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Abstract

The transition toward sustainable healthcare infrastructure demands a comprehensive rethinking of building materials and energy systems, particularly in high-performance medical environments. This chapter investigates the strategic integration of green building materials and energy-efficient architectural practices to create low-carbon medical facilities capable of meeting stringent clinical performance and operational demands. The study emphasizes climate-responsive design methodologies, passive environmental strategies, and region-specific adaptation to reduce operational energy loads. It further explores the embodied carbon implications of material selection, highlighting the environmental trade-offs between conventional and sustainable construction materials—especially in flooring systems, insulation, and structural assemblies. Emphasis is placed on the synergistic use of passive design measures and active system controls, supported by advanced energy modeling techniques to optimize system interaction and performance. Special attention is given to indoor air quality, daylighting, and thermal comfort requirements in sensitive zones such as operating theaters, intensive care units, and emergency departments, the chapter evaluates the potential of hybrid passive-active frameworks in improving energy efficiency without compromising the safety and regulatory constraints inherent in healthcare architecture. Region-specific passive design guidelines are presented to ensure adaptability across varied climatic zones. Through comparative analysis, simulation-driven insights, and lifecycle assessment metrics, this chapter offers a holistic design perspective that supports the decarbonization of healthcare facilities. The findings aim to bridge the gap between sustainable design theory and medical infrastructure implementation, aligning healthcare architecture with global environmental goals.

Keywords: low-carbon buildings, passive design, healthcare architecture, embodied carbon, energy modeling, green materials

Introduction

The global healthcare sector, while essential to public well-being, is a significant contributor to environmental degradation due to its high energy consumption, resource-intensive infrastructure, and substantial carbon footprint [1]. Hospitals and medical centers operate continuously, requiring stringent environmental controls, advanced medical technologies, and energy-intensive mechanical systems [2]. These operational characteristics have positioned healthcare facilities among the most energy-demanding public buildings [3]. As climate change intensifies, there is growing urgency to decarbonize healthcare infrastructure by adopting energy-efficient architectural practices and sustainable material strategies [4]. This shift not only aligns with international environmental goals but also enhances resilience, reduces operational costs, and improves indoor environmental quality for patients and healthcare professionals [5].

In response to this challenge, the integration of green building materials has emerged as a foundational approach for reducing the embodied carbon of medical infrastructure [6]. These materials, which include bio-based composites, recycled content products, and low-impact construction technologies, are increasingly being evaluated not only for their environmental performance but also for their compliance with health and safety standards specific to medical environments [7]. The selection of materials in healthcare facilities must satisfy rigorous requirements related to durability, hygiene, fire resistance, and infection control [8]. Therefore, material performance assessments must go beyond thermal or structural properties and include criteria such as low volatile organic compound (VOC) emissions, antimicrobial surfaces, and ease of sterilization [9]. Strategic material choices made during the early stages of design can substantially lower life-cycle emissions and align healthcare architecture with green certification frameworks such as LEED, BREEAM, and WELL [10].