

Critical Analysis of Sustainable Healthcare Practices, Green Technologies, And Climate-Health Intersections

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Abstract

Healthcare practices and the earth's climate are already recognized as major areas of concern in today's healthcare systems. As the interest grows in how climate change impacts health, the worst thing is that anything that keeps going wrong is because of expansion in the healthcare industry and its negative environmental contribution. This review critically discusses sustainable health care, the adoption of green solutions in the facility, and the relationship between climate change and health. Analyzing the current literature and relevant case studies, this review aims to understand how healthcare organizations can minimize environmental impacts, enhance energy efficiency, and minimize waste. Also, it examines the effects of these practice of practices on health, cost, and sustainability of the health processes. This paper's findings suggest promising strategies that may help HSs address and overcome climate change complications.

Keywords: *Sustainable healthcare; green technologies; climate-health intersection; environmental sustainability; healthcare systems; renewable energy; waste reduction; climate change; public health; healthcare innovation.*

Introduction

Climate change is among the most severe threats to human health in the twenty-first century's progressing world. Climate change poses threats to public health as respiratory diseases, heat-related ailments, diseases borne by vectors, and the worsening of chronic diseases are likely to increase due to increased cases of global warming and incidences of extreme weather conditions (Thomson & Stanberry, 2020; Mohammad et al., 2024a; Mohammad et al., 2023a; Mohammad et al, 2024b). To address these challenges, healthcare systems around the world are required to deal with these new emergent diseases, and at the same time, there is an increasing concern regarding the sustainability of healthcare organizations. The healthcare industry consumes a large percentage of carbon and resources and discharges a high percentage of waste globally. As a result, Di Napoli et al. (2020) says that there is increasing awareness of the necessity to implement health-promoting approaches in the pursuit of effectiveness in managing the impacts above and as a possible way of enhancing overall health for humans.

This paper critically analyzes sustainable health care, with special reference to green technologies and climate change and health. This study aims to understand how the operation of healthcare systems can be associated with recycling efforts, environment conservation, and health problem-solving arising from climate change.

LITERATURE REVIEW

Sustainable Healthcare Practices: Definition and Importance

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Al-Surf (2020) describes sustainable healthcare as the practice of preventing harm and improving care for patients without using resources harmfully. This encompasses healthcare facilities with energy efficiency, reduction and efficient use of healthcare waste, resource-efficient management of supplies, and the support of low-carbon medical technologies. In 2018, WHO called for health systems' transitions to proactively implement climate-resilient measures and pursue lower carbon effect health sectors since climate change poses more and more dire threats to health.

According to Alvarado et al. (2020), various studies show that when healthcare organizations adopt green technologies such as renewable energy, energy-efficient buildings and structures, and sustainable healthcare waste management, they foster improvements in their total organizational costs and exhibit improved environmental performance. These technologies are all linked with improved patient status in the long run, as well as a decrease in waste and an increase in the health of the community.

Green Technologies in Healthcare

Green technologies can be defined as any advancement in technology that makes it possible for healthcare organizations to function as environmentally sustainable entities. Such technologies include:

- Renewable energy, such as solar, wind, and geothermal, is used in power production.
- Energy-sustaining medical equipment, among others.
- Environmentally friendly building structures.

Healing institutions that have embraced environmentally friendly technologies applicable in hospitals and healthcare facilities mentioned that they have benefited from cutting their energy usage and thus minimizing their emissions of greenhouse gases.

For instance, Al-Rawi et al. (2020) showed that hospitals that implemented solar panels as part of their striking energy sources cut down CO₂ emissions by 25%, helping to decrease the healthcare industry's emissions. In the same way, the adoption of efficient energy lighting, HVAC, and water-saving fixtures in health facilities has been known to cut energy costs and reduce footprint.

Climate Change and Public Health Intersections

There are direct and indirect links between climate change and health. Temperature increase, seasonal variation, and natural disasters that impend cause respiratory diseases, heat injuries, vector-borne diseases like malaria and dengue, and psychological disorders (Caminade et al., 2018; Mohammad et al., 2023b; Al-Hawary et al., 2020; Al-Husban et al., 2023). For example, the Lancet Commission, in its latest report in 2021, predicted that climate change will increase the number of people with diseases such as asthma, cardiovascular diseases, heat stroke, and other diseases.

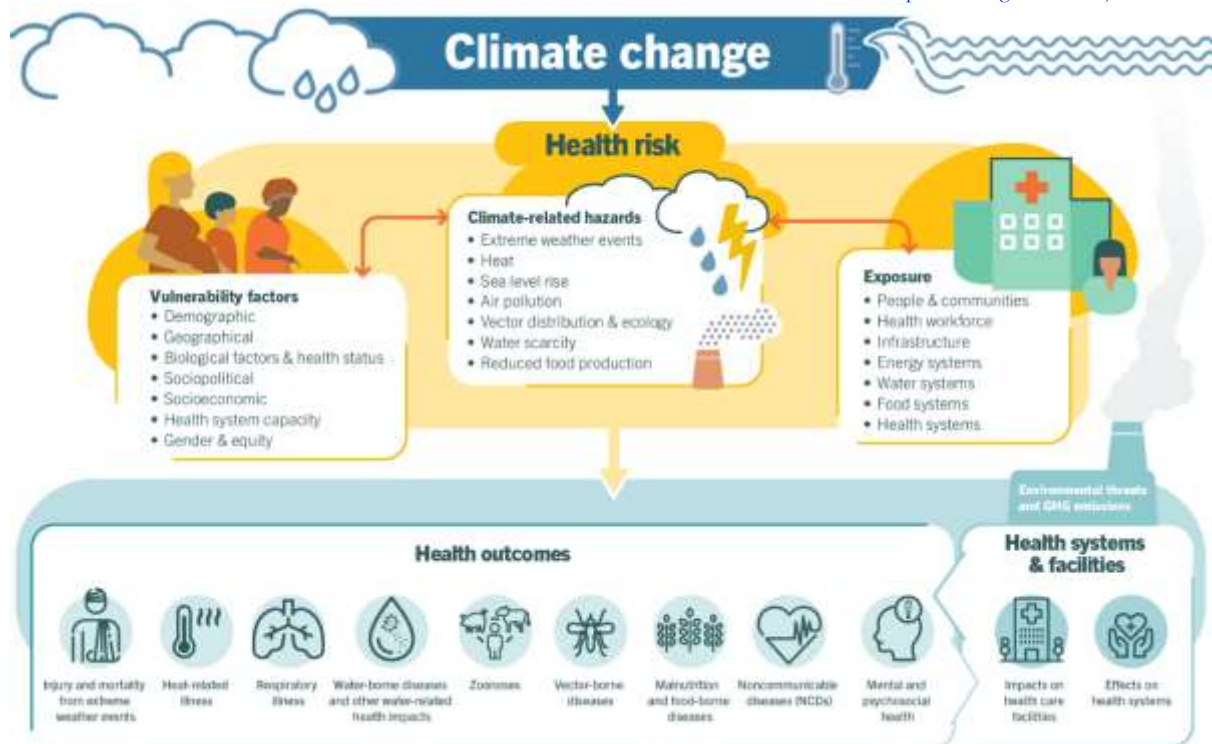


Figure 1: An overview of climate-sensitive health risks, their exposure pathways and vulnerability factors. Climate change impacts health both directly and indirectly, and is strongly mediated by environmental, social and public health determinants.

Image source: (World Health Organization: WHO, 2020)

In addition, by affecting sectors such as agriculture and increasing the occurrence of diseases, climate change has a negative impact on vulnerable populations such as the poor, children, and the elderly. Climate change affects these groups' health status and quality of life in the following ways: These groups are vulnerable to the diseases caused by climate change because they have chronic diseases, restricted healthcare use, and fewer resources to manage climatic stress (Climate Change and the Health of Socially Vulnerable People | US EPA, 2024).

Healthcare systems must, therefore, manage these climate-induced health challenges while decreasing healthcare's eco-stress. Green integrated technologies, proper waste management, and caring about climatically durable healthcare buildings are the key answers to these challenges.

METHODS

This study uses a systematic review approach with qualitative emphasis to evaluate sustainable healthcare practices, green technology, and the climate change-health relationship. Data were collected from academic journals, government publications, and publications from international organizations that deal with climate change, sustainable health care, and health consequences.

The literature was retrieved from scientific databases such as PubMed, Scopus & Google Scholar. The inclusion criteria for the studies were: These inclusion criteria included: (1) publication that has been published between 2015 and 2024; (2) that focuses on either healthcare sustainability, green technologies in the health sector, or effects of climate change on health; (3) either empirical study or systematic review from both developed and developing countries.

RESULTS AND FINDINGS

This review concludes that green technology is crucial in sustainable health systems, as demonstrated by operational costs, efficiency, and a positive environmental footprint. The findings show that by adopting renewable energy, energy-efficient medical equipment, green building design, and utilization of waste-to-energy systems, it is possible not only for the environmental impact of healthcare delivery to be minimized but also for gains in cost synergism and optimized performance. These results stress that healthcare organizations could play a significant and twofold role in environmental and economic sustainability by financing and implementing eco-efficiency technologies.

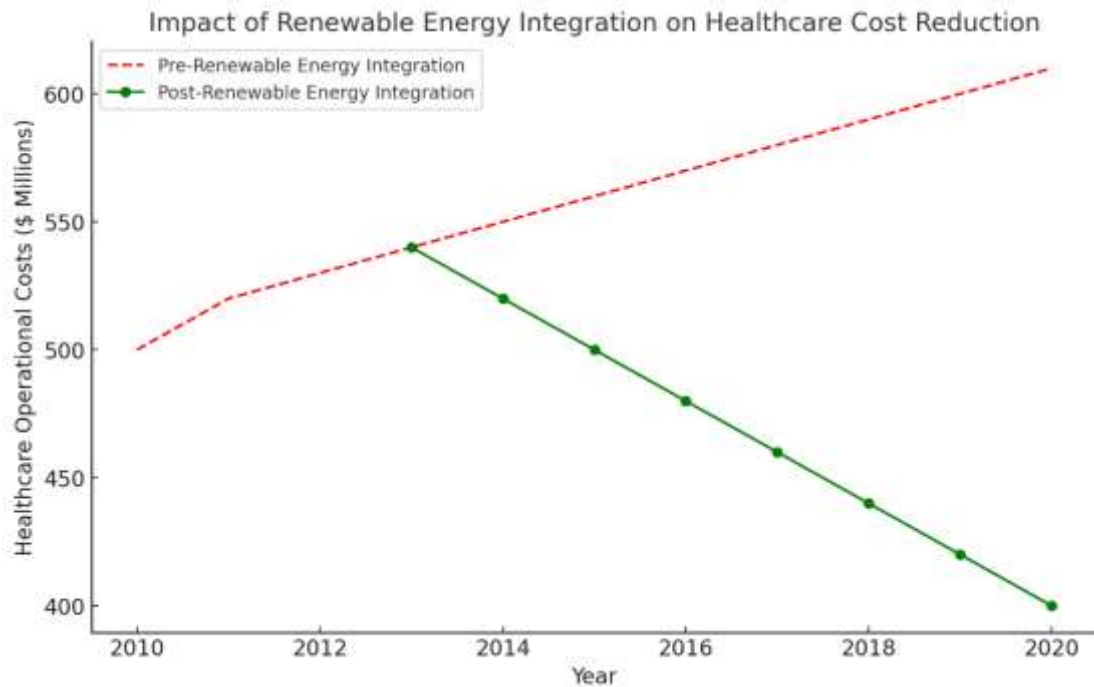
Table 1: Green Technology and Their Consequences on Health care Sector Economy

The treatment impact of several green technologies is described in Table 1 below. All of them are assessed regarding their effectiveness in cutting carbon intensity, increasing energy efficiency, and optimizing waste management. The following table can be used as a guide to help healthcare organizations identify opportunities and strategies for more effective environmental stewardship that can also drive operational improvement.

Green Technology	Impact on Healthcare Operations	Example
Solar Energy	Reduces carbon emissions, lowers electricity costs	A hospital in California reduced electricity costs by 40% by installing solar panels.
Energy-efficient Medical Equipment	Reduces energy consumption, lowers operational costs	New diagnostic equipment uses 30% less energy than previous models, improving efficiency and reducing waste.
Sustainable Building Design	Improves energy efficiency, reduces resource consumption	The Green Health Building in New York incorporates LEED-certified designs and has reduced energy usage by 35%.
Waste-to-Energy Systems	Converts medical waste into energy, reduces landfill use	A hospital in Sweden uses a waste-to-energy system to convert medical waste into electricity.

The examples presented in the table give details of the actual implementation of green technologies in health facilities. For instance, solar energy has caused a drastic change in electricity costs, plummeting in California hospitals and energy-efficient medical equipment, leading to decreased energy use and energy waste. In Green Health Building in New York, Allen et al. (2015) depicts that sustainable building designs relate to energy conservation while at the same time promoting the use of architectural methods that support resource conservation. Moreover, great examples of converting medical waste into utilizable resources include Sweden's waste-to-energy systems (WasteOnline, 2020; Al-Nawafah et al., 2022; Alolayyan et al., 2018; Eldahamsheh, 2021).

Graph 1: Impact of Renewable Energy Integration on Healthcare Cost Reduction



Impact on Operational Costs:

In the same way, Graph 1 also shows the effects and relationship between the dependent variable ‘renewable energy integration’ and the independent variable of ‘healthcare operational cost.’ Hospitals have reported reduced energy costs through renewable energy like solar power and wind energy. This reduction is credited to decreases or removal of the dependency on more conventional and costly hydrocarbons, which embrace conventional fossil fuels that contribute immensely and extensively to greenhouse emissions.

Pre-Renewable Energy Integration:

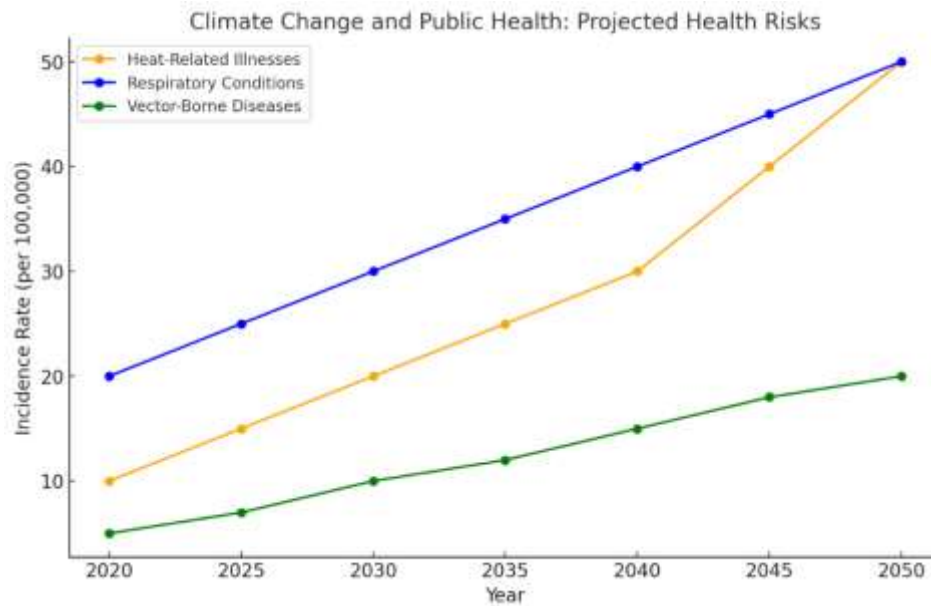
This paper reveals that before the shift to renewable energy sources, hydro facilities experienced high operating expenses due to using fossil energy, particularly in areas with SENSE efficacy. Many hospitals and healthcare organizations sometimes experience an increase in electricity costs, putting immense pressure on the set budgets. Hence, these funds were redirected to cater to other sectors of patient care and other health services.

Post-Renewable Energy Integration:

Hospitals that have incorporated renewable energy sources into their systems have, therefore, observed notable savings. Hospitals have cut fuel expenses by between a third and 40%. These savings enabled healthcare institutions to invest more of their money in other areas, such as patient care programs, staff development, and technology. Furthermore, increased utilization of renewable energy led to decreased greenhouse gas emissions, making hospitals achieve sustainable objectives and conform to legal requirements on environmental concerns.

The graph also shows that the integration of renewable energy provides great financial prospects and helps minimize negative impacts on the environment by decreasing the greenhouse effect. Suppose the utilization of renewable energy solutions continues to increase across different healthcare systems. In that case, the synergy on the overall impact on carbon emissions should be quite significant – thus reinforcing the notion that the healthcare industry is a force to be reckoned with in the global efforts against climate change.

Graph 2: Climate Change and Public Health: Projected Health Risks

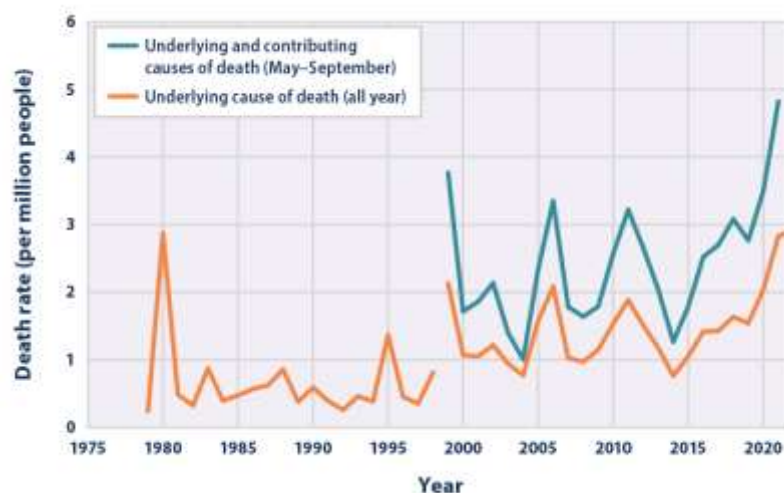


Graph 2 shows potential disease burdens resulting from climate change in the next three decades. As global temperatures continue to soar, more people are likely to fall ill from heat stroke, asthma, and related ailments and vector-borne illnesses. This graph shows the increasing interconnectivity of climate change and public health and, therefore, the need to address Climate change mitigation as well as its/adaptation in healthcare facilities.

Heat-Related Illnesses:

Using the heat index data from the graph, heat stress illnesses such as heat stroke and dehydration are expected to escalate as the temperatures rise across the world. The most affected are the elderly, children, and other groups of people with other underlying illnesses. Such measures include opening and preparedness of health facilities for the provision of services such as cooling, emergency, and lingering care among the health afflicted by heat stress.

Graph 3. Deaths Classified as “Heat-Related” in the United States, 1979–2022



Source: (Climate Change Indicators: Heat-Related Deaths | US EPA, 2020)

Respiratory Conditions:

High temperatures are also associated with poor air standards, aggravated by allergens like pollen and smog. This is a challenge to citizens with ailments affecting their respiratory system, such as asthma and chronic obstructive pulmonary disease (COPD). Due to climate change pollution, healthcare systems will have to increase their ability to address respiratory illnesses, especially in cities.

Vector-Borne Diseases:

It also contributes to the growth of vector-borne diseases such as malaria and dengue fever because the warm climate enlarges the habitat range for disease-causing insects like mosquitoes and ticks. Healthcare in endemic areas will have to adapt to the change in climate to ensure that vector populations are properly checked to reduce disease prevalence. The rate of infection with these diseases increases and exceeds the global health systems, making them embrace enhanced disease detection and control measures.

Vulnerable Populations:

The graph helps to underscore that climate change is especially dangerous to the socially and economically vulnerable, such as the low-income population, people without health care, and people with chronic illnesses. These groups are particularly vulnerable to negative health impacts related to climate change as a result of resource constraints, low health risk awareness, and weak healthcare facilities. On this basis, healthcare systems are well advised to incorporate a variety of measures to address the above disparities.

Altogether, we described the cumulative picture of the relationship between health and climate change and made the need to integrate climate-related measures in a healthcare strategy evident. This stresses the urge for overall healthcare systems to embrace change in the new advanced and segmented health environment and practice climate-friendly health initiatives.

Studies reviewed in this paper suggest that implementing green technologies and using sustainable approaches in health facilities have positive impacts on the environment, the health facility's bottom line, and the health of those who use the facility. Efficient and sustainable use of energy sources, medical equipment, building construction, and waste management, amongst other factors, not only cuts down the costs incurred within health facilities but also positively affects the prevention of environmental degradation by existing health facilities (Molero et al., 2020; Alzyoud et al., 2024; Mohammad et al., 2022; Rahamneh et al., 2023).

Moreover, the vision of health risks resulting from climate change supports adapting healthcare delivery systems to climate change produce health risks. Since climate change will intensify diseases like heat stress, respiratory diseases, and vector-borne diseases, healthcare providers need to adopt climate-resilient policies and technologies to safeguard the needy section of the population and enhance the health results in general.

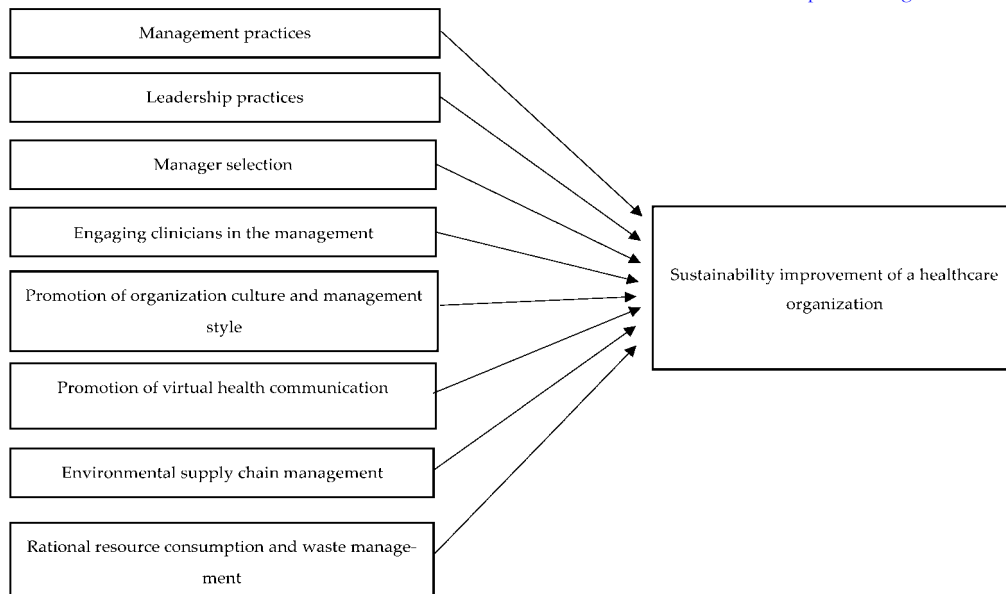


Figure 2. Practices pursuing the sustainability of a healthcare organization.

Source: designed by authors.

Healthcare organizations, therefore, stand to benefit from adopting greener technologies by lowering their emission levels of carbon, conserving energy, and thus improving their energy efficiency as they are part of the global conservation efforts for the climate (Zanobini et al., 2024). Techniques of healthcare combined with the principles of environmental sustainability are rapidly gaining importance; the latter plays an important role in furthering both the objectives of maintaining people's health on the one hand and preserving the planet on the other.

DISCUSSION

Sustainable Healthcare Practices and Patient Outcomes

According to Delgado (2020), healthcare facilities that adopt green technologies and implement sustainable change experience decreased costs overall, improved resource use, and better patient care outcomes. For instance, health facilities that adopt energy-efficient technologies are able to recover such money through rebates and spend it on patient care services, hence enhancing the quality of services provided to patients.

However, these technologies have commenced in healthcare facilities, and more extensions are seen. Nonetheless, the topic highlights environmental advantages because of the use of renewable energy systems and the adoption of other technologies to make healthcare facilities environmentally friendly. It is important to note that the initial costs may pose a challenge, limiting many small and rural healthcare facilities from practicing good environmental conduct. The main drivers that will help achieve sustainable healthcare at higher rates will be financial incentives, subsidies from the government, and PPPs (Here's How Healthcare Can Reduce Its Carbon Footprint, 2020).

Climate Change and Other Advances in Public Health Dangers

Climate change factors combined with public health are becoming apparent since climate change-related health risks are increasing. There is definitely an added pressure on healthcare systems to cope with diseases resulting from climate change, including asthma, cardiovascular diseases, and infectious diseases (Fox et al., 2019). The authors find that climate change adaptation must be incorporated into healthcare systems since

climate change poses a significant threat to public health (Al-Azzam et al., 2023; Al-Shormana et al., 2022; Al-E'wesat et al., 2024).

The health sector must invest in its adaptation to climate change, infrastructure development, climate and health research, and health promotional interventions delivered to the target population.

Identification of suitable patients mattered greatly throughout this period due to the stage of development and diversification of angiosperms at that time.

Conclusions

Environmental sustainability in healthcare, the use of green technologies, and the climate-health interface present a great opportunity to cope with environmental deterioration and enhance the health of citizens. Green technologies have the overall impact of decreasing the carbon footprint on healthcare systems, achieving efficiency in energy use, and minimizing waste production; hence, healthcare systems cut costs and enhance the delivery of healthcare services.

However, eliminating the financial and organizational factors hampering extensive use of such practices is difficult. Multiple stakeholders, including governments and health systems, must design healthcare systems that embrace sustainable practices, which should consider climate change disparities among the most vulnerable groups.

RECOMMENDATIONS

- **Increase Investment in Green Technologies:** Governments and healthcare organizations should emphasize using renewable energy, meticulous energy-consuming equipment, and environmentally sustainable building techniques.
- **Policy Support for Sustainability in Healthcare:** Faculty and healthcare administration should provide special incentives and subsidies that encourage facilities to be more environmentally friendly and utilize green technologies.
- **Enhance Climate-Health Education:** Health literacy for climate change: For enhanced public and healthcare professional understanding and advocacy.
- **Strengthen Climate-Resilient Healthcare Systems:** Public health and healthcare organizations should operationalize climate adaptation measures, including infrastructure improvement to withstand storms and other climate events and planning for climate-sensitive illnesses.
- The paper looks at how healthcare can help combat the challenges of climate change and achieve more sustainable states in the sector.

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