Emerging resilience frameworks; leveraging the benefits of resilience measures for codes and utility programs

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ABSTRACT

Over the past decade energy autonomy, habitability during grid outages, and general reliability of building services have emerged as a growing area of focus for developers, designers, policymakers, and program administrators. Codes and standards, policies, and federal, state, and utility programs focused on resilience in buildings and grid reliability can help bring consistency and scale to best practice approaches to these emerging policy priorities. Such resilience frameworks can provide guidance for appropriate implementation based on local and regional needs and account for regional grid constraints. Barriers exist in the crafting and implementation of resilience frameworks, including how the multiple benefit streams of resilience are evaluated, and in turn applied to technically and economically justify the incremental first costs associated with resilient building design and construction methods. This paper will discuss existing approaches to incorporating resilience considerations into energy codes, standards, policies, and utility programs. The paper will draw upon metrics that apply to hazard categories (in this case extreme heat, extreme cold, and grid reliability) and discuss how these applied metrics can be a tool for evaluating, and economically and technically justifying resilience to different stakeholders to aid in decision making. Lastly the paper will discuss these metrics in context of two case studies: a utility program with the Energy Trust of Oregon, and the Draft Connecticut Climate Resilient Energy Code.

INTRODUCTION

“Resilience” means different things depending on who you ask, often varying based upon their profession or field of study, and in what context the term is being applied. In this paper, the concept of resilience in the built environment is to be understood as the ability or capacity for buildings and infrastructure and their users or occupants, to withstand, respond to, and recover from different forms of acute and chronic stressors, shocks, and disruptions; a definition that draws from and is largely consistent with a broad body of industry research into resilience in buildings and the built environment (Hassler and Kohler 2014) (Castano-Rosa, et al. 2022) (National Research Council 2012).

When discussing resilience in buildings and the built environment, we are describing both an economic and a life-safety issue. World Economic Forum (WEF) and US National Oceanic and Atmospheric Association (NOAA) place the top line values (in US dollars) at $4.3T in global direct costs over the past 50 years, with $2.9T in the United States alone over that

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period, including 6 of the top 10 most expensive events (World Economic Forum 2023) (National Oceanic and Atmospheric Administration 2025). While these numbers are staggering, they are also undercounting the full costs associated with climate disasters and disruption as they do not consider indirect costs such as healthcare, natural asset damage and degradation, the value of loss of life, or supply chain impacts. These disasters resulted in 568 direct or indirect fatalities in the United States, and nearly 2 million globally (National Oceanic and Atmospheric Administration 2025) (World Economic Forum 2023).

Resilience has been at the heart of building design and construction regulation for some time; with the 2006 International Building Code (IBC) intent stating "The purpose of this code is to establish the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations". Indeed, the I-Codes are successful in mitigating damage and disruption resulting from environmental hazards; as a 2020 study released by the Federal Emergency Management Agency (FEMA 2020) found that adoption of the International Building Codes resulted in Average Annualized Losses Avoided (AALA) of $1.6B (Federal Emergency Management Agency 2020).

The FEMA report compared damage to I-Code buildings with pre-I-Code buildings in the major hazard categories of flood, hurricane wind, and seismic activity, and while it retroactively demonstrated that building codes and regulations improve outcomes for damage risk, reliability, and habitability of buildings – it remains challenging to compare and economically and technically justify the initial increased first costs associated with resilient design and construction practices and measures. This is especially true for lower priority hazard categories, including extreme heat and cold, that have historically resulted in lower property damage costs. Additionally, their health-related impacts on occupants are more difficult to track and monetize due to data limitations. Therefore, the added benefits of increased building efficiency and other mitigation strategies for improving thermal stability, comfort, and habitability are not tracked in the FEMA report and similar studies (MMC 2018). Working towards Resilience valuation

The increase and rising costs of disaster events brings attention to the deeper vulnerabilities between buildings and the electric grid for occupants and communities. Building improvements affecting energy consumption can reduce annual energy costs while also addressing resilience concerns. Historically, investment decision-makers consider annual energy cost savings, first costs, and measure lifetime when determining the cost effectiveness of building performance improvements. The increasing importance of the resilience full benefits proffered by these improvements are not captured through this traditional approach. For example, efficiency measures that increase building thermal stability can increase the period of time that occupants can safely shelter in place in the event of a grid disruption. To better account for these benefits, in 2019 the U.S. DOE reached out to its national research laboratories seeking research proposals for expanding methods to address this analysis gap. The scope of work requested focused on the development of a standardized, repeatable calculation methodology to quantify the resilience benefits of energy efficiency and demand flexibility.

A tri-laboratory team, comprised of research staff from Pacific Northwest National Laboratory (PNNL), the National Renewable Energy Laboratory (NREL), and Lawrence Berkeley National Laboratory (LBNL), commenced the awarded work in 2021. Their efforts resulted in the development and demonstration of a procedure for quantifying the effects of building performance improvements on habitability, health, and cost effectiveness. The comprehensive effort is presented in the final report, *Enhancing Resilience in Buildings through Energy Efficiency* (Franconi et al. 2023), and several related publications (Reiner et al. 2022, Sheng et al. 2023, Franconi et al. 2024a, Franconi et al 2024b). The published work outlines a basic workflow and methods that account for hazard risk, exposure of occupants and assets to extreme temperature events, damage assessment, and monetization of value streams. Specifically, the applied analysis determines the added value of efficiency investment by evaluating the impact of energy code adoption1 on building thermal stability during a power outage concurrent with extreme heat and cold, incurred occupant and property damage, annual operational energy use, greenhouse gas emissions, and the associated monetary benefits and costs. The study reveals that in nearly every situation, improving passive efficiency in residential buildings to meet or exceed current energy code saves lives during extreme temperature

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[1] At the time of the analysis, current published code refers to the IECC-2021 for residential buildings and ASHRAE Standard 90.1-2019 for commercial buildings. The beyond code requirements are based on the Passive House Institute U.S. Standard 2021.

events. Installing passive measures in existing single-family buildings to meet code requirements extends habitability by as much as 120% during extreme cold and by up to 140% during extreme heat. Installing passive measures in new single-family buildings to meet or beat current code is cost effective for the locations investigated. While the developed methodology lays the foundation for a standardized cost effectiveness analysis that includes resilience benefits, the authors note that due to current limited availability of needed supporting data, completing the monetization calculations for resilience benefits can be challenging. Yet related impact metrics, including those that quantify the benefit of measures to reduce occupant exposure and increase habitability can be readily determined using building simulation analysis.

NREL proposed a similar assessment process in evaluating the resilience benefits of power systems; "Evaluating a resilience investment requires quantifying, valuing, and monetizing its impact on system resilience" (NREL 2022). For example, as power systems of the future are being planned on military bases or campuses, integrating the value of resilience into investment and operation decisions is critical. The authors concede that doing so can be challenging "due to the context-specific and diffuse nature of benefits, the difficulty of obtaining the data required to accurately determine the benefits associated with a given investment and the lack of universally accepted resilience metrics and analysis approaches." Ongoing work focuses on understanding the value of lost load across customers and regions, impacts on services beyond building energy systems (such as water and telecommunications), and the monetization of impacts related to health, safety, and the economy.

Despite the many valuable findings from the research to date, the work has not coalesced into a standardized methodology for resilience measure valuation that can be widely applied. However, it is still possible for state and local governments and other stakeholders to use the DOE Labs' research and methods for resilience design decision making.

Identifying metrics for evaluating resilience is often a process that project teams, policymakers, and utility program designers go through as they develop a project, policy, or program. This process differs based on stakeholder interests, population vulnerability, location, and risk tolerance, which affects the identified metrics perceived to be aligned with their specific priorities. To address resilience planning needs, the collection of metrics must apply to dominant natural hazards, include the value of lost load, speak to societal benefits, and appeal to a broader range of stakeholders. Identifying these cross-cutting metrics for specific hazard categories and prioritizing their use in project, code, and program design can lead to better stacking of benefit streams, which will further improve as efforts to assign financial or social value to these metrics advance.

This paper looks to highlight how identifying metrics that cut across benefit streams can demonstrate value to multiple stakeholders and aid decision making in favor of resilience; specifically, it will examine how metrics that communicate benefits between extreme heat, extreme cold, and grid reliability are used in a resilience code and a utility program. In both cases there is a primary resilience objective and consideration of the other resilience benefits are secondary. The identification, measurement, and communication of the additional benefits is used as a tool for communicating to a broader range of stakeholders to justify and advance resilience in building design and construction.

METRICS FOR EXTREME HEAT, EXTREME COLD, AND GRID RELIABILITY:

Metrics for thermal resilience and habitability at the building level have been introduced and explored in several research papers in recent years (Franconi 2023) (Bianchi S 2025) (Adhikari, et al. 2025). While the metrics are typically identified by and rooted in their indication of performance for a specific hazard category (e.g. heat), many also communicate performance and benefits to additional hazard categories. Metrics for thermal resilience were primarily pulled from the Tri-Lab study methodology, but the foundations for those metrics drew from LEED Pilot Credits for resilient design first introduced in 2015 and refined and re-released in 2018 in collaboration and alignment with the RELi standards credits (United States Green Building Council 2019). This work established Standard Effective Temperature (SET) and SET degree hours as a standardized method of tracking low and high temperatures deviation from a "safe" base temperature over a period and identified 216 SET degree hours as a safety threshold.

Thermal resilience is especially transferable to grid reliability, as strategies that reduce heating and cooling loads and demand also relieve stress on utility grids during normal and peak operation. The transferability of benefits is more pronounced when considerations and provisions for emergency power are provided, as these emergency power systems can further reduce building base and peak load on the grid, or can serve as dispatchable resources to help alleviate peak demand for utility operators. While the same might not be true in reverse – that strategies for grid reliability are typically good for thermal resilience – many strategies that alleviate grid stresses at the building level result in efficiency improvements to the building envelope or system performances which can reduce base and peak demand. Dispatchable resources that can help flatten grid load profiles and shave peaks can also be used to pre-heat or pre-cool buildings ahead of planned or expected outages, or can provide emergency power to critical services in the event of grid outages. Metrics for building-grid integration for grid reliability were taken from the New Building Institutes GridOptimal Initiative (Miller and Carbonnier 2020).

This paper selects several metrics for thermal resilience and grid reliability to evaluate benefits across the two hazard categories, which can be found in Table 1. The paper will discuss the use of these metrics in the context of two case studies: a resilience code framework and a utility incentive program framework.

Table 1. Thermal Resilience and Grid Reliability Metrics

Metric	Primary Hazard Category	Description	Citation/Source
Heating SET Degree Hours	Thermal Resilience and Habitability	Degree hours below the base temperature threshold over a period	(Franconi 2023) (United States Green Building Council 2019)
Cooling SET Degree Hours	Thermal Resilience and Habitability	Degree hours above the base temperature threshold over a period	(Franconi 2023) (United States Green Building Council 2019)
Days of Safety (days to exceed 216°F/102°C SET dh)	Thermal Resilience and Habitability	Days before 216 SET degree hours are exceeded during a simulated no- or low-power operating condition	(Franconi 2023) (United States Green Building Council 2019)
Cooling energy consumption (kWh/SF)	Thermal Resilience and Habitability and Grid Reliability	An indicator of emergency power requirements to maintain habitable conditions, and magnitude of building peak load for heating and cooling	
Heating energy consumption (kWh/SF)	Thermal Resilience and Habitability and Grid Reliability	An indicator of emergency power requirements to maintain habitable conditions, and magnitude of building peak load for heating and cooling	
Grid Peak Contribution	Grid Reliability	Degree to which building demand contributes to load on the grid during system peak hours	(Miller and Carbonnier 2020)
Onsite Renewable Utilization	Grid Reliability	Building's consumption of renewable energy generated onsite (not exporting to the grid) over a year	(Miller and Carbonnier 2020)
Dispatchable Flexibility	Grid Reliability	Building's ability to automatically reduce demand (shed) for 15 minutes, controlled by utility/third party	(Miller and Carbonnier 2020)
Peak to Average Grid Ratio	Grid Reliability	Ratio of a buildings peak load to average load, an indication of how flat their use profile is	(Miller and Carbonnier 2020)

CASE STUDY: CT-CRE CODE DESIGN

The Draft Connecticut Climate Resilient Energy Code (CT-CRE) was published on March 19, 2025 as a voluntary code intended to provide a design and construction framework for the installation of resilient energy systems to power critical services during grid outages in Connecticut (Clean Energy Group 2025). The code establishes provisions for high-performance passive design – following approaches for climate adapted passive design laid out by organizations such as Passive House Institute (PHI) and Passive House Institute U.S. (Phius) – in addition to requirements for heating, cooling, ventilation, electrical power, lighting, and refrigeration equipment in certain portions of the building to be powered with emergency power. The code additionally outlines minimum sizing criteria for the emergency power systems to serve the connected loads for a 24-hour duration throughout a loss of primary power during a heat or cold event. The code allows compliance by providing emergency power to these critical systems in portions of dwelling units (a bedroom or the primary living space), or in common areas of the building with enough space for all the building occupants. The intent of the two compliance pathways is to allow flexibility in how projects comply depending on site specifics, including accommodations for buildings with vulnerable and mobility-impaired residents where it may be difficult to relocate occupants to a central location.

CT-CRE Analysis Methodology

The CT-CRE was compared against ASHRAE 90.1-2019 baseline buildings according to the metrics previously identified in two scenarios. One scenario looked at the U.S. Department of Energy Prototype buildings that are used for the purpose of designing, testing, and evaluating energy codes in the United States (U.S. Department of Energy 2024). The second scenario looked at real world multifamily building designs.

To evaluate the effectiveness of the CRE code, a preliminary impact assessment was conducted through a joint effort by Clean Energy Group (CEG), American Microgrid Solutions (AMS), the New Buildings Institute (NBI), and the Pacific Northwest National Laboratory (PNNL) (Clean Energy Group 2025). The preliminary evaluation involved two phases: first, developing energy models following the current adopted code (ASHRAE 90.1-2019, the Baseline Code) and the CT-CRE Code (Proposed Code), and second, comparing the energy use and end-use load profiles during two operating scenarios: full power and backup power during grid outage.

The baseline code & proposed CT-CRE code measures were input into multi-family buildings from DOE's prototype models for mid-rise, high-rise, and low-rise with typical weather and low-probability temperature event data for two airports, Brainard (cooler & rural) and Bradley (warmer & urban), characterizing dominant climate zone from CT, CZ5A, using EnergyPlus building simulation engine. The results from Brainard are referenced further in this paper. The code impact assessment considers several factors, including hazard risk identification, exposure analysis (to evaluate the impacts of improved building energy efficiency and occupant exposure during power outages under extreme temperature conditions), vulnerability assessment (to estimate the effects of extreme heat and cold on occupant health, well-being, and potential damages), and mitigation valuation (to quantify resilience metrics, monetary resilience benefits, hazard probability, and traditional efficiency benefits and costs such as annual energy savings and initial measure costs). This paper presents the results of the exposure analysis, and performance according to the GridOptimal metrics.

The CT-CRE code was then evaluated in real world building designs (Design Case) following a similar methodology, with the ASHRAE 90.1-2019 (Baseline Code) and the CT-CRE (Proposed Code). The real-world design used in this comparison is a 109,000 square foot 4-story midrise affordable housing building with a range of units, from studios to 3-bedroom apartments. The building is divided into three wings, and each wing is served by a central heat recovery ventilation unit with localized split system heat pumps providing space conditioning. Compared to the 90.1 2019 Baseline, the CT-CRE design featured improved envelope performance, including significantly reduced infiltration, and more effective heat recovery, but all other parameters were modeled identically between the two cases. For both the DOE Prototype and Design Case exercises, GridOptimal metrics were tested under normal operating conditions while battery-sizing exercises were conducted in a setback condition, with reduced lighting and equipment loads and partially curtailed HVAC operations. Thermal resilience was evaluated by modeling total outage scenarios in which all building systems shut down for a week during extreme summer and winter weather events. The GridOptimal metrics were calculated using the CT-CRE guidelines for both PV and battery sizing which resulted in significant improvements compared to the 90.1 Baseline with no PV or battery systems.

The results for the DOE Prototype analysis for the Thermal Resilience and Habitability metrics and GridOptimal and Grid Reliability metrics can be found in Table 2 and Table 4 respectively. The results for the Design analysis for the Thermal Resilience and Habitability metrics and GridOptimal and Grid Reliability metrics can be found in Table 3 and Table 5 respectively. The thermal values presented in Table 2 and Table 3 are averaged over all residential units. In both cases, the simulation demonstrated reduced heating SET degree hours, extended heating days of safety, and reduced heating energy intensity throughout a grid outage during a cold event. While the DOE prototype models showed a increase in cooling SET degree hours and reduction in cooling days of safety, the Design Case showed improvements. Both simulations demonstrated improvements in three out of four GridOptimal Grid Reliability metrics. The slight increase in the one metric - peak to average grid ratio - illustrates how duck curve generation dynamics of solar reduce average grid demand but don't necessarily reduce the peak demand. While this simulation analysis assumed storage capacity was retained for a grid outage event and did not explore storage being used to reduce grid peaks, it is reasonable to assume that in a real-world operation scenario building operators could use the storage to reduce grid peaks and reduce the peak to average grid ratio.

Table 2. DOE Prototype Thermal Resilience and Habitability Metric Results

Metric	DOE Midrise Prototype (ASHRAE 90.1-2019)	DOE Midrise Proposed (CT-CRE)
Heating SET Degree Hours (Base 54°F / 12°C)	592 / 311	155 / 68
Days of Safety Heating (Days to Exceed 216°F / 102°C SET dh)	3.9	7+
Typical Annual Heating Energy Consumption (kWh/SF)	2.79	1.18
Cooling SET Degree Hours (base 86F / 30°C)	155 / 68	271 / 133
Days of Safety Cooling (days to exceed 216°F / 102°C SET dh)	7	6.4
Typical Annual Cooling Energy Consumption (kWh)	0.76	0.87

Table 3. Design Case Thermal Resilience and Habitability Metric Results

Metric	Design Case (ASHRAE 90.1-2019)	Design Case (CT-CRE)
Heating SET Degree hours (base 54°F / 12°C)	560 / 311	0 / 0
Days of Safety Heating (days to exceed 216°F / 102°C SET dh)	5.0	7+
Typical Annual Heating Energy Consumption (kWh/SF)	1.25	0.15
Cooling SET Degree Hours (base 86F / 30°C)	0 / 0	0 / 0
Days of Safety Cooling (days to exceed 216°F / 102°C SET dh)	7+	7+
Typical Annual Cooling Energy Consumption (kWh/SF)	0.92	0.75

Table. 4 DOE Prototype GridOptimal Grid Reliability Metric Results

Metric	DOE Midrise Prototype (ASHRAE 90.1-2019)	DOE Midrise Prototype (CT-CRE)
Grid Peak Contribution	32	41
Onsite Renewable Utilization	0	16
Dispatchable Flexibility	0	85
Peak to Average Grid Ratio	2.0	2.2

Table 5. Design Case GridOptimal Grid Reliability Metric Results

Metric	Design Case (ASHRAE 90.1-2019)	Design Case (CT-CRE)
Grid Peak Contribution	50	73
Onsite Renewable Utilization	0	24
Dispatchable Flexibility	0	99
Peak to Average Grid Ratio	2.7	2.9

CASE STUDY: UTILITY PROGRAM APPLICATION

For decades, voluntary utility energy efficiency programs have complemented energy codes by providing financial incentives to encourage project teams to exceed code-minimum energy efficiency performance. In most cases, program goals are defined by law or regulation in terms of energy savings, and programs are usually precluded from directly incentivizing non-energy benefits - such as resilience. However, some leading utility programs are exploring ways to help their participants achieve resilience alongside energy efficiency. One such example is the Energy Trust of Oregon's Future Ready Buildings offers through the New Buildings program (Energy Trust of Oregon 2025).

Energy Trust programs operate under a legislative mandate to improve energy efficiency and renewables - not resilience. This means the program cannot post incentives for resilience strategies per se. However, the program team supports resilience when it also has efficiency or renewables benefits. The New Buildings program provides free technical assistance to project teams, including support for design services such as BEM. Members of the New Buildings program implementation team, including some authors of this paper, have begun to incorporate some resilience metrics into Future Ready Buildings technical assistance offerings and to discuss the topic with project teams enrolled in the New Buildings program. In effect, the goal is to help program participants evaluate design options more holistically by quantitatively evaluating and considering the value of resilience alongside that of energy efficiency. The program aims to encourage participants to select design options that both save energy and improve resilience by presenting resilience metrics alongside efficiency metrics to inform participants of the more holistic suite of benefits. Relevant resilience metrics being considered for this program include:

- Summer passive survivability: number of hours/days that indoor conditions will remain within expanded comfort targets during the hottest week with no grid-delivered electricity (e.g., a heat wave event)
- Winter passive survivability: number of hours/days that indoor conditions will remain within expanded comfort targets during the coldest week with no grid-delivered electricity (e.g., a winter storm event)
- Days of safety (similar to metrics in Tables 2 and 3)
- % SH safe, high-risk, and fatal hours (similar to metrics in Tables 2 and 3)
- Peak to average ratio
- Demand Flexibility

The goal of the Future Ready Buildings offers is to support project teams to evaluate these metrics across multiple potential design scenarios using BEM. Each project's model is customized to the specific project design goals, but with program guidelines the models will use consistent definitions of strategies and modeled measures (as much as is feasible). The implementation team then discusses resilience outcomes with program participants as a benefit to be considered alongside energy efficiency. Other non-energy benefits are also discussed as relevant, such as maintenance savings, improved productivity, occupant health and safety, environmental impacts, etc. While program incentives are paid solely based on energy savings, some Future Ready Buildings participants have found that this robust consideration of multiple value streams helps them make more informed decisions: decisions that deliver energy savings alongside resilience.

DISCUSSION ON RESULTS AND NEXT STEPS FOR RESILIENT CODE AND PROGRAM DESIGN

The two case studies provide examples of how resilience considerations can be integrated into code and program design and development processes. In both cases, considerations for an additional hazard or benefit category were used to facilitate monetization of benefits, garner broader stakeholder buy in, or to aid decision-making.

Both the DOE prototype and real-world design studies showed a significant improvement in passive thermal performance during extreme cold events when comparing the CT-CRE standards to a 90.1 2019 Baseline. In the CT-CRE Design Case, even the coldest units remained above the 54°F SET temperature for almost the entire weeklong outage period. During extreme heat events, however, the same envelope improvement measures (like increased insulation, increased air tightness, winter-optimized glazing SHGC) can trap heat inside during cooler nights. The DOE Prototype saw an increase in Cooling SET Degree Hours during the heat event when the CT-CRE Code was applied to the models and caused it to exceed the 216 Cooling SET Degree Hour threshold established in the LEED Pilot Credit. Alternatively, the Design-Case models included operable windows which allowed the spaces to flush with cool night air during the heat event. Under these conditions, both the 90.1 Baseline and CT-CRE models remained below the hazardous SET temperature limit.

Similar trends were observed in annual energy estimates. The improved envelope and significantly reduced infiltration proved particularly impactful in heating season, with both the Prototype and Design cases showing significant reductions in heating energy with the application of the CT-CRE standards. The DOE prototype model did not benefit from operable windows during warmer weather and the CT-CRE envelope improvements trapped heat in the space, increasing cooling energy slightly. In the Design Case, the improved envelope limited heat gain during the day and the operable windows flushed the space at night, reducing total cooling energy. While the Design Case did not show any negative impacts from the winter-optimized envelope, the authors caution that BEM can overestimate the impact of nighttime flush out/passive cooling, due to the well mixed air temperature assumptions in the zones and lack of modeled interstitial spaces. Real-world conditions may not allow for the same level of nighttime flush out that is represented in the results presented.

For the CT-CRE case study, emergency power generation was designed to meet critical loads during a loss of primary power, and the extreme cold event remained the dominant design condition based on loads during the simulated grid outage. Where resilience benefits are being optimized for no-power scenarios, these priorities may need to be evaluated differently to understand the likelihood of outages, the interactions between operable windows and envelope performance in cold versus heat events, and the potential for loss of life under these cold and hot conditions. Both the 90.1 Baseline and CT-CRE design models were able to operate for at least 24 hours in setback conditions with the CT-CRE recommended emergency PV and BESS capacities. Applying the CT-CRE standards did reduce the needed BESS capacity by roughly 50%, significantly extending the potential coverage duration. The CT-CRE Case study used potential revenue and monetization of the battery through a local utility demand response and load management program to justify the first costs of the solar and storage system and demonstrate a positive net present value in the feasibility analysis. Similarly, the GridOptimal metrics assume that the storage systems are being used to the benefit of the utility and are available for participation in their programs, while the Thermal Resilience and Habitability metrics assume that the full storage capacity is available to power critical loads in the event of an outage. In reality, any battery capacity used to reduce peak loads may not be available in the event of an outage.

Identifying performance-based metrics that indicate performance across two or more hazard categories, and identifying where resilient design interventions towards one hazard mitigation goal result in positive improvements for another, can help leverage multiple benefit value streams to facilitate decision making and stakeholder buy-in. These metrics should be included and reported on for project, code, program, and project design to help build a broad body of understanding on the relative impact of resilient design measures and design approaches towards multi-hazard mitigation. Continued work in this space across several hazard categories can help to establish best practices necessary to scale resilient design implementation for buildings and the built environment.

Expanding on the research in the space of resilience valuation and simplifying the valuation methods for performance-based metrics so that code, program, and project implementors can put them to use will allow for benefit stacking to be leveraged to further justify resilience measure investments in buildings. These efforts can help further integrate resilience measures into traditional cost effectiveness analyses for codes and programs.

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