Politecnico di Torino-Department of Energy (DENERG)

Doctoral Dissertation

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Towards Climate Resilient and Energy Efficient Buildings:

A Comparative Study on Energy Related Components, Adaptation Strategies, and Whole Building Performance

By

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Abstract

Climate change is one of the greatest global challenges of our time, and its impacts have already been studied in a variety of research fields. Given that the building sector accounts for a considerable amount of worldwide energy consumption and it is the primary source of greenhouse gas emissions, its contribution to climate change is evident. Therefore, the crucial role of building energy performance in climate change mitigation is a primary concern of a large and growing body of literature. However, buildings are not merely the cause of climate change. Due to their long lifespans, they are also adversely affected by it in numerous ways, demonstrating the importance of fostering their adaption capacity and climate resilience. Up to now, less attention has been paid to the built environment's climate resilience and adaptation compared to its role in mitigating climate change. In addition, there is far too little research on analysing the Italian building stock toward this issue, and there is a need to perform quantitative analyses, particularly on a regional scale. Accordingly, this research attempts to analyse buildings' energy performance, optimization, and thermal comfort in a changing climate (long-term assessment) within a regional scale for Italian building stock. Several adaptation strategies regarding the building's condition and resilient cooling solutions are studied and comparatively analysed to measure their effect on buildings' energy performance and thermal comfort. To this aim, as a first step, future weather data generation methods are studied considering representative concentration pathway (RCP) 4.5 and 8.5 (W/m^2) scenarios introduced by the fifth assessment report of the Intergovernmental Panel on Climate Change. The reliability of these future weather data is assessed, and a weather data set is created for which the systemic errors and biases are also adjusted. Followingly, a preliminary analysis is carried out to draw a clearer picture of the effects of climate change on the Italian built environment for typical and Nearly Zero Energy Buildings (NZEBs). Advanced solar shading/advanced glazing, cool envelop materials (CEMs), and ventilative cooling are the resilient cooling solutions that have been assessed. The results suggest that, depending on the building's condition, mechanical ventilative cooling and ultra-selective double-glazed windows have the greatest impact on reducing the effects of climate change. It has been discovered the combination of these solutions could help keep the trade-offs of energy efficiency. Finally, a global sensitivity analysis is performed to discover the contribution of variances of parameters regarding specific resilient cooling technologies and building conditions to variances of particular key performance indicators representing energy performance and thermal comfort of buildings. This sensitivity analysis is applied to a representative building in the climate zone of Rome -using the created future weather data- and has been performed for three time periods (2010s, 2050s, and 2090s). In brief, the results demonstrated the changes in the built environment energy performance and thermal comfort pattern. For the Italian residential building stock, the annual thermal energy need for space cooling will dramatically increase (up to 55%) while the annual thermal energy need for space heating will moderately decrease. Moreover, the risk of overheating increases significantly (up to 155%). Accordingly, annual electrical energy consumption (from the grid) for cooling and ventilation rises up to 70%. Such changes are highly dependent on the building typology and its state of refurbishment. It is seen that even the NZEBs do not meet the requirements in the future. In addition, the significant contribution of buildings' condition (level of insulation) and their typology is revealed to foster buildings' climate resilience and adaptation capacity.