Climate Resilient Energy Code for Multifamily Affordable Housing

Preliminary Impact Assessment Results

Prepared by

Clean Energy Group

American Microgrid Solutions

New Buildings Institute

with analytical support from

Pacific Northwest National Laboratory

March 2025

About this report

This report details preliminary impact assessment results to assess the climate resilience, energy use, and cost impacts of implementing the measures included the Connecticut Climate Resilient Energy code, a voluntary building code for multifamily affordable housing that was developed to cover the installation of climate resilient energy systems and the provision of power to essential services during grid outages. The code enhances the ability of a multifamily affordable housing building to maintain livable conditions for residents by requiring minimum levels of onsite backup power and by requiring building envelope standards and other measures that increase the ability of a building to maintain habitable indoor temperatures without the active use of heating and cooling systems.

Acknowledgement

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Building Technologies Office Award Number DE-EE0010940.

Contents

Summary of Results

The preliminary impact assessments detailed in this report were conducted to assess the climate resilience, energy use, and cost impacts of implementing the measures included the Connecticut Climate Resilient Energy code, a voluntary building code for multifamily affordable housing that was developed to cover the installation of climate resilient energy systems and the provision of power to essential services during grid outages. The code enhances the ability of a multifamily affordable housing building to maintain livable conditions for residents by requiring minimum levels of onsite backup power and by requiring building envelope standards and other measures that increase the ability of a building to maintain habitable indoor temperatures without the active use of heating and cooling systems.

The results summarized below and detailed in the report are for a representative 30-unit, mid-rise apartment building in Connecticut.

Climate Resilience Impact Results

The code requires minimum thresholds for the installation of onsite solar and energy storage systems to provide backup power for critical building loads that are needed to maintain services for residents sheltering in place. The resulting backup power system includes a 46-kilowatt rooftop solar system and 60-kilowatt / 246-kilowatt-hour battery system. The system provides a minimum of 26 hours of backup power to critical loads under worst case conditions and can typically support critical loads for 59 hours when a grid power outage occurs. Improved building envelope and related thermal efficiency measures significantly improved the building's ability to maintain habitable temperatures during extreme cold events, though they moderately increased indoor temperatures during extreme heat events.

Energy Use Impact Results

Implementation of the code primarily impacts building electricity consumption due to the energy needs of the battery storage system and energy production of the solar system. The battery system increases annual electricity consumption by approximately 8 percent, while the solar system produces enough energy to offset 17 percent of consumption, resulting in a net reduction of 36,635 kilowatt-hours per year.

Cost Impact Results

Because the expense and economic return of many of the code measures can vary significantly depending on specific building characteristics, the cost impact assessment focused on quantifying the lifetime cost of the code's backup power requirements and providing estimated incremental cost values for additional measures, including enhanced envelope measures, urban heat island mitigation, specialized controls, and building operations procedures.

Installing and maintaining the solar and battery storage systems over a 20-year period would cost $695,624. These expenses can be partially or fully offset by available incentives, revenue through program participation, and bill savings, amounting to lifetime economic benefits of $841,972 for a master metered building and $609,105 for an individually metered building. Based on lifetime system costs and benefits, the master metered building would achieve a return on investment of 5.9% and a marginally negative net present value of -$900 over 20 years. The individually metered building would result in an internal rate of return of -6.8% and a net present value of -$123,400

The difference between financial outcomes for the two metering configurations can be attributed to how solar benefits are distributed to tenants through Connecticut's solar incentive program and the ability of a master metered building to realize higher electric utility bill savings. While tenants of the master metered building would not receive any direct economic benefit from the backup power system, the tenants in each unit of the individually metered building would benefit from electric utility bill savings of $2,784 over 20 years.

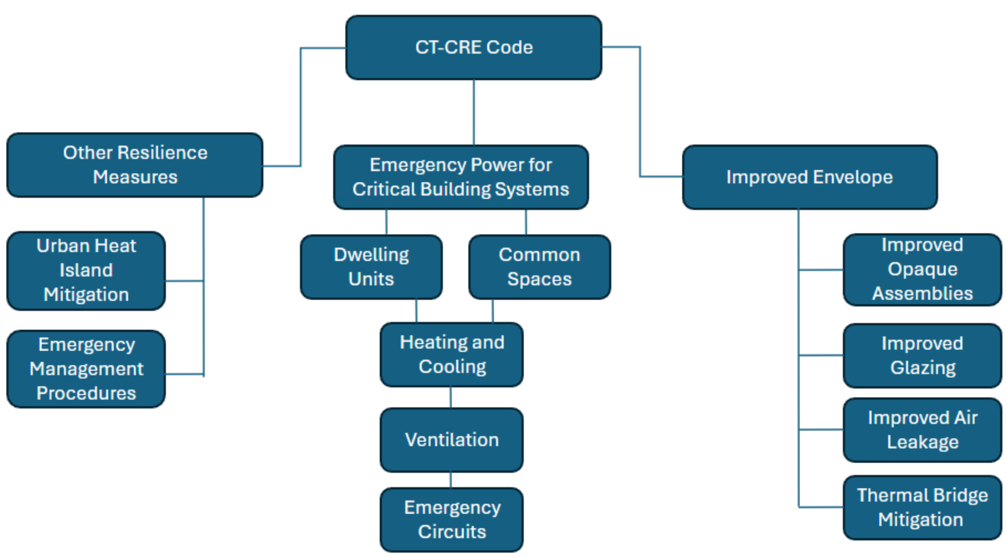
The societal benefits of offsetting emissions from dirtier sources of energy generation and improving health outcomes for residents during power outages were also explored. The benefits of avoiding greenhouse gas and air pollutant emissions were found to result in societal benefits totaling $4,419 annually and $88,389 over 20 years.

Background

The preliminary impact assessments detailed in this report were conducted by American Microgrid Solutions (AMS), New Buildings Institute (NBI), and Pacific Northwest National Laboratory (PNNL) as part of the Climate Resilient Energy Codes for Multifamily Affordable Housing project, a Department of Energy funded initiative under the Resilient and Efficient Code Implementation program. The Climate Resilient Energy (CRE) Codes project is designed to enable greater deployment of climate resilient energy systems, including solar, battery storage, and efficient heating and cooling, to maintain living conditions and power essential services for multifamily affordable housing residents sheltering in place during grid outages. The project is a three-year effort by an integrated team led by Clean Energy Group in partnership with American Microgrid Solutions, the Connecticut Department of Energy & Environmental Protection, the Connecticut Green Bank, the Connecticut Insurance Department, New Buildings Institute, Operation Fuel, and the Yale Center on Climate Change and Health. The work is being guided and informed by an Affordable Housing Advisory Group and a Technical Advisory Group consisting of affordable housing and energy sector stakeholders and representatives, and through feedback from listening sessions and interviews conducted with multifamily affordable housing residents in Connecticut.

The Connecticut Climate Resilient Energy (CT-CRE) code developed through this project is a voluntary code intended to cover the installation of climate resilient energy systems and the provision of power to essential services during grid outages. **Figure 1** depicts a rough outline of the major elements of the CT-CRE code.

Figure 1: Main components included in the Connecticut Climate Resilient Energy (CT-CRE) code.



In order to determine the impact of CT-CRE code measures on a multifamily affordable housing property's climate resilience, energy use, and cost, preliminary impact assessment analyses were conducted. For the purposes of this project, climate resilience is quantified in terms of the duration that an affordable housing building can provide conditions enabling residents to safely shelter in place by maintaining habitable indoor temperatures and preserving access to basic necessities, such as clean water, food storage, and electricity to charge and power essential devices.

Preliminary Impact Assessment Assumptions and Methodology

PNNL used the Department of Energy's prototype buildings to conduct performance simulation analyses for a mid-rise multifamily building. The building was modeled as a four-story facility with 30 residential units and code-compliant common area spaces for a total indoor building space of approximately 33,700 square feet. Total building occupancy was assumed to be 90 residents. The building was modeled with a fossil-based heating system.

Two building efficiency scenarios were explored: 1) compliance with current adopted Connecticut building codes and 2) compliance with the voluntary CT-CRE code. Building performance was analyzed using typical weather and extreme temperature event data for two Connecticut locations – the Hartford-Brainard Airport and Bradley International Airport. PNNL assessed the ability of the mid-rise building to passively maintain livable temperatures during power outage events under extreme heat and cold weather conditions.

PNNL provided energy use and building load shape data to AMS for normal building operations and under reduced building load conditions that represent the common area energy use supported by a backup power system. The code is designed so that common area spaces can be used as a temporary shelter space for residents during a grid outage. AMS used the reduced building load data to size a solar and battery storage system meeting the backup power requirements of the CT-CRE code, which specifies and minimum of 24 hours of backup power to essential services, such as common area Heating, Ventilation, and Air Conditioning (HVAC) systems, lighting, and plug loads. This sizing information was used to determine the cost and climate resilience impacts of the backup power system. NBI assessed existing case studies and market data to determine potential cost and energy impacts of additional building envelope and other resilience measures included in the CT-CRE code. Societal and health benefits were also explored.

The preliminary results detailed in this report will be refined and updated once the CT-CRE code has been finalized based on public comment and feedback from stakeholders.

Climate Resilience Preliminary Impact Assessment Results

The CT-CRE code enhances the ability of a multifamily affordable housing building to maintain livable conditions by requiring measures that improve both the energy resilience and thermal resilience of a building. Energy resilience is improved by requiring minimum levels of onsite backup power and controls and procedures that reduce the level of energy demand during outage events. Thermal resilience is improved by requiring building envelope standards and other measures that increase the ability of a building to maintain habitable indoor temperatures throughout a power outage without the use of active heating and cooling systems, also known as passive survivability.

Backup Power

The CT-CRE code requires minimum sizing thresholds for onsite solar and energy storage systems installed to provide backup power for critical building loads that are needed to maintain services for residents sheltering in place. While in some cases the space available for solar and energy storage may not be sufficient to fully meet the code backup power requirements or it may be cost-prohibitive to meet the requirements with solar and storage alone, the impact assessments assume that backup power will be solely provided by rooftop solar and battery storage as opposed to a hybrid backup power system incorporating a generator or fuel cell.

During a grid outage event, the CT-CRE code stipulates that building energy demand should be decreased by reducing interior lighting and equipment, reducing HVAC, and relaxing temperature setpoints. These measures result in an estimated critical load that represents approximately 15 percent of the full building load during normal operations. The solar and battery storage systems were sized to provide a minimum of 24 hours of backup power to these common area critical loads. The 24-hour minimum duration represents a worse-case scenario when building loads are high and solar is not available to power loads and recharge the battery system.

The resulting backup power system includes a 46-kilowatt (kW) rooftop solar system and 60-kW / 246-kilowatt-hour (kWh) lithium-ion battery system. The system provides a minimum of 26 hours of backup power to critical loads and can typically support critical loads for 59 hours. **Figure 2** shows the solar system design for the modeled mid-rise building.

Figure 2: Representative design of a 46-kW rooftop solar system for the a mid-rise multifamily apartment building.

Passive Survivability

The passive survivability impact of the CT-CRE code was determined based on Standard Effective Temperature (SET) degree hours. SET is an effective indoor temperature metric that accounts for indoor dry-bulb temperature, relative humidity, mean surface radiant temperature, and air velocity, as well as the activity rate and clothing levels of occupants. SET degree hours are the number of degrees above or below a specified indoor comfort threshold summed over a specified period. The impact assessments use SET degrees of less than 54°F for extreme cold and greater than 86°F for extreme heat, which are the comfort thresholds referenced in the LEED pilot credit. If the temperature in an apartment unit were to drop to 52°F (two degrees below the threshold) for one hour during a cold weather outage event, that would represent two SET degree hours. To earn the pilot credit, the cumulative SET degree hours above or below the threshold cannot exceed 216 SET degree hours over a 7-day period.

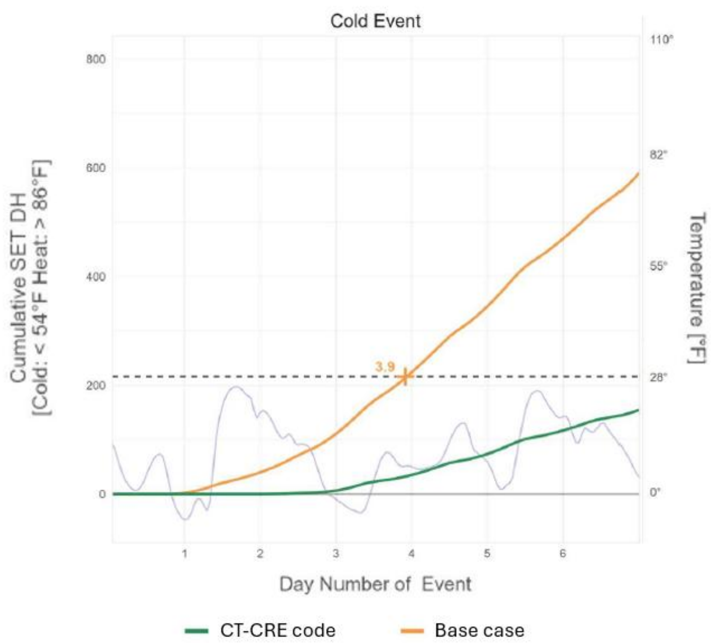
The impact assessment analysis provided SET degree hours occurring over 3- and 7-day periods under extreme heat, with temperatures in the upper 80s and low 90s for multiple days, and extreme cold, with temperature remaining well below freezing and dipping below zero on some days, with no power. The analysis determined SET degree hours for each apartment unit within the building, as well as an average based on all apartment units.

Table 1 shows the change in average SET degree hours for a mid-rise apartment in Connecticut that has implemented the CT-CRE code as compared to a base case where the building meets current Connecticut building code standards. As shown in **Table 1** and **Figure 3.a**, implementation of CT-CRE code measures significantly reduces the average number of SET degree hours during extreme cold events, representing a notable increase in the comfort and habitability of the apartment building during a grid outage. However, the improved building envelope requirements result in a moderate increase in SET degree days during extreme heat events, representing slightly warmer temperatures than the base case over a 7-day period, as shown in **Figure 3.b**.

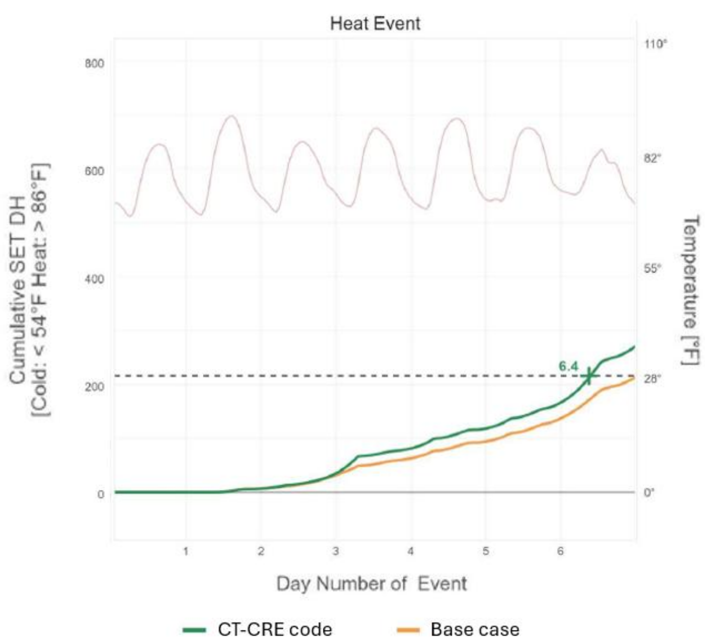
Table 1: Change in SET degree hours for a mid-rise multifamily apartment building complying with current Connecticut building code requirements (base case) and Connecticut Climate Resilient Energy (CT-CRE) code requirements during extreme cold and heat events (Bradley International Airport weather data).

	Outage duration	SET degree hours		% reduction
		Base case	CT-CRE code	
Extreme cold	3 days	131	13	90%
	7 days	676	203	70%
Extreme heat	3 days	22	21	4%
	7 days	121	143	-18%

Figure 3: SET degree hours (DH) for a mid-rise multifamily apartment building complying with current Connecticut building code requirements (base case) and Connecticut Climate Resilient Energy (CT-CRE) code requirements during an extreme cold event (a) and extreme heat event (b) (Bradley International Airport weather data). The dashed line indicated the 216 SET DH threshold representing the point at which indoor temperature conditions become uninhabitable.



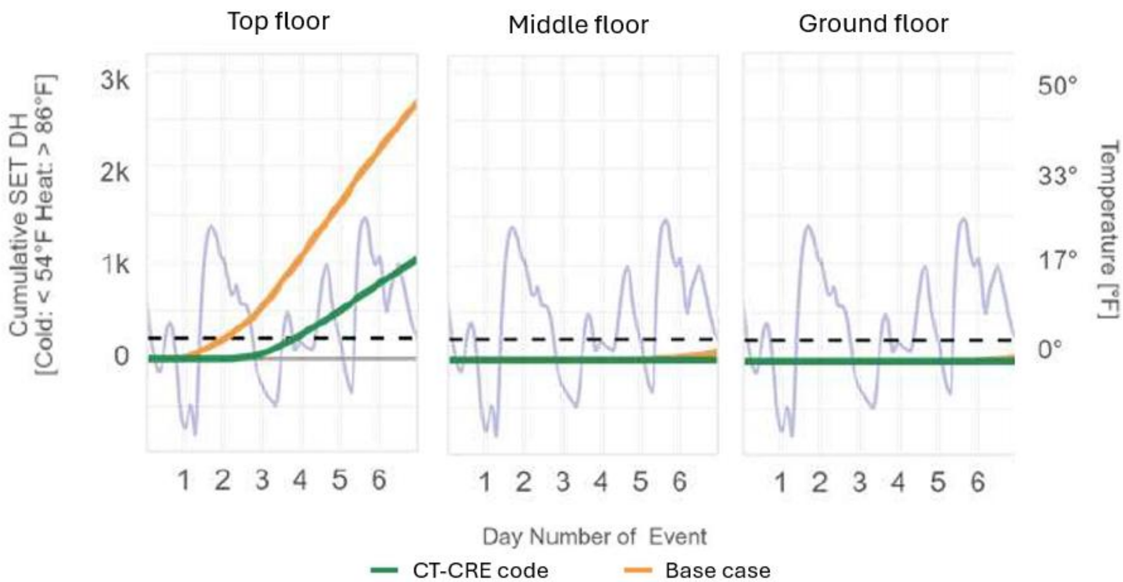
(a)



(b)

While the CT-CRE code greatly improves the passive survivability of the building during extreme cold events, some units did exceed the livable threshold of 216 SET degree hours over a 7-day period. As shown in **Figure 4**, top floor apartments were most impacted, whereas middle and ground floor units experienced fewer SET degree hours.

Figure 4: SET degree hours (DH) for top floor, middle floor, and ground floor apartment units in a mid-rise multifamily building complying with current Connecticut building code requirements (base case) and Connecticut Climate Resilient Energy (CT-CRE) code requirements during an extreme cold event (Bradley International Airport weather data). The dashed line indicated the 216 SET DH threshold representing the point at which indoor temperature conditions become uninhabitable.



Energy Use Preliminary Impact Assessment Results

Implementation of the CT-CRE code primarily impacts electricity consumption due to the energy needs of the battery storage system and energy production of the solar system. Battery storage increases onsite electricity consumption because the system requires a certain amount of energy to operate even when it is not actively being used, known as parasitic load. There are also roundtrip energy losses when a battery is charged and discharged. The 246-kWh battery system modeled for the mid-rise apartment building would result in increased electricity consumption of 21,900 kWh per year, which represents about an 8 percent increase in building electricity consumption. The solar system is estimated to produce 58,535 kWh of electricity each year, approximately 17 percent of the building's annual electricity consumption. The net impact of the solar and battery system results in an overall annual energy reduction of 36,635 kWh. However, because the solar system would be installed in front of the building's utility meter, the solar energy savings would not be directly reflected in the building's energy consumption, as discussed in the following section.

Additional CT-CRE code measures, such as improvements to the building's thermal envelope, were found to have a minimal impact on electricity consumption, resulting in less than a 1 percent change in annual consumption. The thermal improvements may reduce the energy consumption of the fossil-based heating system, but calculating onsite fossil fuel consumption was beyond the scope of the preliminary assessment process.

Cost Preliminary Impact Assessment Results

Backup Power

Table 2 details the economic assumptions used to assess the cost impact of implementing the backup power system requirements of the CT-CRE code.

Table 2: Economic assumptions for backup power system cost impact assessment.

Discount rate		6%
Electric utility cost escalation		3%
Operation & maintenance (O&M) escalation		2%
Solar	Installed cost	$3.29/W
	O&M	$995/year
Energy storage	Installed cost	$1,416/kWh
	O&M	$3,984/year

System cost

Based on these assumptions, the total backup power system cost to install a 46-kW solar system and 60-kW / 246-kWh battery storage system was calculated to be $503,796. Over a 20-year operating period, operation and maintenance (O&M) expenses would total $120,007. Additional replacement costs of $71,821 would be necessary to replace the solar inverter in year 16 and the battery inverter and modules in year 12.

Savings and incentives

Incentives and bill savings were calculated over a 20-year period to determine the system's net cash flow, internal rate of return (IRR), and net present value (NPV). System costs, incentives, and savings are detailed in **Table 3**.

Investment Tax Credit

The most significant upfront incentive for the system is the federal investment tax credit (ITC). The ITC covers at least 30 percent of the installed cost of solar and energy storage systems under 1 megawatt in capacity, or for larger systems that satisfy certain prevailing wage and apprenticeship requirements. Nonprofit entities, like many affordable housing providers, can receive the ITC through a payment mechanism known as Direct Pay. The ITC incentive for the mid-rise apartment building's backup power system is $149,500.

Residential Renewable Energy Solutions

The State of Connecticut offers a solar program for residential and multifamily housing customers served by the utilities Eversource and UI. Multifamily housing properties with more than four units are eligible to participate in the Residential Renewable Energy

Solutions (RRES) program through a Buy-All compensation mechanism that requires the solar system to be installed on the utility side of the building's electricity meter, known as a front-of-the meter system. The utility purchases all solar energy produced by the system and compensates the participating building owner at a set rate. Because the solar system is not behind the building's electricity meter, it does not directly impact building electricity consumption.

Multifamily properties participating in the RRES program receive a set tariff rate of $0.3195/kWh for all energy generated by the solar system. Properties that provide housing to households that have incomes at or below 60 percent of the State Median Income are eligible for an additional adder of $0.055/kWh, increasing the total incentive to $0.3745/kWh. RRES for multifamily affordable housing stipulates that a portion of this economic benefit must be shared with residents. Individually metered sites, where each unit pays a separate utility bill for their electricity use, must share 20 percent of the tariff directly with tenants in the form via an on-bill monetary credit of their utility bills. Master metered sites, where the housing provider pays for electric utility expenses, are required to invest the net present value of 25 percent of the RRES tariff on eligible upgrades. Energy storage systems are an eligible building upgrade investment.

Participation in RRES results in a total economic benefit of $417,546 for the mid-rise building over 20 years. For the individually metered building, this revenue is split between the building owner, who receives $334,037, and tenants, who receive $83,509. The tenant benefit translates into an electric utility bill reduction of $2,784 per unit, or about $12 in savings per month over 20 years. For the master metered building, 25 percent of the RRES NPV is $60,435, which was applied to the upfront cost of the battery system.

Energy Storage Solutions

Connecticut also offers an energy storage incentive program, called Energy Storage Solutions (ESS). ESS provides an upfront incentive for participating battery storage systems and a performance-based incentive to compensate battery owners for discharging their system when called on by the utility to help manage periods of high energy demand. Rates for the performance-based incentive are $200/kW discharged during the summer during the first five years of program participation (dropping to $115/kW for the next five years) and $25/kW discharged during the winter (dropping to $15/kW in years six through ten). The assessment assumes that the battery system participates in 90 percent of potential discharge events. The combined upfront incentive and performance-based incentives for the battery system total $205,728.

Electric Utility Bill Savings

To determine electric utility bill impacts, it was assumed that the property is within the Eversource Connecticut service territory. Commercial bill impacts are based on the utility's Rate 30: Small General Electric Service tariff. Residential bill impacts were calculated based on both the Rate 1: Residential Electric Service and Rate 7: Residential Time-of-Day Electric Service tariff.

Because the solar system is configured as a front-of-the meter system and building efficiency measures resulted in minimal impacts on electricity consumption, the battery system is the only component of the CT-CRE code that has a significant direct impact on the building's electric utility bills. While the battery increases electricity consumption due to parasitic load, it can be operated to discharge during times of higher onsite electricity demand to decrease demand-related utility charges, which can represent a large portion of monthly electric utility bills for commercial customers, including multifamily housing properties. The master metered building has a much higher potential for demand charge savings because the electricity demands of both common areas and residential units are included in the same commercial account. By decreasing demand-related expenses by about $7,000 per year, the master metered building can achieve a net utility bill reduction of $69,239 over 20 years. The individually metered building, which can only lower demand charges by about $900 annually, experiences a net increase of $80,119 in electric utility expenses over the same period because the demand savings are not high enough to offset additional electricity consumption charges resulting from the battery system.

Building owner financial return

Table 3 summarizes the economic impact of the CT-CRE code backup power system on the building owner. For the master metered building, the backup power system was found to have a net cash flow of $146,347, representing a 5.9 percent IRR and marginally negative NPV of -$900 over 20 years. The individually metered building has a net cash flow of negative $86,520, representing a -6.8 percent IRR and 20-year NPV of -$123,400. The difference between financial outcomes for the buildings can be attributed to the ability of the master metered property to apply the tenet-benefiting portion of RRES to the cost of the battery system and to realize much higher annual demand charge savings.

Table 3: Summary of the economic impact of the CT-CRE code backup power measures for master metered and individually metered buildings.

	Master metered	Individually metered
System cost		
Installed cost	$503,796	
O&M expenses	$120,007	
Replacement expenses	$71,821	
Total cost	**$695,624**	
Savings and incentives		
30% federal ITC	$149,459	
Utility bill savings	$69,239	-$80,119
RRES program	$417,546	$334,037
ESS program	$205,728	
Total revenue	**$841,972**	**$609,105**
Financial return		
Net cash flow	**$146,347**	**-$86,520**
IRR	**5.9%**	**-6.8%**
NPV (6%, 20-year)	**-$900**	**-$123,400**

Passive Survivability

Because the code's passive survivability measures are highly building-specific, the preliminary impact assessments did not directly quantify their cost impact. **Tables 4-7** include a high-level overview of estimated implementation cost impacts for each passive survivability measure in the CT-CRE code.

Enhanced envelope

The CT CRE Code uses passive house (Phius) levels of performance as a framework for structure of the enhanced envelope measures. While passive house levels of envelope performance do add a cost premium, they also reduce building loads and consequently reduce the capacity of heating and cooling systems, potentially reducing the cost of those systems. **Table 4** includes estimated cost impacts for the code's enhanced envelope measures.

Table 4: Overview of estimated cost impacts for the CT-CRE code enhanced envelope measures.

Code Component	Requirement	Cost impact
Enhanced insulation	Increased R-values / decreased U-values in envelope table	Incremental cost of $0.80 / square-foot (SF) in Climate Zone (CZ) 5 for premium insulation. A 2024 review of case studies of Phius buildings showed a range of 1.4% - 4.1% incremental cost

		premium over standard code-minimum construction.[1]
Enhanced glazing systems	Reduced U-values, optimized SHGC, likely triple pane windows	A 2023 study prepared for the Northwest Energy Efficiency Alliance (NEEA) evaluated manufacturing two window upgrade scenarios using Energy Star v6 windows as a baseline.[2] • High performance double pane, achieving U-0.22 saw incremental cost of $1.80 - $2.05 per square foot of window area • Triple-glazed unit saw increment cost of $1.75-$2.10 This study reflects only the manufacturing cost increase. Triple-glazed windows may have a slight increase in installation cost as well, due to their being heavier.
Thermal bridging mitigation	Thermal bridging mitigation envelope design	The 2021 International Energy Conservation Code (IECC) has limited provisions for thermal bridging, merely noting in the R402.1.5 Total UA alternative requirement that US calculations shall include thermal bridging effects of framing materials. The thermal bridging requirements introduced in the CT-CRE code are comparable to those provided in Passive House and introduced in the 2024 IECC Commercial chapter C402.7. While upfront costs of the thermal bridge mitigation code measures were found to be in the range of $1.33/SF in a Washington State code proposal analysis, many of the measures are simple design changes and design details and do not have any cost premium.[3] The requirements for cantilevered concrete balconies were the item that added cost premium of $1.33/SF.
Reduced air leakage	Reduced infiltration air leakage targets	A 2008 paper for American Council for an Energy-Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings found incremental construction costs associated with reducing air leakage from 6.72 ACH 50 to 2 ACH 50 are $0.60/ft2.[4]

[1] "How Much Do Phius Buildings Cost?," Passive House Institute U.S., February 2024, https://www.phius.org/sites/default/files/2024-02/Phius%20Multifamily%20Cost%20Data.pdf.
[2] Steve Selkowitz, "Study of High-Performance Windows Incremental Manufacturing Cost," Northwest Energy Efficiency Alliance, 2023, https://neea.org/resources/study-of-high-performance-windows-incremental-manufacturing-cost.
[3] Duane Jonlin, "State of Washington State Building Code Council," July 16, 2021, https://sbcc.wa.gov/sites/default/files/2021-07/159_TAG%20Rev_C402_2_8_C402_2_9_thermal%20bridging_071621_0.pdf.
[4] Betty M. Tolkin, et al., "How Much More Does It Cost to Build an EnergyStar Home? Incremental Cost Estimation Process," ACEEE Summer Study on Energy Efficiency in Buildings, Vols. 2-339, p. 10, 2008, https://www.aceee.org/files/proceedings/2008/data/papers/2_346.pdf.

		This only covers construction costs, there may be additional costs incurred for testing and verification requirements. Whole building blower door test costs vary depending on the size of the building, but for the mid-rise prototype cost would be in the $3,000-$5,000 range.

Urban heat island mitigation

The urban heat island requirements that NBI has recommended for the CT-CRE code draws on language from NBI's Extreme Heat and Urban Heat Island Code Overlay.[5] Considering the significant cost of extreme heat to cities at the scale of millions of dollars annually – including but not limited to increased cooling costs, lost worker productivity, and added health care costs – building codes that mitigate the urban heat island effect are a valuable tool for cities. In practical terms, these code measures increase the solar reflectance of materials and require shading of building and site surfaces, which contributes to lower local air temperatures. Considerations for pervious surfaces are also included, as the recharging of groundwater reduces surface temperatures while also reducing detrimental stormwater runoff.

The recommended code language for extreme urban heat focuses on increasing building and site solar reflectance; increasing building and site shading, primarily through vegetation; and increasing site water permeability, primarily through permeable pavements and pavers. **Table 5** includes estimated cost impacts for the code's urban heat island mitigation measures.

Table 5: Overview of estimated cost impacts for the CT-CRE code urban heat island mitigation measures.

Code Component	Requirement	Cost impacts
Vegetation		
Existing trees/vegetation	Height of 20 feet above grade	None; existing vegetation must be protected during construction.
New trees/vegetation	Height of 20 feet above grade	Average $400 per medium tree, including labor/installation costs.[6] [7]
Building and site solar reflectance index (SRI) at least one or any combination of the following		
SRI of walls, roofs, and material	Minimum SRI of 29	Little to no added costs to use materials with colors that meet the SRI requirement.

[5] "Extreme Heat and Urban Heat Island Code Overlay," New Buildings Institute, 2024, https://newbuildings.org/resource/extreme-heat-and-urban-heat-island-code-overlay/.
[6] Lauren Bongard, "How Much Does It Cost to Plant a Tree?," Angi, October 21, 2024, https://www.angi.com/articles/how-much-do-trees-cost.htm (accessed January 13, 2025).
[7] Sarah Noel, "How much do landscapers charge to plant shrubs, flowers, and bushes?," HomeGuide, February 23, 2024, https://homeguide.com/costs/landscaping-installation-cost (accessed January 13, 2025).

SRI of site hardscape	Minimum SRI of 29	Little to no added costs for surfaces that are already light in color. For example, concrete without added color pigment typically meets the SRI requirement. For dark colored surfaces, approximately $0.04 per square foot per year for high-SRI pavement coatings that last 7 years on average.
Underground parking	Parking under building	On average, over 4x more expensive than surface parking ($42.5k vs $10k per parking space)[8] [9]
Site hardscape permeability		
Permeable pavement	Percolation rate not less than 2 gal/min • ft^2	Installation up to 50% more expensive than conventional pavements ($12-28/square foot), but concrete and asphalt generally have higher maintenance and replacement costs.[10] [11] Permeable pavement mixes demonstrate significant lifecycle cost savings, primarily reduced maintenance and stormwater treatment costs, compared to impervious pavements.[12] [13] Can also reduce cold-weather snow and ice management costs.[14]
Permeable pavers	Percolation rate not less than 2 gal/min • ft^2	Installation up to 20% more expensive than conventional pavers ($22-34/square foot). Similar lifecycle cost savings as permeable pavements.
Example: Void-structured	Percolation rate not less than 2 gal/min • ft^2	Installation up to 30% more expensive than traditional concrete pavement.[15] Similar lifecycle cost savings as permeable pavements, with

[8] "Cost Of Building A Parking Garage," August 19, 2024, https://dcplm.com/blog/cost-of-building-a-parking-garage/ (accessed January 13, 2025).

[9] "This vs. that: underground parking versus at-grade parking," DBS Group, February 12, 2021, https://www.dbsg.com/blog/surface-parking-vs-underground-parking/ (accessed January 13, 2025).

[10] "Permeable Pavement Fact Sheet," The Chesapeake Bay Trust, March 9, 2022, https://cbtrust.org/wp-content/uploads/Fact-Sheet-and-Guidelines_Permeable-Pavement_030922.pdf.

[11] "Maintenance and Costs of Green Infrastructure," Rutgers Cooperative Extension Water Resources Program, June 2017, http://water.rutgers.edu/Presentations-FixingFlooding/PM_TractA_MaintenanceConstructionCosts.pdf.

[12] Talal Rehan, Yan Qi, and Anne Werner, "Life-Cycle Cost Analysis for Traditional and Permeable Pavements," National Concrete Pavement Technology Center, March 1, 2018, https://www.cptechcenter.org/ncc-projects/life-cycle-cost-analysis-for-traditional-and-permeable-pavements/.

[13] "Novant Cotswold Medical Building," Belgard Commercial, July 13, 2023, https://www.belgardcommercial.com/case-studies/novant-cotswold-medical-building/ (accessed January 13, 2025).

[14] "Green Infrastructure benefits of permeable pavement," Minnesota Pollution Control Agency, February 16, 2023, https://stormwater.pca.state.mn.us/index.php?title=Green_Infrastructure_benefits_of_permeable_pavement (accessed January 13, 2025).

[15] "Grasscrete," Sustainable Paving Systems, 2019, https://www.sustainablepavingsystems.com/products/grasscrete/ (accessed January 13, 2025).

concrete ("Grasscrete")		some of the greatest cost savings coming from the durability of void-structured concrete.

HVAC specialized controls

The CT-CRE code requires balanced energy and heat recovery ventilation, as well as advanced controls to operate HVAC systems according to different schedules and setpoints during a grid outage event. **Table 6** includes estimated cost impacts for the code's HVAC specialized control measures.

Table 6: Overview of estimated cost impacts for the CT-CRE code HVAC specialized control measures.

Code Component	Requirement	Cost impacts
Automatic temperature setbacks in the event of a failure of the primary power	Capable of achieving temperature setbacks to 60°F for heating and 82°F for cooling	Mandatory automatic temperature setbacks would only be activated in the event of a failure of the primary power and would not be expected to save energy in typical operation. A 2011 report on Upgradeable Setback Thermostats for the California Building Energy Efficiency Standards found the incremental cost to be $68.36.[16] With inflation this would be $95.88 in 2024 dollars. Assuming (1) thermostat per dwelling unit or thermal zone, this cost would be $95.88 per unit / thermal zone.
System airflow controls in the event of a failure of the primary power	Capable of adjusting airflows to 50% of minimum required design airflow	$200 - $450 per damper actuator, on average.[17]
Balanced heat/energy recovery ventilation	Required balanced heat/energy recovery ventilation (HRV/ERV).	$1,200 - $1,500 per dwelling unit (If using distributed /unitary systems).[18]
Flood preparedness	HVAC systems located a minimum of 2-feet above	Little to no added cost. This requires appropriate siting of resilient systems outlined in the code.

[16] California Utilities Statewide Codes and Standards Team, "Codes and Standards Enhancement Initiative (CASE) Upgradeable Setback Thermostats," California Public Utilities Commission, 2011.
[17] "Honeywell Damper Actuators For Sale," Blackhawk Supply, https://blackhawksupply.com/collections/controls-damper-actuators/honeywell?srsltid=AfmBOoogsAcHlQw2YHgalcJb9rIUUrMuNaBgX4SjrdPh7TcNFEyr0OZA&sort_by=best-selling (accessed January 13, 2025).
[18] V. Robert Salcido, et al., "National Cost Effectiveness of the Residential Provisions of the 2021 IECC," Pacific Northwest National Laboratory, June 2021, https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf.

	the FEMA 500-year base flood elevation	

Emergency management and building operations procedures

The CT-CRE code emergency management and building operations procedures requirements stipulate that project design teams provide an operations and management manual to building owners for use by building operations staff and residents during a grid-outage event. The intent of this requirement is so that key personnel understand how the building systems will perform during an outage, how to optimize energy use and building system operation to maximize the energy capacity of the emergency power system, and where key services in the building like potable water, electric power, and refrigeration for medicine can be accessed. The code will provide a template to guide the development and provision of this manual, and it is anticipated to be a marginal soft cost add wrapped into the design and construction team process. **Table 7** includes estimated cost impacts for the code's emergency management and building operations procedures.

Table 7: Overview of estimated cost impacts for the CT-CRE code emergency management and building operations procedures.

Code Component	Requirement	Impacts
Building Operations Manual	Provide an emergency management and operations manual for use by building owners and operators in the event of a grid outage.	Marginal soft cost wrapped into design, ~$500 - $1,500
Resident Operations Manual	Provide an emergency management and operations manual for use by residents and operators in the event of a grid outage.	Marginal soft cost wrapped into design, ~ $500 - $1,500

Societal and Health Benefits

In addition to economic benefits, installing solar and battery storage results in societal and health benefits by offsetting emissions from dirtier sources of energy and by improving health outcomes for residents during power outages. While the value of these benefits can be challenging to monetize, they can be reflected in the value of incentives provided to encourage increased clean energy adoption.

The preliminary cost impact assessment process considered three value streams: social cost of greenhouse gases, improved air quality, and improved health outcomes for affordable housing residents.

Social cost of greenhouse gases

The social cost of greenhouse gases metric is designed to represent the total future societal damage caused by emitted greenhouse gases, or to quantify the total future benefit of avoided emissions. The Environmental Protection Agency (EPA) calculates current and future social costs for three primary greenhouse gases: carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O).[19] To quantify the benefits of avoided emissions, these values can be applied to the average greenhouse gas emission intensity of the electric grid.

NBI used a tool that combines EPA's 2023 eGrid data with information from the National Renewable Energy Laboratory's 2024 Standard Scenario report to determine the emission intensity Connecticut's electric grid.[20] [21] Based on this information, it was calculated that annual generation from the 46-kW solar system would avoid 14.8 metric tons of CO2, 192 pounds of CH4, and 0.13 pounds of N2O each year. As shown in **Table 8**, this would result in a total societal benefit of $3,384 each year and $67,689 over a 20-year period.

Public health

Offsetting fossil fuel power generation with onsite solar energy can also reduce the emission of air pollutants, improving local and regional air quality. NBI used EPA's Co-Benefits Risk Assessment Health Impacts Screening Mapping Tool (COBRA) to quantify and evaluate the public health impact of decreased criteria pollutants associated with avoided fossil fuel combustion.[22] COBRA evaluates the air quality, human health, and health-related economic benefits from reductions in emissions of particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds. As shown in **Table 8**, air pollutants avoided due to solar system generation would result in annual health benefits ranging from $870 to $1,200 for communities in Connecticut and neighboring states, with an average benefit of $1,035 per year and $20,700 over a 20-year period. These health benefits are primarily attributable to decreased mortality, reduced asthma symptoms and cases, and fewer days of missed school due to illness.

---

[19] "Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances," U.S. Environmental Protection Agency, November 2013, https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf.

[20] "Emissions & Generation Resource Integrated Database (eGRID)," U.S. Environmental Protection Agency, https://www.epa.gov/egrid (accessed January 13, 2025).

[21] "Standard Scenarios 2024," National Renewable Energy Laboratory, https://scenarioviewer.nrel.gov/?project=5573be35-16d1-4bc3-8c4d-38529c7bb640&mode=download&layout=Default (accessed January 13, 2025).

[22] "Co-Benefits Risk Assessment Health Impacts Screening Mapping Tool (COBRA)," U.S. Environmental Protection Agency, https://www.epa.gov/cobra (accessed January 13, 2025).

Table 8: Summary of societal and public health benefits resulting from the solar system modeled for a mid-rise apartment building implementing the CT-CRE code.

Avoided emissions benefit		Annual	20-years
Social cost	CO2	$3,141	$62,812
	CH4	$238	$4,768
	N2O	$5	$109
	Total	***$3,384***	***$67,689***
Public health	Low	$870	$17,400
	High	$1,200	$24,000
	Average	***$1,035***	***$20,700***
Total benefit		**$4,419**	**$88,389**

Resident health

The CT-CRE code is designed to help ensure that affordable housing residents can more safely shelter in place during a power outage. The measures included in the code aim to increase the length of time that a multifamily affordable housing building can remain habitable by improving thermal efficiency and powering critical, in some cases lifesaving, services so that residents can avoid the negative health outcomes associated with exposure to extreme temperatures and loss of access to health care services, such as electricity-dependent medical devices.

Quantifying the value of improved resident health resulting from CT-CRE code implementation is beyond the scope of this preliminary impact analysis. However, the cost of emergency department visits, which typically spike during outage events, particularly outages coinciding with extreme weather, can serve as a starting point to estimate the potential value of avoided negative health impacts. Based on data provided by the Connecticut Office of Health Strategy, the cost of a commercially insured emergency department visit ranges from $300 for a low-level emergency to $1,700 for a patient with complex health concerns, with a median cost of $968 per visit.[23] If, for example, providing access to power outlets for charging medical devices during at least the first 24-hours of a grid outage would prevent an average of three emergency departments visits per year for the modeled mid-rise apartment building, then the avoided health benefits would amount to $2,904 per year and $58,080 over a 20-year period. While this methodology serves as a useful frame of reference for quantifying the resident health benefit of the CT-CRE code, it

[23] Data provided from the State of Connecticut All-Payer Claims Database for calendar year 2023, see https://portal.ct.gov/ohs/programs-and-initiatives/all-payer-claims-database?language=en_US.

fails to capture the many non-emergency health benefits that could result from improved living conditions during outages.