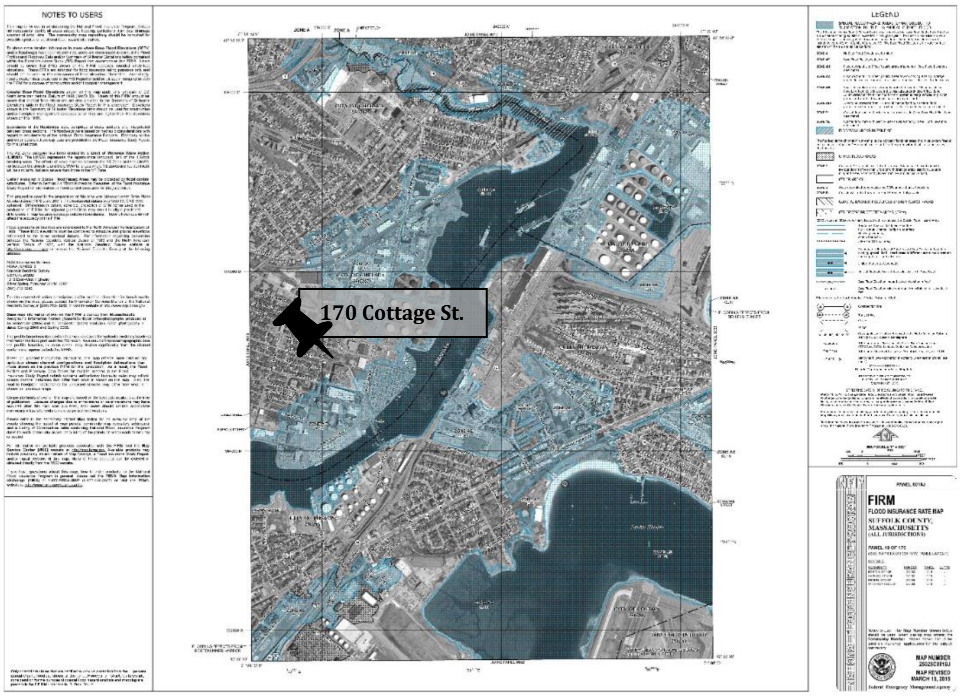
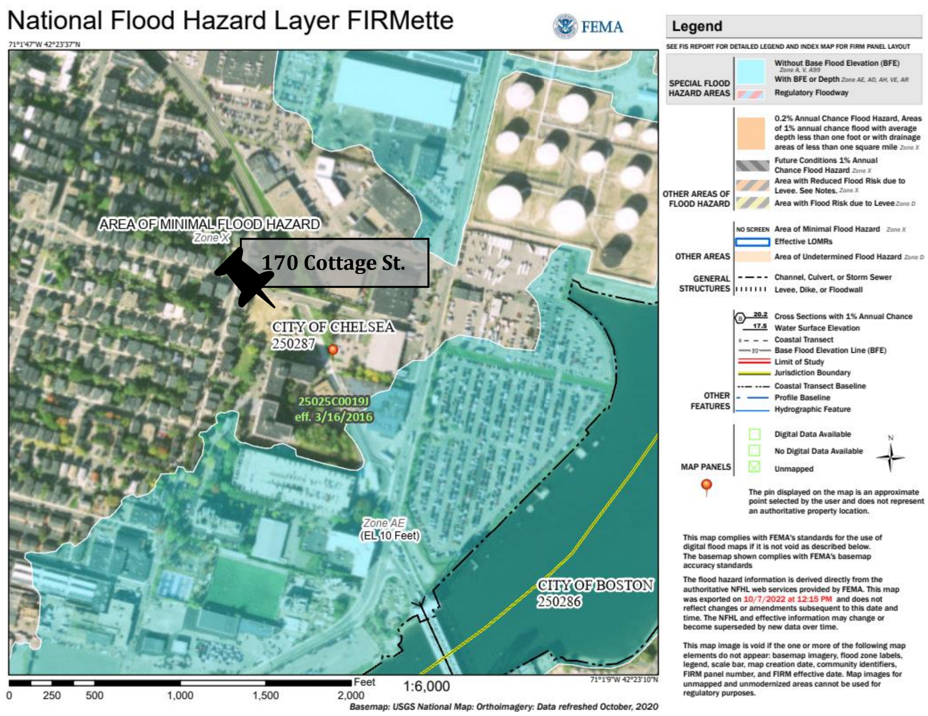


Image 8. FIRMETTE PDF



Identifying FEMA Resources for Tenants

Federal assistance in preparing for and recovering from natural disasters is not only for homeowners. Renters are also able to utilize the programs and resources provided by FEMA to increase their resilience to flood risk. Through these programs, renters are eligible to purchase flood insurance, receive disaster relief funds, and can potentially decrease their insurance rates by encouraging their towns and building owners to make resilience improvements.

Disaster Relief

In declared disaster areas, renters are eligible to apply for financial support under FEMA's Individuals and Housing Program and FEMA's Other Needs Assistance Program. Help provided by these programs is in the form of grants and does not have to be repaid. It can be used to pay for rent, security, deposits and essential utilities such as gas and water (although not internet or cable) while their old unit is restored to livable conditions. Funds are based on the Fair Market Rent for their home area, and can also be used to reimburse out-of-pocket expenses for lodging since the disaster. Additionally, assistance can cover other serious needs directly induced by the disaster, such as child care, medical/dental expense, funeral costs, damages to an essential vehicle, moving expenses, or damages to uninsured important household items.

National Flood Insurance Program (NFIP)

Renters are able to purchase a "Contents Only" flood insurance policy through the NFIP. The policy covers up to $100,000 in damages to personal belongings. Clothing, furniture, electronics, mattresses, kitchenware, appliances, artwork, and books are all covered by the program, but coverage for these contents is only available for rental units that are not on the lowest elevated floor (excluding basements).[8] To be eligible for policy coverage, damages have to be caused directly by flooding that affects at least two acres or two different properties.

Reducing Flood Insurance Premiums

The NFIP offers discounts on flood insurance premiums for properties located within areas that participate in their Community Rating System (CRS). The CRS assigns participating communities a score between 1 and 10 depending on their efforts to go above and beyond minimum requirements to improve flood risk resiliency. These discounts range from 5% to 45%, and renters can have a role in lobbying their town officials and building owners to make significant resilience improvements or to join the program.

[8] FEMA, 2022, *National Flood Insurance Program: Flood Insurance for Renters*, https://agents.floodsmart.gov/sites/default/files/nfip-flood-insurance-for-renters_brochure_02-2022.pdf

REopt: Renewable Energy Integration & Optimization Tool from the National Renewable Energy Laboratory (NREL)

- **Tool Purpose:** REopt helps a building owner/operator test the financial and resilience impacts of renewable energy and backup battery systems, among others. The tool can also be used to generate financial summaries, and to optimize system sizes for cost savings. If used with the optional advanced settings, this tool can generate sophisticated cost and savings projections.
- **Tool URL/web address:** https://reopt.nrel.gov/
- **Tool Creator:** NREL – the National Renewable Energy Laboratory
- **Estimated Time for Analysis:** 1-2 hours
- **Considerations:** Setting up an account is recommended to allow saving results. The tool can perform an analysis using default inputs. Accuracy will improve if any building specifics are known, including utility rates, building electricity usage, potential system size and costs for PV. Defaults can also be used, and iterations are encouraged.

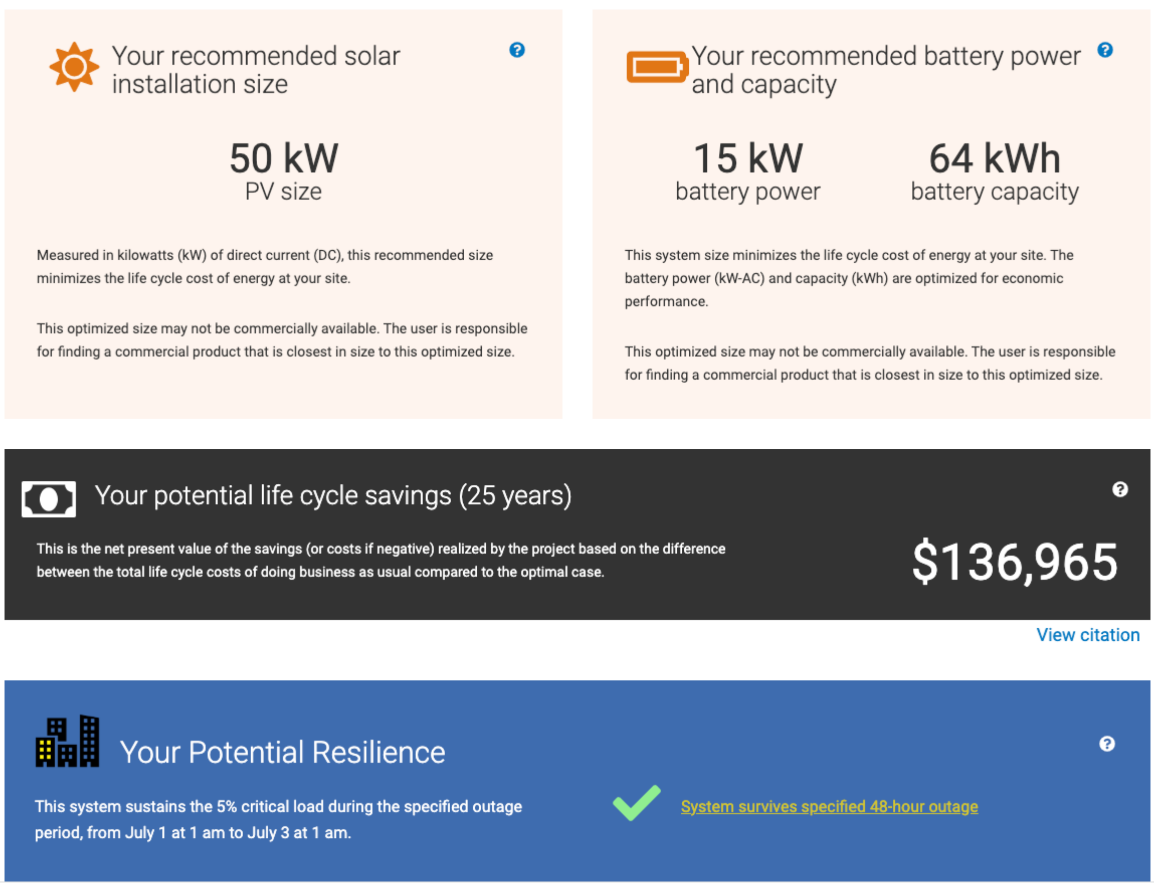
Tool Summary

NREL calls REopt a "techno-economic decision support platform…to optimize energy systems for buildings, campuses, communities, microgrids, and more." The REopt tool can help building owners/operators choose a pathway to any of 3 energy goals:

- Cost Savings
- Resilience
- Clean Energy

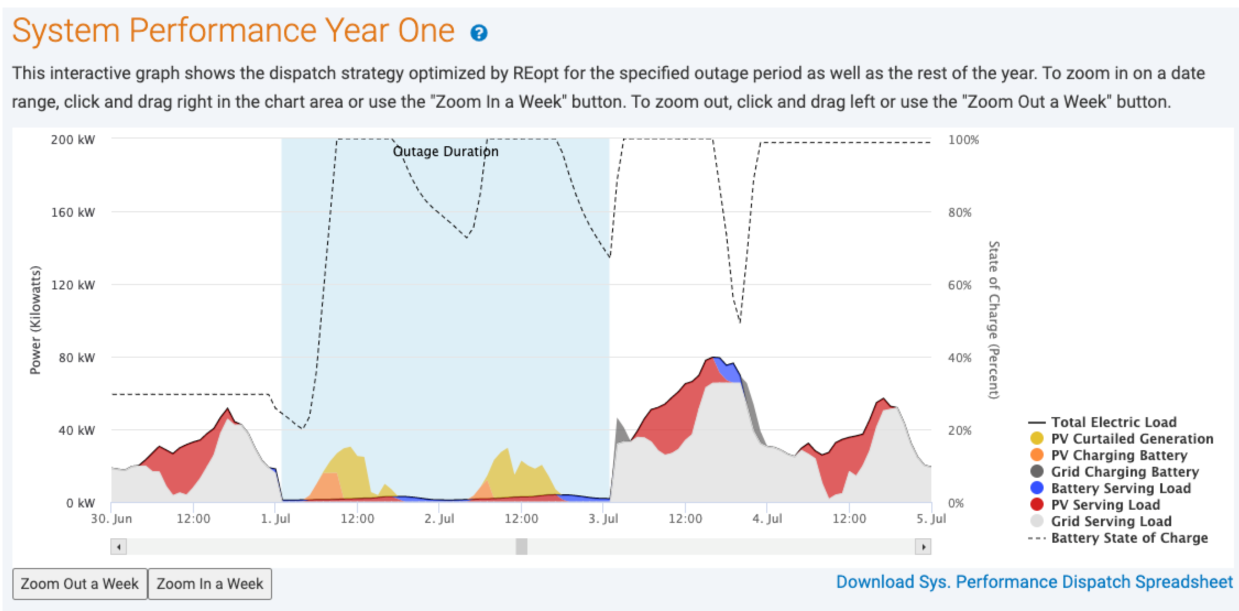
To start, the user chooses the systems for inclusion in the building. Options include solar PV, battery, wind turbines and other like ground source heat pumps. The user is then prompted to enter basic site information, and defaults are already in place if these are not known. For resilience, users are prompted to enter the % of load to be backed up, and how long a given outage is expected to last. New Ecology typically selects 5% as an electrical backup rate in order to represent the critical systems load or a space of refuge. Users can also input financial data and system costs if known or rely on defaults. Users can enter expected system sizes for Solar PV and/or batteries. For PV systems, it may be helpful to have a general system size in mind, either from NREL's PVWatts Calculator, Google's Project Sunroof or from a PV evaluation tool like Helioscope. Please note that each category allows for extensive detailed "advanced inputs" for financial and system data. The more detailed information input, the more accurate the results will be. However, these "advanced inputs" are not required, and useful analysis can be performed without them. The REopt system then sizes an optimal PV and battery system based on user inputs, and reports on financial savings as well as a system's ability to provide power through an outage (with the outage duration chosen by the user). Below is an example output for a midrise apartment building that can accommodate up to 50kW of PV on the rooftop (Image 9). New Ecology specified that the property be able to power systems at 5% of a typical load during a 48-hour mid-summer power outage. The solar and battery size recommendations are output as shown below, along with the lifecycle savings from the system as sized. The lifecycle savings does draw on inputs like local electricity rates, and other financial inputs including any defaults entered by the user.

Image 9. REopt Summary Results for a Resilience Analysis of a Mid-Rise Apartment Building



The summary report also presents a graph of the electricity profile during an outage, and how the building systems function to supply power to residents during an outage (Image 10).

Image 10. REopt Summary Resilience Results a Mid-Rise Apartment Building During a 48-hour Power Outage



The graph above looks complex, but it tells a useful story. On the X-axis is time, here the outage is expected to last from 1am on July 1 until 1am on July 3, representing a 48-hour power outage. This period was chosen to represent conditions during a time of peak cooling needs. During that 48-hour period, New Ecology set the power requirement to be 5% of the typical load, representing device charging and the capability to power a space of refuge. The dashed line represents battery state of charge (please note the axis label to the right of the image), which drops at night. During the daylight times the PV system is charging the battery and providing power to the building. At night, blue indicates that the battery is serving the load, and the falling battery state of charge reflects this as well. After 48 hours, at 1am on July 3 in this simulation, grid power is restored. Using the default values in REopt for battery cost, a battery of this size would cost (15kW*$775) + (64kWh*$388) = $36,457. In 2022, utilities in MA offer battery connection incentives under the *Connected Solutions* program.

Financial Analysis Reporting

Image 11. REopt Summary Financial Results (partial) for a Resilience Analysis of a Mid-Rise Apartment Building

Results Comparison

These results show how doing business as usual compares to the optimal case.

	Business As Usual	Resilience	Financial
Life Cycle Cost Breakdown			
Technology Capital Costs + Replacements, After Incentives	N/A	$159,288	$158,672
O&M Costs	$0	$10,876	$10,876
Total Utility Electricity Cost	$1,148,310	$892,022	$898,653
Lifecycle Costs of Climate Emissions (included in objective)	$0	$0	$0
Lifecycle Costs of Health Emissions (included in objective)	$0	$0	$0
Summary Financial Metrics			
Total Upfront Capital Cost Before Incentives	N/A	$208,264	$207,646
Year 1 O&M Cost, before tax	$0	$850	850
Total Life Cycle Costs	$1,148,310	$1,011,345	$1,017,359
Net Present Value	$0	$136,965	$138,459
Payback Period	N/A	10.07 yrs	10.01 yrs
Internal Rate of Return	N/A	9.6%	9.7%
PV Levelized Cost of Energy	N/A	$0.150/kWh	$0.150/kWh

REopt outputs also include a detailed financial breakdown, and can report on both a "resilience" system profile as well as a case that is optimized for financial performance. Image 11 above shows a breakdown of expected utility costs under each scenario: Business as usual as connected to the power grid for 100% of energy, a PV & battery system optimized for resilience, and a PV & battery system optimized for financial benefit. Cost before incentives, after incentives, O&M costs, and the Net Present Value of system savings are all presented. The image above shows a partial presentation of the information available, and the REopt system shows a much more detailed understanding in the web interface. The report can include the monetized value of the environmental and health benefits of reduced emissions, if desired.

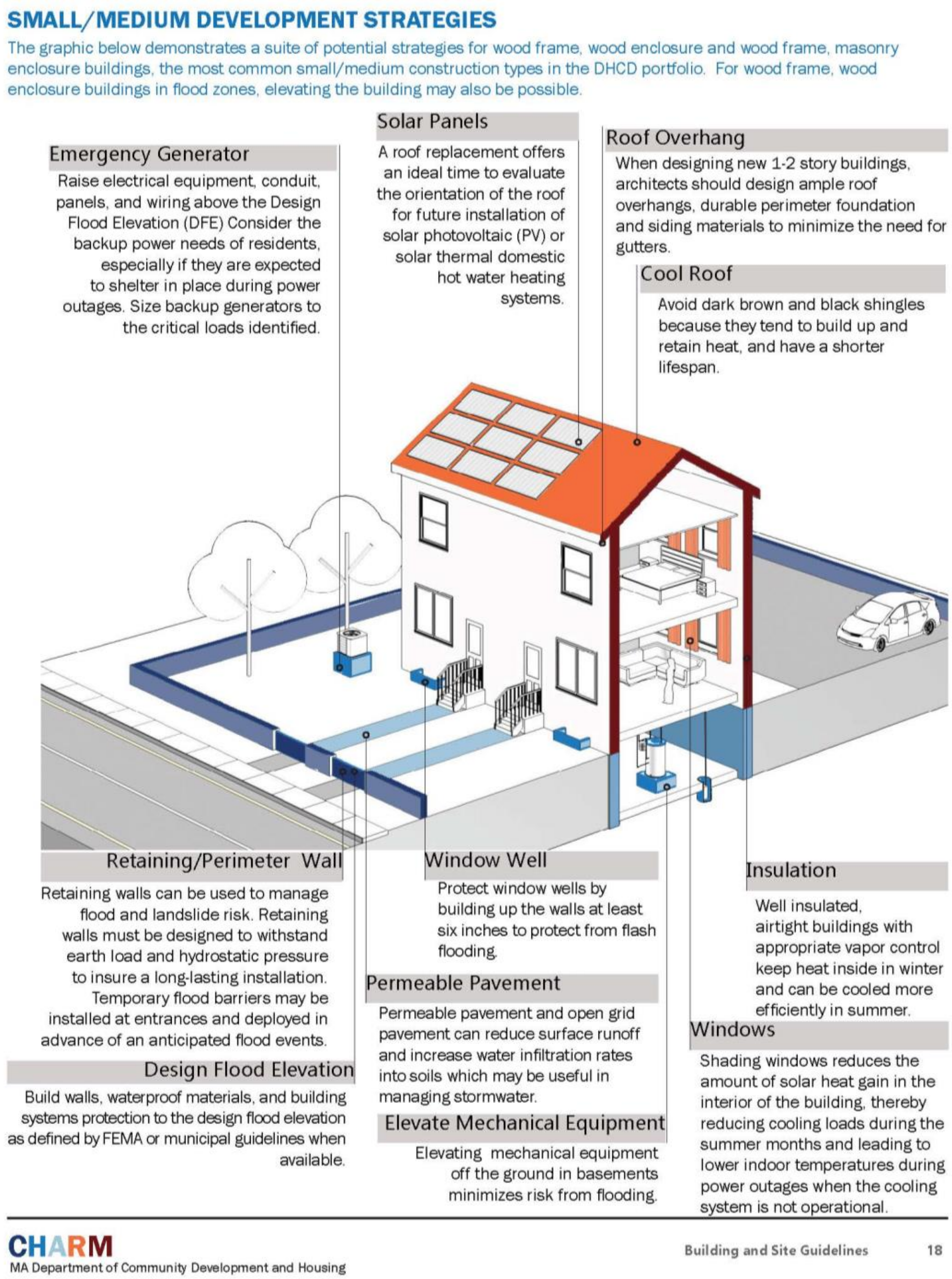
CHARM (Climate Hazard Adaptation and Resiliency Masterplan) Resources

- **Tool Purpose:** The set of Climate Hazard Adaptation and Resilient Masterplan resources were designed to support resilience at publicly funded housing in Massachusetts. The strategies, tools, and resources are broadly applicable both to new construction projects and when conducting periodic renovations of existing buildings. The resources range from very accessible graphics, to lists by building component, and extend to construction specification recommendations for detailed guidance. In general, the *Charm Building and Site Guidelines* provides an accessible guide to review resilience options for the challenges presented at a given new construction location.
- **Tool URL/web address:** https://www.mass.gov/service-details/resiliency-initiatives and https://www.mass.gov/service-details/design-construction-guidelines-standards
- The tools for this resource are also part of the appendix of this document.
- **Tool Creator:** MA Department of Housing and Community Development (DHCD), Kleinfelder and New Ecology
- **Estimated Time for Analysis:** 2-3 hours to review for applicable strategies
- **Considerations:** The *Charm Building and Site Guidelines* are useful for a first pass to consider resilience needs and opportunities at a given property once the risks are known. A next step for analysis could be to review the *Resiliency Design Guidelines - Compiled* which are organized according to construction specifications index sections and specifically address resiliency needs and emergency preparedness.

Tool Summary

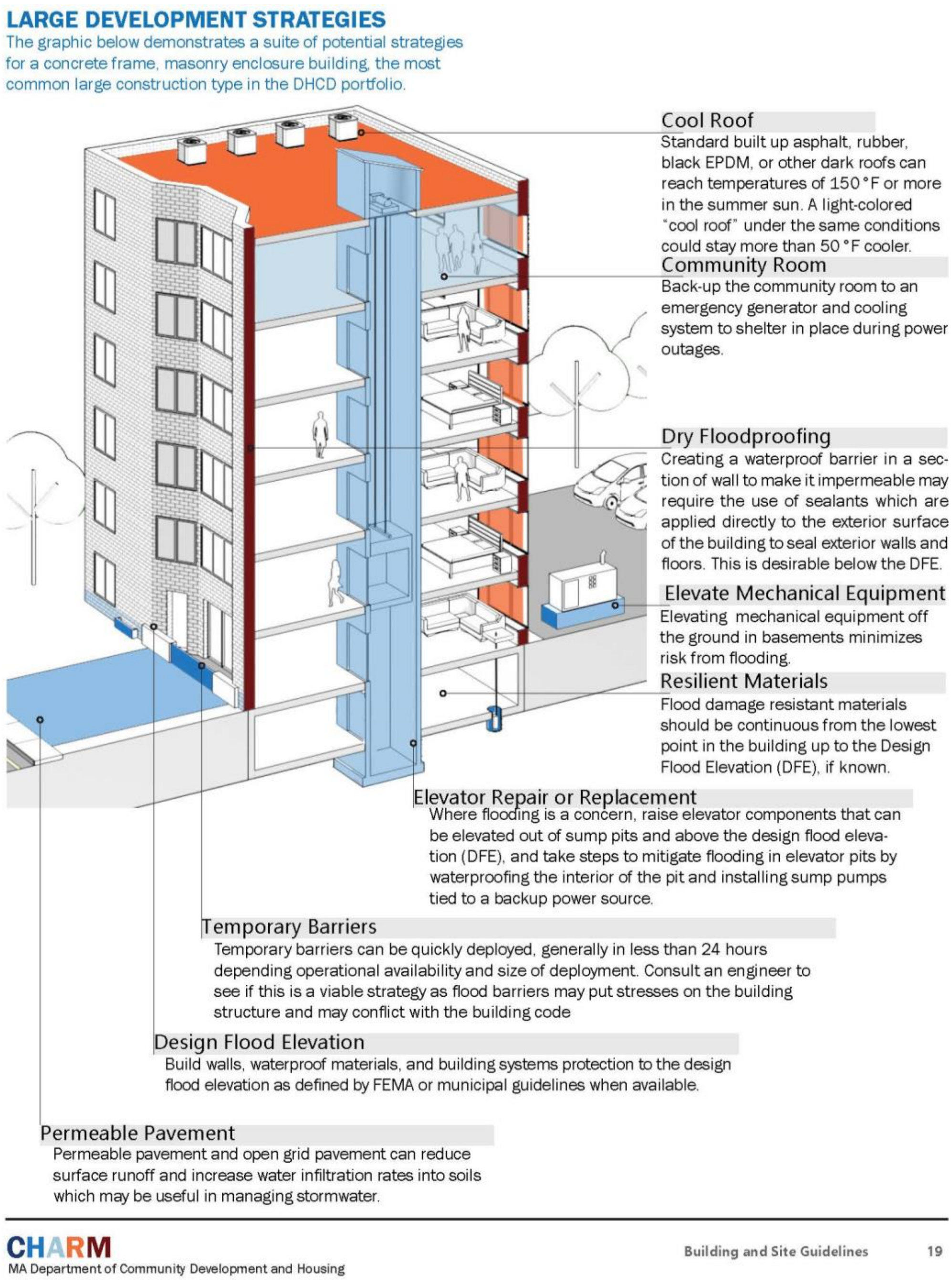
The Charm Building and Site Guidelines includes a list of resilience best practices by strategy type, and also includes an accessible graphical depiction of how resilience strategies can be applied to multifamily buildings and townhomes. The graphical depictions are an excellent way to begin planning for resilience needs and are included here in Images 12 and 13.

Image 12. Charm Building and Site Guidelines Resilience Graphic[9]



[9] Department of Housing and Community Development, 2021, *CHARM Building and Site Guidelines*, https://www.mass.gov/doc/charm-building-and-site-guidelines

Image 13. Charm Building and Site Guidelines Resilience Graphic



The *Charm Building and Site Guidelines* also include a list of resilience strategies by building and site component, and this list makes a great second step for analyzing resilience needs. Climate hazards including precipitation, storm surge, and extreme heat are considered. A brief summary of strategies by building component category is presented below in Image 14.

Image 14. Charm Building and Site Guidelines Resilience Best Practices

RESILIENCE BEST PRACTICES

The Design Guidelines provide a range of strategies for enhanced resiliency of buildings through the implementation of systematic building component improvements. Below are the best practices from each guideline section grouped by structure/enclosure, building systems, and site to provide a more comprehensive overview of how to apply the guidelines to projects.

Building Strategies

Resilient Structure and Enclosure **The most effective wall assemblies are well insulated, air and water tight to keep flooding out and maintain comfortable indoor temperature.**	Climate Hazard: Precipitation	Climate Hazard: Storm Surge	Climate Hazard: Extreme Heat	**Guideline Section**
Repairing or improving the thermal performance of **masonry** at all properties should always be done with attention to managing moisture and permeability as well as thermal performance.			◆	04 20 00 Unit Masonry
Use **wood** building materials which are considered flood damage resistant, meaning they can withstand direct contact with water for at least 72 hours without being significantly damaged.	◆	◆		06 10 00 Rough Carpentry 06 20 00 Finish Carpentry
For some residential buildings, the Massachusetts Energy Code requires a **continuous air barrier** assembly for new construction buildings or additions at opaque exterior walls or soffits, including joints and junctions to abutting constructions to control air movement through the wall. The air barrier also serves as a liquid-water drainage plane when flashed to discharge water to the exterior.	◆	◆		07 10 00 Waterproofing and Dampproofing
The most **effective wall assemblies** have a primary **water barrier** (the exterior cladding: brick, clapboards, shingles, etc.) and a secondary, vapor-open, bulk water barrier (house wrap with all joints taped, peel-and-stick membrane, liquid-applied air and water barrier, or other product).			◆	07 20 00 Building Insulation & Moisture Protection
Making improvements to **roof drainage** will help buildings address water penetration and structural failures. Improving roof insulation at the eaves of sloped roofs will reduce the freeze-thaw cycling of ice and snow on the roof that leads to ice dams.	◆		◆	07 30 00 Asphalt Roof Shingles

NEW ECOLOGY
Community-Based Sustainable Development

LISC BOSTON

Summary of resilience strategies from Charm Building and Site Guidelines:

Structure and Enclosure:

- Roofs: Roof drainage, materials, flashing and moisture barriers are key for water management.
- Walls: Considerations for walls including air and water barriers, and the use of building materials that can withstand submersion in water.
- Door and window openings: Materials considerations, shading and specifying corrosion resistant hardware are addressed.

Resilient Interiors:

- Walls: Construct walls to resist damage from moisture. Gypsum and insulation type, and using gaps to prevent moisture wicking are considerations.
- Flooring: Elimination of carpeting and the use of slip resistant waterproof flooring is recommended.
- Elevators: Raising elevator components and protecting elevator pits are considerations.

Building Systems Strategies:

- Raising equipment and sealing penetrations near ground level are focal points.
- Backup power: setting aside space for future battery storage and/or providing permanent exterior electrical connections so that mobile backup generators can be connected to a building are considerations.

Site Strategies:

- Flood mitigation using retaining walls or deployable flood barriers are items to consider.
- Landscaping could consider the use of green infrastructure to manage stormwater, and reduce area temperatures.
- Highly reflective pavement or open grid pavers may help to reduce heat island impacts.
- Backwater valves can be installed on sewerage lines to help prevent the reverse flow of sewerage into a building, especially during coastal storms in areas where sanitary and storm sewers are not separated.

Resiliency Design Guidelines – Compiled The Resiliency Design Guidelines can be useful when writing or reviewing construction specifications for a given project. It is generally organized by construction specification section, and addresses resiliency considerations for building components. The Resiliency Design Guidelines also include further links to other resources for some building components. Links to FEMA and other resources may help for projects for specific risks or hazards.

Urban Sustainability Directors Network (USDN) – Guide to Developing Resilience Hubs

- **Tool Purpose:** USDN has assembled a step-by-step guide to creating and operating resilience hubs in order to support residents and distribute resources before, during and after a natural hazard event. Once hazards are known, a team can proceed to plan for establishing a successful resilience hub. A team can set service goals, build partnerships, prioritize services, identify solutions, develop the site and install solutions, and plan for activating and operating the site. This document walks teams through the considerations for planning and preparing a resilience hub.
- **Tool URL/web address:** https://www.usdn.org/resilience-hubs.html and

  http://resilience-hub.org/wp-content/uploads/2019/10/USDN_ResilienceHubsGuidance-1.pdf
- **Tool Creator:** NREL – the National Renewable Energy Laboratory
- **Estimated Time for Analysis:** 2-3 hours for initial planning. Complete planning will take further team involvement.
- **Considerations:** Tools presented in this guide should be major assets with the resilience hub planning process. From diagnosing risks to reviewing the financial feasibility of solar and backup power systems, substantial portions of the work required to plan a resilience hub will be already accomplished by using other tools presented in this document.

Tool Summary

Resilience hubs can serve as areas of refuge during and after storms, power outages, and other emergency situations. Providing a space of refuge for cooling or heating, charging communications devices, refrigerating medicines and providing food and water can be among some of the basic service needs that resilience hubs can provide. Planning for the inclusion of a resilience hub in a new construction project is to some extent a building systems consideration, but the building systems may be determined after a process to consider the overall goals of a resilience hub project.

The Urban Sustainability Directors Network has prepared a guide to help organizations plan for the unique needs and opportunities at a given property. They have broken their process down into 6 phases:

- **Phase 1:** Assess Vulnerability & Select Service Area
- **Phase 2:** Establish Team, Partnerships and Goals

- **Phase 3:** Identify & Evaluate Sites
- **Phase 4:** Identify Resilience Solutions
- **Phase 5:** Develop Sites & Install Solutions
- **Phase 6:** Activate & Operate Sites (Image 15)

Image 15. Cover Sheet Image of USDN's 6 Phase Guide to Creating Resilience Hubs

NEW ECOLOGY
Community-Based Sustainable Development

LISC BOSTON

NEI Emergency Preparedness Plan

- **Tool Purpose:** NEI has developed an easy-to-use template to assist multifamily communities in preparing for emergency events and establishing the procedures and responsibilities necessary for an effective disaster response.
- **Tool Location:** Appendix B, attached separately as a single document.
- **Tool Creator:** New Ecology Inc.
- **Estimated Time for Implementation:** 2-3 hours for comprehension by Emergency Preparedness Coordinator, 2-3 hours to meet with staff to assign roles and responsibilities, 3-4 hours for annual/semiannual review meets and tabletop exercises, and 9-14 hours meeting preparation/follow up by the coordinator.
- **Considerations:** Planning steps, forms, checklists, and practice resources are collected in one place, helping with ease of distribution. The Emergency Preparedness Coordinator must be able to dedicate time for plan implementation and plan maintenance. Successful implementation requires engagement from respective staff members and residents.

Tool Summary

Resiliency involves mitigating risk exposure, but also includes improving community capacity to withstand and recover from emergency events. Having a plan in place in the event of an emergency situation is crucial for resident safety, minimizing damage to building structure and systems, sustaining communications and key resident services, and restoring building operations to normal as quickly as possible. This New Ecology resource provides guidance to communities in developing their Emergency Preparedness Plan and can also be used as a template for the plan itself. Collaboration is a key in this guide, and an expectation is that an Emergency Preparedness Coordinator will be named on the management staff. This person can help to gather information resources, and each year can bring together the team for a tabletop simulation so that all are prepared in the event of an emergency. Resources are presented in English and Spanish in the template provided, and teams can add or subtract from the materials as it fits them best. New Ecology recommends that each property have an Emergency Preparedness Plan, and that it be reviewed annually.

EXAMPLE RESILIENCE ASSESSMENT

The following assessment demonstrates how the discussed tools could be employed in practice to understand present and future climate risks facing a development site. It then provides an example of how the tools can be used to assess different resilient solutions in terms of cost-effectiveness and relevance to the identified risks.

Overview and Risk Evaluation

170 Cottage Street is located in Chelsea, MA. The land is currently undeveloped, and it is served by the nearby MBTA Silver Line SL3 which travels south to the South Station rail hub, and north to the Chelsea terminal station with a connection to the MBTA commuter rail. The Silver Line is co-located at this location with the Chelsea Greenway, a walking and bicycling path which runs from Eastern Ave to Chestnut Street, and is approximately 0.7 miles long. The Chelsea Creek is located to the south and southeast of the site. Based on the contour maps of the City of Chelsea, the lowest site elevation is approximately 14 feet above sea level on the Cottage Street Side.[10]

[10] City of Chelsea Contour Map, *Maps Online*, https://www.mapsonline.net/chelseama/index.html#x=-7906647.389005,5219334.325995,-7906265.203864,5219496.75468

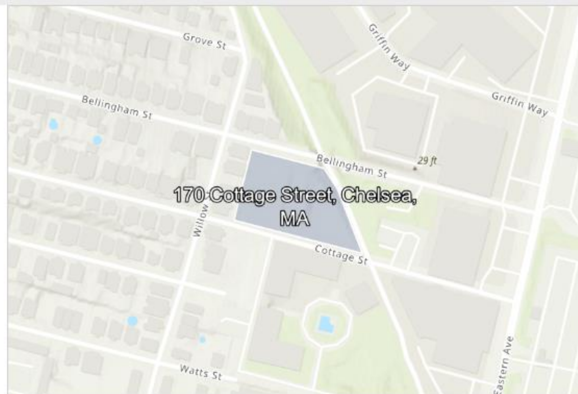
Image 16. Climate Resilience Design Standards Report, 170 Cottage Street

Project Summary

Estimated Capital Cost: $50000000.00
End of Useful Life Year: 2094
Project within mapped Environmental Justice neighborhood: Yes

Ecosystem Service Benefits	Scores
Project Score	Low

Exposure	Scores
Sea Level Rise/Storm Surge	Moderate Exposure
Extreme Precipitation - Urban Flooding	High Exposure
Extreme Precipitation - Riverine Flooding	Not Exposed
Extreme Heat	High Exposure



Asset Preliminary Climate Risk Rating Summary

Number of Assets: 1

Asset Risk	Sea Level Rise/Storm Surge	Extreme Precipitation - Urban Flooding	Extreme Precipitation - Riverine Flooding	Extreme Heat
Potential Multifamily Housing	Moderate Risk	High Risk	Low Risk	High Risk

For a new construction project, such as new townhouses or row homes on 170 Cottage Street, it is important to consider future risks that will materialize over the lifespan of the building so these concerns can be addressed and mitigated during design. The **Climate Resilience Design Standards Tool** from the RMAT team and the National Storm Surge Risk Maps Interactive Viewer are useful to diagnose forward looking risk exposure. From the Climate Resilience Design Standards tool, the summary presented in Image 16 considers risks through 2070. Using that tool, the projected site risks include high risk of flooding by precipitation, moderate risk from sea level rise/storm surge, and high risk from extreme heat.

To investigate the future risk of flooding to the development site, users could then look at the Climate Resilience Design Standards 2070 map output, the most forward-looking map provided by the tool. The output in Image 17 shows that in 2070 part of the site will be at 0.5% annual risk of flood, but that the risk is still contained to the southeastern portion of the site.

Image 17. Projected Water Surface Elevation in 2070, 170 Cottage St, Chelsea, MA

Climate Resilience Design Standards Tool:
Sea Level Rise/Storm Surve Design Criteria
Projected Water Surface Elevation Map: 2070, 0.5% (200-yr)

Project Name: 170 Cottage Street, Chelsea, MA
Location (Town): Chelsea

0.05 0.1 0.25 Miles

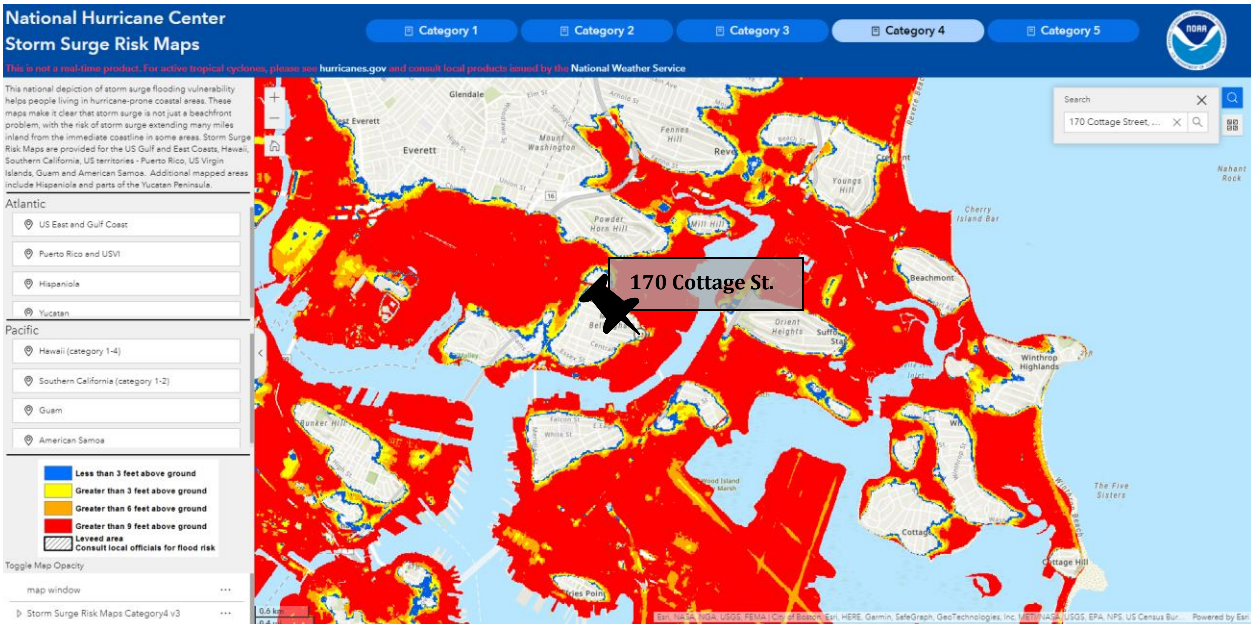
Created by: fstone
Date Created: 10/3/2022
Tool Version: 1.2

N

Asset Name	Planning Horizon	Return Period	Max	Min	Area Weighted Average
			(ft-NAVD88)		
Potential Multifamily Housing	2070	0.5% (200-yr)	14.2	14.2	14.2

These flood risk findings should be supplement by checking the site's exposure to storm surge inundation using NOAA's National Storm Surge Risk Maps. From the map shown in Image 18, there is evidence that the property will be on the edge of the risk maps for a Category 4 hurricane. The design team may consider using a space of refuge to support residents during and after a storm event, if residents are not evacuated.

Image 18. Category 4 Hurricane Risk Map, Maximum Zoom, 170 Cottage St, Chelsea, MA



Applicable Design Strategies

A brief assessment of the project's risk exposure yielded two key concerns – the site's exposure to excessive heat and to flooding from both precipitation and sea level rise/storm surge. At this point in the process, design teams can use the CHARM tool to source mitigation strategies for the risks facing their development. A summary of all potentially applicable design strategies from the CHARM tool is presented below in Table 1. Related hazards are identified as follows: "EP" = emergency preparedness, "P/SLRSS" = precipitation/sea level rise and storm surge, "H" = extreme heat, "W" = wind. Design teams may find it useful to sort this list in order of priority and roughly estimate the costs associated with each relevant design strategies. Laying out options in this manner can help design teams identify cost effective solutions that address the most pressing concerns.

Considering the risks present at the 170 Cottage Street site, this table can first be used to address flooding exposure. At 170 Cottage Street, it may be useful to use landscaping to keep floodwaters from the entering site and to increase infiltration onsite. Landscaping could incorporate rain gardens and rain swales, or could be a physical flood barrier in the form of terraced park with a floodable lower level. Alternatively, moveable flood barriers or elevating structures and critical equipment could be used at the corner of the property.

Secondly, the project site's exposure to excessive heat risk is concerning because excessively hot days can lead to power disruptions as energy use spikes in the area. Power disruptions are a severe danger to vulnerable residents who may not be able to cope with the adverse climate conditions. Using the table, the design team can identify and consider strategies to minimize this risk such as using cool roofing materials. The table suggests strategies for increasing resilience to excessive heat induced power outages though focusing on maintaining backup power to critical systems and installing quick connects on the exterior of the building for temporary generators to power cooling and other systems. Importantly, it also notes how improvements to the building envelope including insulation and air sealing will enable a building to maintain comfortable conditions for residents for longer during utility outages and promote passive survivability.

Table 1. CHARM Applicable Design Strategies

Strategy Name	Hazard	Strategy Details	Applicable Design Guideline Section
Wet Floodproofing	P/SLRSS	FEMA defines wet floodproofing as "Permanent or temporary measures applied to a structure or its contents that prevent or provide resistance to damage from flooding while allowing floodwater to enter the structure or area. Generally, this includes properly anchoring the structure, using flood resistant materials below the Base Flood Elevation (BFE), protection of mechanical and utility equipment, and use of openings or breakaway walls."	06 10 00 ROUGH CARPENTRY 06 20 00 FINISH CARPENTRY 08 10 00 DOORS AND FRAMES 09 20 00 GYPSUM 09 30 00 TILE 09 64 00 WOOD FLOORING 09 65 00 RESILIENT FLOORING 09 68 00 CARPET 09 90 00 PAINTING 14 20 00 ELEVATORS

Strategy Name	Hazard	Strategy Details	Applicable Design Guideline Section
			22 00 00 PLUMBING 23 00 00 HVAC 26 00 00 ELECTRICAL 33 00 00 SITE UTILITIES
Dry Floodproofing (Building)	P/SLRSS	Dry floodproofing of a building is installing measures applied to a structure to prevent damage from flooding by preventing floodwater from entering the structure. There are two types of dry floodproofing: active and permanent. Active measures require removable elements to be put into place before an anticipated flood. Permanent measures are fixtures and systems integrated into the structure itself, which do not need to be manually deployed in the event of an emergency. Dry floodproofing is prone to a high risk of failing in lightweight wood-framed buildings, however, and is not recommended for wood-framed building exteriors or openings per FEMA guidance.	07 10 00 WATERPROOFING AND DAMPPROOFING 07 90 00 SEALANTS 08 10 00 DOORS AND FRAMES 32 30 00 SITE IMPROVEMENTS 33 00 00 SITE UTILITIES
Stabilize Slopes	P/SLRSS	Slopes stabilized with retaining walls, terraces, or plantings, will be less likely to erode over time or to erode suddenly in the event of a flood, potentially destabilizing part of the building or adding debris to floodwaters. Engage a civil engineer to identify steep slopes on site and stabilize with terracing, ground cover, structural wall or other method to reduce erosion and prevent the movement of materials on site during a flood.	32 30 00 SITE IMPROVEMENTS

Strategy Name	Hazard	Strategy Details	Applicable Design Guideline Section
Site Perimeter Floodproofing	P/SLRSS	Temporary or permanent barriers surrounding the site and preventing floodwaters from entering building. Requires management of rain water and storm drain water entering the enclosure either by storage and infiltration, pumping it out, or providing an outlet.	32 30 00 SITE IMPROVEMENTS 32 90 00 LANDSCAPING
Resilient Elevators	P/SLRSS	Protect elevator shafts below the BFE and design shaft walls to resist the hydrostatic pressure of floodwater, program elevator controls to return car to flood safe floor in the event of flooding and to shut down all but one elevator in the event of a power outage, install flood alarms in pits, and keep controls and equipment above the BFE.	14 20 00 ELEVATORS
Backwater Valves	P/SLRSS	Backwater valves are installed where the wastewater pipe exits the building, so sewage only flows outward. Valves have a hinged flapper that remains open to allow outward flow, but seals tightly if there is backpressure. Install individual backwater valves on the lowest fixtures in the building, or whole-building backwater valves for storm sewer and sewer lines. Will require incorporation into an emergency plan to ensure proper operation during an extreme event.	33 00 00 SITE UTILITIES
Sump Pumps	P/SLRSS	Sump pumps are submersible pumps set in sump pits and designed to remove water from the lowest point in a building as water accumulates during minor or moderate flood events. Sumps are typically built in sump basins in basement floors but can also be incorporated into slab-on-grade floors	26 00 00 ELECTRICAL

Strategy Name	Hazard	Strategy Details	Applicable Design Guideline Section
		and elevator pits. Sump pumps are designed for intermittent use. Chronic water problems require repairing the drainage system in addition to or in lieu of installing a pump.	
Elevated Equipment	P/SLRSS	Elevating mechanical and electrical equipment above the base flood elevation reduces the risk that the equipment will be damaged or destroyed in the event floodwaters enter the lowest level of the building and increases the likelihood that the building will remain operational even if the building floods. Critical equipment can be elevated in place by moving it off the floor to a wall or by moving it onto a platform and out of harm's way. Equipment that is replaced as a result of elevating it should be replaced with and energy efficient alternative. Engage an engineer or contractor with experience designing and specifying efficient equipment.	22 00 00 PLUMBING 23 00 00 HVAC 26 00 00 ELECTRICAL
Elevated Living Spaces	P/SLRSS	During a plan and spec review, convert residential units on floors below the BFE to parking, storage, common rooms and community space, or entryways. Ensure equipment in these areas is portable and can be moved to safety before anticipated flooding.	N/A
Flood Damage Resistant Siding	P/SLRSS	Wood or composite siding can be damaged by flood waters and require replacement. When designing a property, consider replacing siding with fiber cement board (FCB). FCB can also be a good solution in high wind areas.	07 40 00 SIDING

Strategy Name	Hazard	Strategy Details	Applicable Design Guideline Section
Safeguard Fuel Storage	P/SLRSS	Secure fuel storage fixed and portable tanks and containers to prevent spillage and movement in case of a flood. Perform this task as necessary during routing operations and maintenance.	N/A
Quick Connects for Mobile Heating, Cooling, and Power	EP	Quick connects are connection points on the exterior of the building for hooking up temporary backup heating, cooling, or electrical equipment. Quick connects to hot water piping, chilled water piping, or electrical panels allow temporary mobile heating, cooling, and power equipment to connect to the building and provide services in the event of damage to permanently installed equipment. Install quick connects for power, heat, and cooling such that temporary equipment can be connected at the street in the event of an extended outage.	N/A
Maintaining Backup Power to Critical Systems	EP	Backup power can allow building elevators, heating, cooling, ventilation, lighting, refrigeration, and other electrically powered systems to operate in the event of a power outage, depending on the capacity of the backup power system. Provide a generator or other backup system sized to meet critical loads and with fuel capacity for expected power outage duration. Critical loads could include elevators, fire pumps, sump pumps, water booster pumps, emergency outlets, fans, pumps, and controls for heating and cooling systems, alarms and security systems, food and medicine refrigeration, telecommunications, or others. An elevator may require its own	07 07 00 SOLAR PHOTOVOLTAIC SYSTEMS 26 00 00 ELECTRICAL

Strategy Name	Hazard	Strategy Details	Applicable Design Guideline Section
		backup generator to continue operating during a power outage.	
Access to Potable Water	EP	Provide potable water storage in a central system or portable potable water storage containers: 1 gal/person/day for 1 day in stored bottled water, plus 1 gal/person/day for 6 days in collapsible storage capacity.	N/A
Solar Photovoltaic (PV) Systems + Storage	EP	Solar PV can be located on a roof with southern exposure and no shading from rooftop equipment, ground mounted, or located on a parking canopy to offset common area electric consumption. Solar PV feasibility should be provided by a PV installer or investigated using Helioscope - or PV Watts to estimate power production based on the roof area and orientation. Properties with existing solar photovoltaic (PV) systems may be able install battery storage and make the PV system islandable for use in a power outage. A battery could be located inside or outside and connected to the PV array through an islandable inverter(s) to provide backup power capacity for a community resiliency space and other critical loads. Battery feasibility analysis should be provided by a battery designer/installer or investigated using the Geli tool – geli.net or REopt Lite – reopt.nrel.gov/tool. Solar PV with or without batteries can be used to provide some backup functions to a Resilience Hub.	07 07 00 SOLAR PHOTOVOLTAIC SYSTEMS 26 00 00 ELECTRICAL

Strategy Name	Hazard	Strategy Details	Applicable Design Guideline Section
Develop Emergency Management Plan	EP	A disaster can come at any time or can progress more slowly, but one of the most crucial factors in protecting the safety and well-being of housing residents is the coordination of the housing management staff in responding to the event. Using best practices developed for a wide range of emergency responses to prepare and respond to disasters, guided by an emergency management plan, housing management staff can respond quickly and effectively when disaster strikes. Provide a plan and contact list for staff, leadership, and residents to communicate effectively throughout a disaster. Follow the DHCD Emergency Preparedness Plan guidance to creating an organization- and development-level coordination, communication, and information sharing emergency plan.	N/A
Creating Community Resiliency Spaces	EP	Community spaces should offer a safe and secure environment for residents and a central location for emergency services. Existing community, dining, or multi-purpose rooms could provide this space.	N/A
Window Shading	H	Shading windows reduces the amount of solar heat gain in the interior of the building, thereby reducing cooling loads during the summer months and leading to lower indoor temperatures during power outages when the cooling system is not operational. Add overhangs to south-facing windows or awnings to east- or west-facing windows. Or, add interior window shading treatments.	08 50 00 WINDOWS

Strategy Name	Hazard	Strategy Details	Applicable Design Guideline Section
Cool Roof	H	A cool roof is a reflective, light colored roof that reduces the amount of solar energy a building absorbs by reflecting the solar energy back into the atmosphere. Cool roofs can be a painted-on or membrane product and reduce the building's cooling load and allowing the interior to remain comfortable longer in the event of a power outage on a hot day. Cool roofs also reduce local heat island effects.	07 30 00 ASPHALT ROOF SHINGLES 07 50 00 MEMBRANE ROOFING
Insulate Walls and Roofs	H	Insulating the exterior envelope of a building makes the interior less susceptible to large temperature swings and improves the efficiency and effectiveness of heating and cooling systems.	07 20 00 BUILDING INSULATION AND MOISTURE PROTECTION 07 30 00 ASPHALT ROOF SHINGLES 07 50 00 MEMBRANE ROOFING

Solar Photovoltaic (PV) and Battery Storage Evaluation Using the NREL REopt Tool

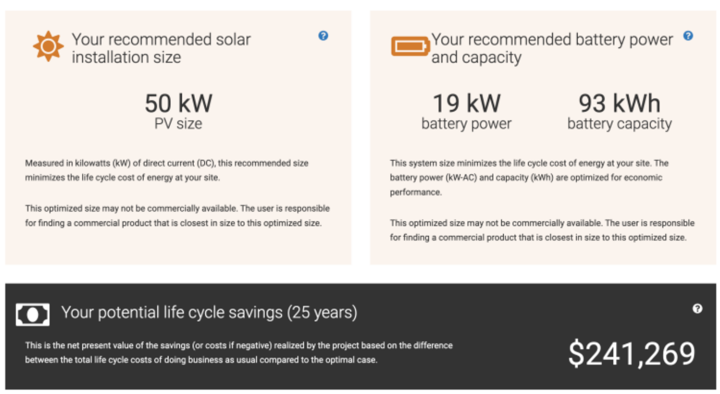
Both flooding events and excessive heat days can contribute to power disruptions and outages. Table 1 from the CHARM tool highlights that a solar photovoltaic and battery storage system can be a powerful tool for maintaining back up power during these emergencies. Design teams should consider this system as a resilience measure so that critical heating, cooling, refrigeration, and communication lines can be maintained or quickly restored. In considering the system, The NREL REopt tool can help a design team refine the financial projections for a solar or solar and battery storage project. As inputs are refined, system outputs will be more accurate, and will likely be more useful to development teams. This tool is used here to model such a system for 170 Cottage Street. The assumptions for the preliminary analysis are listed, and teams are welcome to incorporate aspects from the following inputs for their modeling.

Assumptions for the 170 Cottage Street Solar and Battery storage preliminary analysis include:

- Electrical load is the NREL default value for a "Midrise apartment"
- Critical electrical load is estimated at 5% of the default power needed for the default "Midrise apartment"
- Electricity rates are set at Eversource Energy: Greater Boston General Service G-2/B-2
    - This can easily be changed to reflect a demand meter, as needed
- The outage modeled is a 48-hour grid power outage starting at 1am on July 1, with the battery starting at 50% state of charge
- Refundable ITC of 30% is assumed for both the solar PV and battery storage system
- Neither the 20% bonus credit for federally subsidized affordable housing, nor the 10% bonus credit for solar project in low-income communities is assumed.
- Battery costs are assumed at NREL default settings:
    - Energy Capacity Costs ($/kWh) at $388
    - Power Capacity Costs ($/kw) at $775
- Battery lifetime of 10 years is assumed
    - Battery replacement costs are default values showing a discount from current costs. Battery prices are expected to decline.
    - Solar PV costs are estimated at $3.44 per Watt or $3,440 per kW
- The maximum Solar PV system size is limited to 50kW, with the minimum set at 30kW
- MA SMART Solar incentives estimated at 10.7 cents per kWh for a duration of 20 years
- No utility incentives for the battery system were assumed, although these are currently available in MA (Connected Solutions). The total incentive value is challenging to predict and is based on utility needs
- Grid emissions factors are US EPA AVERT Northeast Region, with default values for annual decreases in grid emissions factors
- Host effective tax rate of 0%, discount rate of 5.64% and electricity escalation rate of 1.9%
- No MACRS depreciation counted for the project

Results with the above assumptions for 170 Cottage Street return a 50kW solar PV system coupled with a battery system of 19kW battery power and 93kWh of battery capacity. Total lifecycle savings over 25 years is estimated at $241,269 (Image 19). This system is expected to provide electricity to cover 5% of typical system load during a 48-hour outage, and does so with capacity to spare, not falling to lower than 75% (approximate) state of charge during the outage. The difference in system size and performance for a "resilience" focused system as compared with one optimized for financial considerations is negligible. The comparison is presented here to show a capability of the analysis tool (Image 20).

Image 19. NREL REopt Results Comparison for PV & Battery Systems Optimized for Resilience v Financial Performance, 170 Cottage St, Chelsea, MA



The resilience focused system is expected to cost $222,965 before incentives, and $176,347 after incentives (Image 20). The net present value of the savings over 25 years is estimated at $241,269. Payback is estimated at 7.59 years. The PV system sized at 50kW is expected to provide 21% of the building's electricity needs, although the building electrical load is an NREL default value. An estimated value based on existing buildings in the portfolio may help refine this number. Not shown above, but available in another section of the NREL report output is an estimate that building CO2 emissions will be reduced by 21.47% with this system in place.

Image 20. NREL REopt Results Comparison for PV & Battery Systems Optimized for Resilience v Financial Performance, 170 Cottage St, Chelsea, MA

Results Comparison

These results show how doing business as usual compares to the optimal case.

	Business As Usual	Resilience	Financial
System Size			
PV Size	0 kW	50 kW	50 kW
Battery Power	0 kW	19 kW	19 kW
Battery Capacity	0 kWh	93 kWh	92 kWh
Energy Production and Fuel Use			
Average Annual PV Energy Production	0 kWh	56,939 kWh	56,939 kWh
Average Annual Energy Supplied from Grid	263,453 kWh	208,243 kWh	209,906 kWh
Renewable Energy Metrics			
Annual Renewable Electricity (% of electricity consumption)	0%	21%	21%
Life Cycle Cost Breakdown			
Technology Capital Costs + Replacements, After Incentives	N/A	$176,347	$175,542
O&M Costs	$0	$14,697	$14,697
Total Utility Electricity Cost	$1,551,770	$1,188,161	$1,197,223
Lifecycle Costs of Climate Emissions (included in objective)	$0	$0	$0
Lifecycle Costs of Health Emissions (included in objective)	$0	$0	$0
Summary Financial Metrics			
Total Upfront Capital Cost Before Incentives	N/A	$222,965	$222,193
Year 1 O&M Cost, before tax	$0	$850	850
Total Life Cycle Costs	$1,551,770	$1,310,501	$1,318,758
Net Present Value	$0	$241,269	$243,158
Payback Period	N/A	7.59 yrs	7.54 yrs
Internal Rate of Return	N/A	12.5%	12.6%
PV Levelized Cost of Energy	N/A	$0.155/kWh	$0.155/kWh

Inclusion of a Resilience Hub

Lastly, all project teams should consider the inclusion of a resilience hub and ensure that a future emergency preparedness plan is specified. Using the Urban Sustainability Director's Network Guide, the property management and resident groups can work through the six-step guide to planning for and activating a resilience hub. The guide provides a template for a collaborative process to assess risks and set goals, and to finally install solutions. This collaborative effort can be done early on in development planning, and can be completed with the available resources and resilience goals in mind. A resilience hub can be an asset to the community during normal operations, and can be a vital resource to residents and the community during an emergency.

At 170 Cottage Street, the risk of power disruptions and the potential for the site to serve as a place of refuge for nearby areas that could be inundated by storm surge both support the inclusion of resilience hub. Adding this space of refuge on-site, or having a dedicated space of refuge nearby will likely be very helpful to provide essential services during outages or emergencies. New Ecology would recommend incorporating the Urban Sustainability Director's Network Guide and would later facilitate the implementation of NEI's Emergency Preparedness Plan.

APPENDIX 1: FEMA FLOOD ZONE TABLE[11]

Special Flood Hazard Zone *Mandatory flood insurance purchase requirements and floodplain management standards apply.*	Zone A	Areas determined using less detailed methodologies that are subject to inundation by the 1%-annual-chance flood event. No BFEs shown.
	Zone AE and Zone A1-30	Areas subject to inundation by the 1%-annual-chance flood event, as determined by detailed hydraulic analyses. BFEs are shown on the maps.
	Zone AH	Areas subject to inundation by 1%-annual-chance shallow flooding (usually areas of ponding), where average depths are between 1 and 3 feet. BFEs are shown on the maps.
	Zone AO	Areas subject to inundation by 1%-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average flood depths derived from detailed hydraulic analyses are shown in this zone. Some areas with high flood velocities, such as alluvial fans and washes, are designated as Zone AO. Communities are encouraged to adopt more restrictive requirements for these areas.
	Zone A99	Areas subject to inundation by the 1%-annual-chance flood event, but which will ultimately be subject to reduced flood hazard upon completion of a flood protection system that is under construction. Zone A99 may only be used when the flood protection system has reached specified statutory progress toward completion. No BFEs or depths are shown.

[11] Reproduced. FEMA, 2022, *Risk Rating 2.0: Equity in Action, NFIP Flood Insurance Manual: Appendix D*, https://www.fema.gov/sites/default/files/documents/fema_nfip-flood-insurance-manual-appendices_102022.pdf

	Zone AR	Areas that result from a non-accredited flood protection system that is being restored to provide flood hazard reduction from the base flood.
	Zone AR/AE, AR/AH, AR/AO, AR/A1-30, AR/A	These areas have dual flood zones. This reflects both the presence of a non-accredited flood protection system that is being restored and areas that are subject to flooding from other water sources.
	Zone V	Areas along coasts subject to inundation by the 1%-annual-chance flood event with additional hazards associated with storm-induced waves. Because detailed hydraulic analyses have not been performed, no BFEs or flood depths are shown.
	Zone VE and Zones V1-V30	Areas subject to inundation by the 1%-annual-chance flood event with additional hazards due to storm-induced velocity wave action. BFEs derived from detailed hydraulic analyses are shown.
Moderate or Minimal Hazard Areas *Mandatory flood insurance purchase requirements and floodplain management standards <u>DO NOT</u> apply.*	Zones B and X (Orange Shaded)	Areas of moderate flood hazard, between the boundaries of the SFHA and the 0.2%-annual-chance (or 500-year) flood zone
	Zones C and X (Unshaded/Clear)	Areas of minimal flood hazard, outside the SFHA and at elevations higher than the that of the 0.2%-annual-chance (or 500-year) flood. If a community's local flooding is too small to map, but they participate in the NFIP, they may not have a published map. The NFIP considers all areas within these communities to be Zone X (previously known as Zone C), and flood insurance coverage is available under the Regular Program.
	Zone D	Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance is optional and available, and rates in Zone D areas are commensurate with the uncertainty of the

	flood risk. Agents should also use the Zone D rating when a community incorporates portions of another community's area where no map has been prepared

APPENDIX 2: NEI EMERGENCY PREPAREDNESS PLAN

Attached As Separate Document