Sustainable Retrofits for Affordable Housing: A Comparative Analysis in Mediterranean Contexts

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Abstract Cities account for over 66% of global energy and are major contributors to climate change. Within Positive Energy Districts (PEDs), retrofitting existing buildings is key to reducing operational energy demand. However, embodied environmental impacts of construction materials are frequently overlooked, particularly in affordable housing, where cost constraints are critical. This study evaluates how material selection can balance environmental, technical, and economic criteria to support a more inclusive and sustainable energy transition. A four-step methodology is applied: (1) defining scope and materials for energy retrofitting in Spain, drawing from the portfolio of solutions developed within the POSEIDON project; (2) collecting data on embodied impact, thermal performance, service life, and cost from recognized local sources; (3) compiling a comparative table; and (4) interpreting the results to assess the strengths and limitations of each material, emphasizing their implications for decision-making in affordable housing renovation. The analysis of façade, roof, and window components reveals trade-offs between cost, environmental impact, thermal efficiency, and durability. Among the materials evaluated, insulation types illustrate these trade-offs particularly well. EPS is cost-effective with low thermal conductivity but entails moderate embodied carbon and a high reliance on fossil resources. Mineral wool, though more expensive and emissive, offers better fire resistance, durability, and thermal efficiency at similar or lower thicknesses. Roofing systems show significant GHG variability during installation. Double-glazed windows offer strong thermal performance, though their carbon footprint varies with frame and glazing type. These findings highlight the importance of detailed life cycle data to guide sustainable retrofit strategies. Due to limited data availability, the use (B1–B7) and end-of-life (C1–C4) stages were excluded. Future research should consider these phases to capture the full life cycle impact of retrofit materials. Despite these limitations, the study offers practical recommendations to support more inclusive and informed decisions in energy-efficient renovation, contributing to a socially just and environmentally responsible energy transition.