

Role of Solar Photovoltaics in Powering Hospitals and Clinics in Remote and Off-Grid Areas

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Abstract

Reliable and continuous electricity supply is a critical enabler of effective healthcare delivery, particularly in remote and off-grid regions where conventional grid infrastructure is either unavailable or unreliable. The integration of solar photovoltaic (PV) systems into healthcare facilities offers a sustainable and decentralized energy solution capable of powering critical medical services, preserving cold-chain logistics, and supporting digital health infrastructure. This chapter presents a comprehensive examination of solar PV applications in rural and underserved healthcare settings, focusing on system design, hybrid configurations, energy storage integration, and smart energy management. Emphasis is placed on the impact of digital health technologies on power consumption patterns, the role of Internet of Things (IoT) and Artificial Intelligence (AI) in optimizing energy usage, and the design of modular and scalable systems that can adapt to evolving operational needs. Environmental and architectural considerations, including lighting, ventilation, and spatial planning, are analyzed to enhance system performance and usability. Through case studies and performance evaluations, the chapter highlights successful implementations and identifies critical challenges related to financing, technical capacity, and policy alignment. The findings underscore the transformative potential of solar PV in advancing healthcare resilience, energy independence, and equitable access in marginalized regions.

Keywords: Solar Photovoltaic Systems, Off-Grid Healthcare, Energy Resilience, Smart Energy Management, Hybrid Power Systems, Rural Health Infrastructure

Introduction

The availability of dependable electricity is a foundational element for delivering safe, effective, and uninterrupted healthcare services [1]. In remote and off-grid locations, healthcare facilities often suffer from irregular power supply or a complete absence of electrical infrastructure, posing serious risks to patient care and clinical operations [2]. Essential services such as neonatal care, surgical procedures, vaccine refrigeration, and diagnostic testing rely heavily on electricity to function [3]. Traditional alternatives, particularly diesel generators, are frequently used but present numerous limitations including high operational costs, complex maintenance requirements, fuel dependency, and environmental pollution [4]. These challenges severely constrain the capacity of healthcare institutions to function optimally in underserved

settings. To address this gap, renewable energy technologies, particularly solar photovoltaic (PV) systems, are increasingly being adopted as viable and sustainable alternatives. Their decentralized nature and adaptability make them ideal for healthcare applications where grid extension is impractical or economically unfeasible [5].

Solar PV systems offer a modular, scalable, and clean source of electricity that can be customized to meet the varying energy demands of healthcare facilities across different geographic and climatic regions [6]. As the global health sector evolves toward more technologically advanced service delivery, energy demands are concurrently increasing [7]. New medical equipment, digital health platforms, and electronic data management systems introduce additional loads that traditional off-grid solutions cannot adequately support [8]. Solar PV, when paired with energy storage systems and intelligent control mechanisms, provides a high level of energy security that can sustain critical healthcare functions around the clock [9]. The declining cost of PV technology, coupled with improved storage efficiency and smart monitoring tools, has enhanced its feasibility for remote healthcare deployment, solar power contributes to climate mitigation by reducing carbon emissions associated with fossil fuel use, aligning healthcare infrastructure development with global sustainability goals [10].