Examine and classify residential buildings with integrated renewable energy systems based on their energy resilience performance under typical and extreme climate conditions in cold climates

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Abstract

The future of buildings and society must focus on resilience. This article introduces a new concept for an energy resilience framework, incorporating a classification system to measure and evaluate the energy resilience of buildings in Nordic climates. The goal is to compare the energy resilience of single-family homes built in the 1970s and 2020s, both equipped with renewable energy sources and storage, to assess their performance in maintaining heating during power outages under typical and extreme weather conditions. The research involves dynamic simulations of the buildings and their renewable energy systems, conducting parametric analyses to derive resilience indicators, which are then used to evaluate the buildings' performance with both passive and active energy strategies. An economic assessment is also carried out by calculating the total costs associated with the design variables. To account for the challenges posed by climate change, the study uses a simplified approach to model regional climate variations, considering the potential impacts of extreme weather on energy resilience. For the older building without photovoltaic (PV) panels, the duration of resilience increased from 1 to 3 hours, and the degree of disruption (DoD) shifted from 0.545 to 0.3 between extreme cold and warmer climate conditions, with higher DoD values indicating poorer performance. Seasonal variations also impacted resilience, with longer durations of habitability and robustness in spring compared to winter. Incorporating PV and battery storage improved resilience. The new building exhibited an increase in robustness from 3 to 15 hours, along with longer habitability periods. The DoD ranged from 0.496 to 0.22 in extreme cold to warm climates without renewable energy systems, showing improved performance. When PV and battery storage were added, the new building achieved better performance with lower DoP values and required less PV and battery capacity than the old building. Additionally, the color grading system (ranging from red to green) was used to identify and classify optimal technical solutions and design variables for each building type and climate scenario, aiding in decision-making. The total costs of these optimal solutions varied, with new buildings requiring lower investment for optimal performance. However, the cost of achieving optimal resilience during extreme cold weather was higher for both building types. The proposed resilience framework, indicators, classification, and cost evaluation can guide improvements in building regulations, ensuring the construction of resilient buildings, particularly in response to extreme climatic conditions.

Reference

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