Green and Sustainable Healthcare Management: A Comprehensive Review of Green Practices, Challenges, and Future Directions

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Abstract

The medical sector, though vital to human health, has a significant environmental impact by utilising high energy, consuming large resources, and producing substantial volumes of waste. This review seeks to find the imperative to make a shift towards green and sustainable healthcare management through examining the environmental footprint of health systems by looking at energy consumption, medical waste, carbon footprint, and water usage. The report identifies important sustainability practices, including energy-efficient building design, biophilic architecture, digital health innovation, and integrated waste and water management systems. Through global case studies and policy models, it highlights the institutional, governmental, and international networking roles to advance green healthcare systems. There has been significant progress so far, yet implementation challenges, including financial resources, regulatory lacunae, and awareness, remain. The review concludes by outlining prospects, driven by technology, policy support, and education, in favour of an inclusive strategy that integrates environmental sustainability into the framework of healthcare systems to enhance public health and global resilience.

Keywords: Biophilic Design, Digital Healthcare, Eco-Friendly Hospitals, Green Healthcare, Green Hospital Design, HVAC Efficiency, Healthcare Carbon Footprint, Greywater Reuse, Sustainable Healthcare

Introduction: Toward Environmentally Sustainable Healthcare Systems

The healthcare industry exerts a significant environmental impact due to its intensive use of resources, substantial waste generation, and associated pollution. To mitigate these impacts, it is imperative to quantify the environmental pressures arising from healthcare activities. Sustainable healthcare refers to the provision of quality, affordable medical care that minimises environmental harm - A priority that has become increasingly urgent in the wake of the global COVID-19 pandemic. While technological advancements, such as rapid diagnostics, remote working, and digital education, played a pivotal role in curbing the virus's spread, they also introduced new challenges. These include the surge in single-use plastics and electronic waste, exacerbating waste management issues and amplifying social and digital disparities. The pandemic led to an unprecedented increase in medical waste, much of which is incinerated, contributing directly to air pollution and greenhouse gas emissions. Delays in the collection and disposal of such waste further heighten health risks for patients, healthcare workers, and local communities. Climate change, air pollution, and improper waste management pose serious threats to both environmental and human health, necessitating a transition toward eco-friendly healthcare systems. Green or sustainable healthcare management integrates environmentally responsible practices into all facets of healthcare, including infrastructure, operations, and policymaking. This includes efforts to reduce carbon emissions, optimise resource use, implement sustainable procurement, and build climate-resilient health systems. The importance of sustainable health is also emphasised by global policy instruments such as the United Nations Sustainable Development Goals (SDGs) - Goal 3 (Good

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Health and Well-being) and Goal 13 (Climate Action). Different governments and institutions have created green hospital programs that focus on minimising waste, energy efficiency, and sustainable infrastructure development (Ababneh *et al.*, 2019).

But beyond these efforts, widespread use of sustainable practices is being held back by cost constraints, unawareness, gaps in regulations, and resistance to operational changes. Among the significant obstacles is the lack of standardised measures to assess the environmental performance of healthcare systems. In order to promote sustainable healthcare, there has to be more integration of environmental objectives, grounded in collective cooperation among policymakers, clinicians, and communities. Developing ecologically sustainable healthcare systems is not a future goal but a current necessity for public and planetary health (Anåker & Elf, 2014; Attrah *et al.*, 2022). Despite extensive global attention on green healthcare, existing studies remain fragmented: many focus on single domains such as waste management or energy conservation, whereas fewer synthesise these practices holistically or compare implementation between high-, middle-, and low-income settings. The literature also shows an imbalance between empirical findings and normative recommendations, with limited data-driven evaluation of sustainability outcomes. This review addresses these gaps by critically examining evidence-based practices, identifying implementation barriers across contexts, and mapping future research and policy priorities.

Review of Literature

Environmental Impact of Healthcare Systems

Environmental Impacts of Health Systems. Health systems are responsible for the general environmental waste and pollution that cause these dangers, but the healthcare workers and facilities are also responsible for the treatment of patients made sick by or hurt due to climate change. This is a serious threat to the healthcare industry. Nearly 5% of the world's greenhouse gas emissions are attributed to the health care system, which would rank it fifth in terms of pollution as if it were a country. Collaborating with those addressing climate change and biodiversity loss concerns to promote environmental raising the level of sustainability in healthcare activity and systems is the first step in minimising countries' carbon footprint. A Energy use in hospitals Hospitals, or referred to as health care buildings, are public buildings which are typically open all day and night. The environment, society, and the economy are affected by having these buildings become energy efficient (Blix & Levay, 2018).

Energy Consumption in Hospitals

Hospitals, also referred to as health care buildings, are public facilities that are typically open twenty-four hours a day. The economy, the environment, and society at large are all impacted by improving these buildings' energy efficiency. Global warming has caught the attention of the globe. The building sector is responsible for around 30 to 40 per cent of the world's energy use and the problems of energy scarcity. The cost of electricity and the amount of CO_2 involved in the generation of electricity through the use of fossil fuels are both impacted by building energy efficiency. The temperatures of the world are rising because of the uncontrolled emission of carbon dioxide into the atmosphere. All over the world, both the developing and industrialised countries are experiencing urban warming, or increasing temperature, observable in densely populated urban cities. In addition to having an impact on agriculture and cattle husbandry, rising global temperatures also result in growing energy needs for the control of the built environment. Also, it damages the general public's health (Borowiak & Krzywonos, 2022; Eckelman & Sherman, 2016).

Medical and General Waste Generation

Medical Waste (MW) is described by the World Health Organisation (WHO) as waste generated by healthcare operations and can include a range of products, such as spent needles and syringes, medical devices, chemicals, radioactive materials, and filthy dressings (Western Health, n.d.). Body parts, blood, and samples for diagnosis. Around the world, countries are struggling to develop the planning and infrastructure required to appropriately dispose of the increasing volume of medical waste caused by the COVID-19 pandemic. Plastic materials accounted for around 35% of medical waste, providing an opportunity for recycling and sustainable resource recovery. To avoid catastrophic infectious waste stockpiling during and after pandemics, all nations must implement environmentally sustainable medical waste management practices (Wijesooriya *et al.*, 2023).

Carbon Emissions from Healthcare Transport and Supply Chains

It is imperative that there be solutions to address Greenhouse Gas (GHG) emissions in the world's health care sector, which accounts for approximately 46% of global emissions (Simpeh *et al.*, 2022). The global dataset shows that countries with higher levels of logistical activity will experience higher healthcare costs owing to higher fuel imports, carbon emissions, and economic activity in relation to logistics (Pradhan. B, 2020). Human releases two significant greenhouse gases, namely carbon dioxide (CO_2) and carbon

monoxide (CO) activity. Worldwide, the majority of carbon emissions result from the transport of products. Commodity transport and production account for about 45% of the greenhouse gas emissions (Fortis Healthcare, n.d.). Hence, we need to confine these emissions within a supply network.

Water Usage and Pollution

Human existence depends on water, which is also a vital resource for the economy and a key component of the climate control cycle (Priyalal, 2015). Though 2.5% of the water on Earth is frozen, less than 3% of it is fresh. Humanity has thus been forced to rely on the remaining 0.5% to meet its freshwater requirements. One of the sectors that needs more water for daily operations is the healthcare sector. To ensure the hospital's long-term water use, water conservation and efficiency measures must be given top priority. Further, the total consumption of water by a hospital is distributed among its departments. Healthcare facilities belong to either a commercial or a public building category. But there are some significant and non-core functions conducted by healthcare centres, and water is utilised in varying amounts for each of those services. Indoor water consumption for drinking, washing, and personal hygiene in all buildings, including healthcare facilities. Kidney dialysis and laboratory water-treatment equipment, vacuum pump equipment, medical air and compressor machinery, sterilisers and central sterilising departments, laboratory hood scrubbers, X-ray machinery and film developers, and therapeutic baths and treatments are only a few of the unique water-utilising activities that are employed within healthcare facilities. Effective and efficient utilisation of water is an excellent requirement for medical facilities, and water management practices have become increasingly important as water is used by large hospitals for many different uses (Rahat N., 2024).

Findings and Discussion

Key Areas of Sustainable Practices

Energy Efficiency and Renewable Integration in Sustainable Building Design

An energy-efficient building provides a pleasant living environment within the building with the minimum amount of energy usage while maximising resource utilisation efficiency. An energy-efficient building maintains the building in a fully working and thermally comfortable state for the inhabitants as well. As the price of energy is rising and the energy crisis is becoming a real situation, the necessity of offering energy-efficient building designs is more urgent. According to energy statistics data acquired for 2017 for India from the Ministry of Statistics and Program Implementation, buildings consume the second-highest amount of energy after industries. An energy-efficient building strikes a balance across all areas of energy consumption in a building by offering a given mix of passive solar design strategies, energy-efficient equipment, and renewable sources of energy (Farghali *et al.*, 2023). One of the common issues is that ongoing growth in the human population demands constantly higher consumption of energy and other natural resources, which wipes out the benefits accrued from resource use efficiency gains and increased renewable energy production. Green alternatives are biomass stoves and boilers, hybrid heat pumps, geothermal heating, solar thermal systems, solar photovoltaic systems, electric boilers, compressed natural gas and hydrogen (Fortis Healthcare, n.d.). Renewable energy resources are the preferred choice to replace fossil fuels in the near future. Comprehensive efforts have been taken to generate renewable energy resources at viable costs at a commercial level, including solar, wind, and biomass energies. It has been achieved through technological developments that utilise renewable energy sources efficiently at lower costs. The proportion of world renewable energy consumption among total energy consumption shows a strong growth trend. This indicates that the world renewable energy industry has a high-speed development momentum and high development potential. It has been widely verified that higher consumption of renewable energy can promote global energy conservation and emission reduction (Giakoumakis G., 2021). Although the different renewable sources of energy have good characteristics, they are largely intermittent and therefore must be combined with other renewable sources of energy as well as/or efficient energy storage systems (Gillis & Gatersleben, 2015). Solar power, either solar thermal or solar PV, has already been utilised in many applications, *e.g.*, residential, desalination, transportation, drying, irrigation, *etc*. To this end, various efforts have been undertaken to account for some of these advances and applications. Concentrated Solar Power (CSP) technologies are among the hopeful technologies to produce both heat and electricity. Extensive investments have been made worldwide in developing these technologies. Through the conversion of the kinetic energy of wind, wind energy can either be directly converted into mechanical power or indirectly into electrical power. Advanced technology nowadays and the evolution of a turbine and its parts have led to significant advances in power, power generation and efficiency. Biomass is one of the most accessible forms of energy, which is efficiently utilised in a variety of applications ranging from traditional combustion to direct application in fuel cells to produce electricity. The transformation of biomass into biofuels like biodiesel and biochar are exciting technology that may be used for numerous uses. Production of biodiesel has

numerous merits, for example, easy transport, increased heating values, and versatile use, *i.e.*, numerous uses such as the use by diesel engines. Though renewable energy sources are sustainable and do not have zero or less negative impacts on the environment around them, the majority, like wind and solar power, generate energy periodically. Thus, renewable energy sources must be combined with energy storage systems (Gupta & Chakraborty, 2021). The high rate of energy consumption can be attributed to the reason that most of the new buildings, from commercial to domestic, have been planned and developed with no consideration for passive architecture and depend greatly on technologies like Heating, Ventilation and Air-Conditioning (HVAC) systems to create a healthy indoor climate. However, it is quite inefficient and costly to use electricity for these purposes. Energy efficiency in thermal comfort services like HVAC systems is of crucial significance because the population of the world spends 80-90% of their time indoors. Demand for the HVAC system is hence significant because, as compared to other stages, this stage is much more extended in duration and comfort levels required for human health and work productivity need to be offered at this stage. believe that since the majority of the human population spends a very high 90% of their time indoors, the creation of energy-efficient HVAC systems would go a long way in saving energy and curbing greenhouse gas emissions. Renewable energy sources over fossil-derived energy sources should be selected to reduce energy use during the building operation phase, thus prioritising the utilisation of renewable energy sources (Healthcare Without Harm, n.d., Joseph *et al.*, 2021, Kaiser Permanente, 2020).

Integrating Biophilic Design into Green Building for Environmental and Human Well-Being

In addition to serving its intended practical purpose, the ideal green building seeks to protect the surrounding natural environment. Assuring appropriate use of land, water, energy, and materials, as well as minimising disturbance to natural ecosystems, are the goals of its design and operation. Green buildings are a crucial tactic to lessen the negative effects that traditional building methods have on the environment, the economy, and society. In addition to using a lot of energy, buildings are a major source of greenhouse gas emissions; by 2035, it is predicted that building-related carbon emissions will total 42.4 billion tons worldwide. Frameworks and green building rating systems that offer quantifiable sustainability criteria serve as guidance for environmentally friendly design. Incorporating biophilic design principles, which are based on the connection between humans and nature, into these technologies has gained popularity recently. Utilising natural patterns and components in constructed spaces to improve human health and well-being is encouraged by biophilic design. Natural elements can lower stress and enhance cognitive function, according to biophilic design theories, which are backed by theories in environmental psychology such as Attention Restoration Theory and Stress Recovery Theory. Decades of data on the beneficial effects of nature on human well-being highlight the promise of biophilic design as a useful element of sustainable architecture, despite the paucity of research on the subject (Kluge *et al.*, 2023).

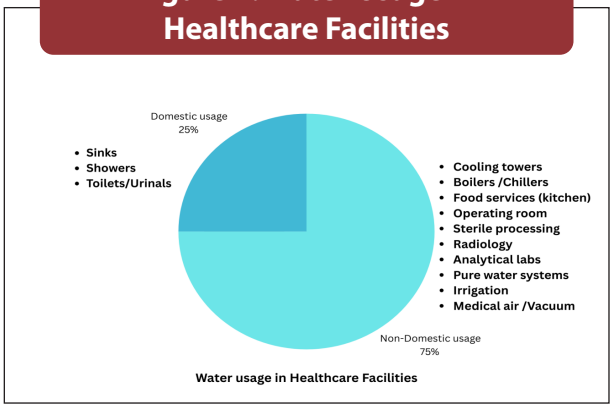
Waste Management: Segregation, Recycling, Minimisation of Medical and Plastic Waste

Typically, high-revenue nations produce as much as 0.5 kg/hospital bed of toxic medical waste. The plastics most commonly used to produce operating room instruments and equipment include Polyvinylchloride (PVC), Polyethene (PE), Polypropylene (PP), Polyurethane (PU), and copolymers. The first three categories can and are being recycled. Waste from medical facilities can be minimised and waste avoided. The minimisation may be tackled from various fronts, including the reduction of waste at source, recycling, and inventory control. Reduction of waste at the source may be through the reuse of materials that will not be injurious to the users, including washable tablecloths, tableware, and cleaning supply refill containers. Recycling can assist in reducing waste by recycling metals, plastics and food waste through composting. Lastly, stock management will establish a systematic arrangement of the medicines stock to avoid duplication and buying of unnecessary items that may go to waste, thereby minimising potential waste. Segregation determines the different categories of waste and how they may be collected separately. Segregation is attained mainly by segregating different MW categories into different coloured bins or bags designated for each category (Komilis & Fouki, 2012). Waste recycling is the utilisation of generated waste or by-products for similar or alternative uses. A vast majority of waste generated by the health care industry is non-hazardous waste that is predominantly sent to landfills. Utilisation of waste dumps and landfills can be minimised through recycling of utilised products like plastics, batteries, paper, glass, metals, and silver utilised during photographic processing. Food waste and organic refuse can be employed for the purposes of composting. Ash from incineration can be utilised after treatment in concrete and as a building material. The thermal energy generated through incineration could be utilised to warm up water for a central heating system. Recycling begins with the identification of materials to be recycled, followed by the process of sorting the materials. Hand sorting is feasible, but the operation is time-consuming. Here, plastics are sorted according to

colour, shape, material type, *etc*. Automated methods of sorting have gained tremendous popularity nowadays. Near Infra-Red (NIR) gives a high speed of identification. This method is effective for transparent plastic. The X-ray fluorescence method, based on the organic nature of the polymer, has been used to separate PVC from PET. Separation methods such as density separation, froth flotation methods involving surfactants, electrostatic separation, air separation, *etc.,* are also utilised. Once sorted, cleaned and collected, the plastic wastes are typically sent to four popular plastic recycling paths: (a) primary recycling, (b) secondary recycling, (c) tertiary recycling and (d) quaternary recycling. Primary recycling: It involves the recycling of plastic waste into a product with similar properties to the original material. Secondary or mechanical recycling is the recovery of plastic waste through the use of mechanical processes. Tertiary recycling or chemical recycling breaks down plastic materials to smaller molecules, typically liquids or gases that are utilised as the feedstock in an operation that produces chemicals and fuels. Quaternary recycling or incineration: This method significantly minimises the volume of waste and consists of energy recovery from waste plastic through incineration. Incineration is the most common treatment process because of its suitability in treating all types of waste. It is mainly applied for the treatment of infectious liquid wastes like blood, urine, faeces, or hospital sewage. The usual chemical disinfectants employed are the bleach solution (1%) or a diluted active chlorine solution (0.5%). The rejects of the above stages are moved to a sanitary landfill for disposal. But landfills are not the best option for the management of MW because of their impact on the environment (Singh. N & Tang.Y, 2022), in figure 1.

The impact includes water and soil pollution from leachate and the release of gases into the atmosphere from the degradation of waste. Therefore, the waste to be disposed of must be reduced to the barest minimum, and that is assured by a circular economy. Short-term decomposition of waste is the secondary process, while long-term decomposition of waste is the main process accounting for waste disposal in landfilling. Precautions need to be undertaken to provide safe MW disposal, which include rapid waste cover, Burial in old municipal waste with a minimum burial of three months, a waterproof base, at least 2 m above the water table, and no chemical disposal (Komilis *et al.*, 2012; Lee SM *et al.,* 1991, Lee D. 2022).

Figure 1: Water Usage in Healthcare Facilities



Water Conservation

Water is an essential commodity for life, economic development, and the sustainability of the environment. India is facing a surging water shortage, particularly in urban zones, since the nation has over 17% of the world's population but only approximately 4% of renewable freshwater resources. The irresponsible and excessive utilisation of water resources exacerbates this deficiency. Hence, it is necessary to develop water management systems that are future-ready to ensure efficient use and sustainability in the long term. At home (drinking, bathing, washing, and cooking), in business (cooling, sanitation), institutions, and the public sector (park irrigation, road maintenance, and firefighting), water is critical. The water demand pattern of a building needs to be considered while planning its water infrastructure, such as pumping systems, reservoir capacities, pipe sizes, and treatment plants. Greywater reuse systems and low-flow fixtures are two innovative water conservation methods that hold much potential for satisfying increasing demand while safeguarding this precious resource. Showerheads, faucets, and toilets with low flow rates are designed to use much less water than conventional systems. Low-flow showerheads and faucets, for instance, can reduce water flow rates by 20–60% without compromising functionality (Adeyeye K., 2020). Through cutting water consumption at homes by 50–75%, these technologies save consumers financially as well as environmentally. In addition, by conserving water and adjusting schedules based on present weather patterns, advanced irrigation methods such as drip irrigation and weather-based controllers optimise outdoor water usage. Greywater reuse is another promising strategy. For toilet flushing and irrigation of landscapes, greywater wastewater from showers, sinks, laundry rooms, and kitchen basins (excluding toilet and food waste) can be treated and reused (Van de Walle. A, 2023). Filtration and biological processes are often employed in treatment methods to remove impurities and ensure that the water is fit for reuse. Greywater recycling system buildings reduce their reliance on fresh water and facilitate a circular water economy. Reusing greywater is a viable and remunerative activity that conserves natural resources and enhances drought resilience. Yet for the systems to be successfully implemented, there needs to be incentives to developers and families to

adopt greywater technologies, favourable regulatory environments, and public consciousness. To develop viable water infrastructure in cities, it is crucial to back these systems (Sayed *et al.*, 2023; Shi *et al.*, 2021).

Digitalisation in Healthcare: Enhancing Efficiency and Environmental Sustainability

In the healthcare industry, digitalisation has become a disruptive force that is changing the way services are managed, accessed, and provided. And offered. Both the scale of digitisation and interest in its potential applications have increased immensely in the healthcare sector. There are many health-oriented applications on contemporary smartphones that enable users to store and interpret health information, control chronic ailments such as diabetes and heart ailments, track wellness, and communicate with health experts remotely. The quick evolution of computer programs, artificial intelligence tools, and advanced hardware such as surgical robots and assistive technology, such as automated hygiene systems for the elderly and others with physical disabilities, has been made possible by this growing digital infrastructure. The expectations of the public regarding healthcare accessibility have also shifted due to digital tools. Patients are insisting that healthcare interactions should be as convenient as in other sectors, with round-the-clock access through easy-to-use digital platforms. The use of Electronic Health Records (EHRs) across large sections of the population has been among the greatest technological breakthroughs. Since they don't involve large volumes of paper records and X-ray films, these systems have reduced healthcare's environmental footprint immensely. As an illustration, an extensive-scale EHR system covering 87 million individuals reduced about three million gallons of gasoline a year by replacing 68 tons of x-ray film and 1,000 tons of paper documents. It cut down considerably on patient travel. The transition to digital systems does involve additional energy use, however, from data centres and home computers, which could contribute to additional electrical waste. Reports show that EHRs have a net positive environmental impact despite this. In addition, telemedicine platforms have increased sustainability through reduced in-person visit requirements, which reduces emissions from transportation. Overall, the digital transformation of healthcare not only enhances data management and service delivery but also contributes significantly to environmental sustainability (Sijm-Eeken *et al.,* 2023).

Case Studies and Global Initiatives

Healthcare organisations are embracing green practices in energy use, waste management, water conservation, transportation, procurement, and infrastructure within the aim of sustainable healthcare administration, whose objective is to minimise environmental effects while maintaining quality patient care. These initiatives are aligned with the urgency of addressing climate change and global sustainability goals. Kaiser Permanente went carbon neutral in the US in 2020 through sustainable purchasing practices, green building practices, and renewable energy use (Wilderer, 2004). Similarly, waste and energy efficiency are among the top concerns of the Cleveland Clinic. With its commitment towards becoming carbon neutral by 2040 by using electric ambulances, low-carbon clinical processes, and green supply chains, the United Kingdom's National Health Service (NHS) is leading the way globally (Yang *et al.*, 2022). Sweden and Germany are world-famous for their sustainability techniques, such as Karolinska University Hospital's green roofs and geothermal energy utilisation, as well as their energy-efficient hospital designs.

India's top private hospitals, such as Apollo and Fortis, are employing green building techniques, such as water harvesting and solar power (Zaman *et al.*, 2022). Implementation on a large scale is still difficult. Australia actively lowers the environmental impact of healthcare with programs like Western Health, which use digital resource tracking, solar electricity, and green catering (Zhao *et al*., 2022; Kaiser permanente, 2020), Table 1.

With an emphasis on catastrophe resistance and the integration of renewable energy, Canada and Japan make investments in energy-smart and climate-resilient hospitals. The case of Cleveland Clinic Abu Dhabi represents how countries within the Middle East region, such as Saudi Arabia and the United Arab Emirates, are incorporating sustainability into their health systems. The World Health Organisation (WHO) is fostering climate-resilient health systems through policy environments and technical support (Miao *et al.*, 2024), and networks such as Global Green and Healthy Hospitals (GGHH) and Health Care Without Harm (HCWH) support organisations globally to adopt sustainable practices (Zurl *et al.*, 2025). These global efforts reflect a growing commitment to aligning healthcare service with public health and environmental stewardship goals.

Barriers and Challenges

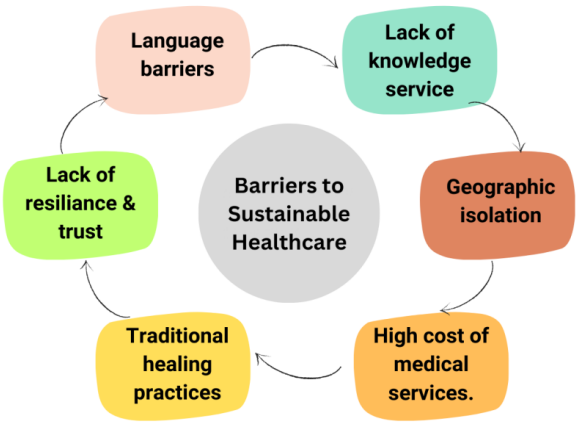
In order to achieve long-term public health objectives and lessen the healthcare sector's environmental impact, green and sustainable healthcare practices must be adopted. However, moving toward sustainability presents major challenges for healthcare organisations worldwide, especially in low- and middle-income nations. The lack of funds is one of the biggest obstacles. A significant upfront investment is needed to build renewable energy sources, retrofit hospitals

Table 1: Case Studies of Sustainable Hospitals Globally

Country	Institution	Key Initiative	Outcome
USA	Kaiser Permanente	Carbon neutrality	Zero emissions since 2020
UK	NHS	Net Zero NHS 2040	Electric ambulances, low-carbon care
Germany	Karolinska (Sweden)	Geothermal/green roofing	Reduced cooling loads
India	Apollo Hospitals	Solar + rainwater harvesting	Lower utility dependence
Australia	Western Health	Solar + digital resource tracking	Lower energy footprint

with energy-efficient systems, and adopt sustainable waste management. Even while these adjustments result in long-term cost savings, many institutions—particularly public hospitals with limited funding—remain put off by the initial capital expenditure. Insufficient knowledge and instruction among medical practitioners. There is a general lack of involvement with green efforts because many administrators and clinical staff are not formally educated or exposed to environmental sustainability concepts. Implementing and maintaining sustainable practices in the day-to-day operations of healthcare facilities can be challenging. Gaps in regulations and policies also obstruct development. Environmental requirements for healthcare facilities are either inadequate or not adequately implemented in many nations. This includes lax laws governing energy efficiency, hospital waste management, and procurement practices (Aldogiher & Halim, 2025). Due to this, sustainability programs remain fragmented and do not have the institutional backing needed for systemic change. Environmental goals are often secondary to clinical effectiveness and patient care outcomes in numerous healthcare systems. Sustainability is typically viewed as a secondary matter in stressful healthcare environments. Resistance to change on the part of employees also exists, as they might feel that green programs would only add to their workload without generating any tangible benefits (Shin *et al.*, 2025). Lack of reliable data and performance indicators is a significant barrier. Advanced techniques and data infrastructure are required in order to track the environmental performance of healthcare facilities, yet they are often unavailable, particularly in developing countries. It is difficult to track progress, set targets, and demonstrate the return on investment for sustainability projects because of the unavailability of data. Access to cutting-edge green technologies, like renewable energy sources or high-efficiency HVAC systems, is frequently hampered by technological constraints, such as availability, cost, or the technical know-how needed for installation and upkeep. Coordinated tactics at several levels are needed to overcome these obstacles. The shift towards sustainable healthcare must be accelerated through policy changes, more funding, training, education, and the creation of evaluation tools.

Figure 2: Barriers to Sustainable Healthcare Implementation



Barriers to Sustainable Helthcare Implementation.

The commitment to mainstreaming sustainability into the very core of healthcare systems worldwide must increase alongside the world's acknowledgement of interdependence in climate change and public health in figure 2, (Quttainah M. A. & Singh P., 2024).

Opportunities and Future Directions

Apart from the environmental and health advantages, shifting to green and sustainable healthcare also offers structural and cost advantages. Healthcare organisations all over the world have an important responsibility in reducing their environmental footprint as climate change further impacts public health. Global regulatory norms, new technologies and changing public expectations will all contribute significantly towards future healthcare sustainability and facilitate mainstream uptake. Innovation in technology carries one of the highest promises. Physical infrastructure requirements and energy use can be minimised via the convergence of digital health solutions like electronic health records, telemedicine, and intelligent energy

management systems. Additionally, hospitals can switch to solar, wind, or geothermal power sources, particularly in energy-intensive environments, as renewable energy technologies become more available and inexpensive. Two other powerful drivers are policy support and foreign assistance. Foreigners' policies that provide strategic guidance to other countries to incorporate environmental sustainability into healthcare planning encompass the World Health Organisation's Operational Framework for Climate-Resilient Health Systems. In addition, networks like Global Green and Healthy Hospitals (GGHH) enable the sharing of best practices and expertise in every healthcare organisation worldwide (Zhao *et al.*, 2022). The economic returns of sustainable healthcare are only gradually being appreciated. Long-term savings realised from minimised waste, energy conservation, and streamlined supply chains can dramatically reduce operating costs, in spite of high initial costs (Shin *et al.*, 2025). Green building rating tools such as LEED and IGBC also provide blueprints to guide the construction of ecologically friendly and financially viable infrastructure. Additionally, rising consumer demand for green healthcare is driving the industry toward sustainable practices. Healthcare institutions are increasingly under pressure from patients and local communities to demonstrate environmental responsibility, and integrating sustainability into Corporate Social Responsibility (CSR) programs can improve hospital reputation and patient trust. (Shaban et al., 2024). Leadership education and development will be essential in the future. Tomorrow's professionals will be able to drive sustainable change if medical, nursing, and healthcare management courses reflect environmental influences. At the same time, organisational leadership's dedication to sustainability will guarantee that green initiatives are incorporated into strategic decision-making. Climate change resilience is also a significant opportunity. Sustainable design, such as flood-proofing, energy independence, and climate-resilient infrastructure, could assist in enhancing the preparedness and reliability of health systems as the occurrence of unusual weather occurrences and health crises rises.

Conclusion

Growing environmental consciousness, legislative efforts, and the healthcare industry's dedication to lessening its ecological imprint are all contributing to the steady global acceptance of green and sustainable healthcare practices. This change is not without difficulties, though. Large-scale implementation is nevertheless hampered, especially in low- and middle-income nations, by a lack of funding, a lack of knowledge and training among medical professionals, lax enforcement of regulations, and technological restrictions. Notwithstanding these obstacles, there are encouraging prospects for the future. A solid basis for change is provided by developments in digital health technologies, growing legislative backing, public demand for environmentally friendly treatment, and the incorporation of sustainability into leadership development and education. In order to guarantee robust, effective, and ecologically conscious health services for future generations, sustainability must be ingrained into healthcare systems holistically—through governance, funding, infrastructure, and culture.

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