Advancing Sustainability in Healthcare Facilities: A Systematic Review of Strategies for Energy Efficiency, Stakeholder Engagement, and Environmental Impact

Anis Syahmina Mohd Soleh, Putri Zulaiha Razi*, Nurhidayah Azmy, Noram Irwan Ramli, Fatin Zafirah Mansur, Roziah Zailan

Faculty of Civil Engineering Technology, University Malaysia Pahang Al-Sultan Abdullah Lebuh Persiaran Tun Khalil Yaacob, 26300, Kuantan Pahang, Malaysia

***Corresponding author**

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ABSTRACT

The growing global population and aging demographics have created extraordinary pressure on healthcare systems, necessitating an immediate adoption of sustainable practices within healthcare facilities. In response to these challenges, many healthcare organizations are implementing energy-efficient systems and renewable energy sources, such as solar panels and utilizing energy-efficient lighting and HVAC systems to reduce greenhouse gas emissions and operational costs. However, despite the increasing awareness of healthcare facilities environmental impact, research on the integration of environmentally sustainable approaches throughout the healthcare delivery process, encompassing construction, design, and daily operations, while simultaneously addressing environmental, social and economic sustainability remains inadequate. Hence, this study utilized systematic literature review to investigate the effective strategies that can be implemented across the entire healthcare operations. The review was conducted based on ROSES (Reporting standards for Systematic Evidence Syntheses) framework. This review identified five (5) main themes along with thirteen (13) sub-themes that cover strategies for advancing sustainability in healthcare facilities at different levels. The findings underscore the importance of operational efficiency at every stage of healthcare delivery while maintaining high-quality patient care. Additionally, the results emphasize the necessity of involving multiple stakeholders throughout the decision-making process and calls for further research to address existing gaps in the literature regarding sustainability in healthcare. This study also contributes in achieving Sustainable Development Goals (SDG's) SDG 3 (Good Health and Well -Being), SDG 9 (Industry, Innovation and Infrastructure), and SDG13 (Climate Action).

Keywords: Sustainability, Healthcare, Energy Efficiency, Environmental, Stakeholder Engagement

INTRODUCTION

The increasing global population, coupled with a growing aging demographic, has placed substantial pressure on healthcare systems, necessitating the expansion and enhancement of healthcare infrastructure (Mosadeghrad, 2014). As demand for healthcare services continues to rise, there is an urgent need for facilities that encompass a wide spectrum of care, including hospitals, clinics, ambulatory centers, and specialized institutions such as psychiatric and maternity care facilities (*Health Facilities*, 2017). Ensuring the long-term sustainability of these facilities requires strategic planning and the integration of environmentally conscious healthcare solutions. Concurrently, rapid advancements in medical technology and healthcare delivery have led to heightened expectations regarding service efficiency, patient-centered care, and the overall quality of healthcare environments (Shen et al., 2023). These evolving demands underscore the necessity for healthcare systems to adopt sustainable practices that not only minimize environmental impact but also enhance operational efficiency. A multidimensional approach that incorporates technological innovation, evidence-based policy frameworks, and cross-disciplinary collaboration is critical to fostering resilient and sustainable healthcare infrastructure (A.

Hussain et al., 2024).

Sustainability in healthcare refers to the coordinated administration of key processes by healthcare providers to achieve social, environmental, and economic objectives while maintaining quality and service at an affordable cost (Lega et al. (2013); M. Hussain et al. (2018); Wagrell et al. (2022)) . It is crucial to implement innovative strategies that improve the population's health and address the socioeconomic determinants of health. A sustainable healthcare facility comprises multiple environmental, technological, social, and economic elements. By identifying, assessing, and surveying these variables, the sustainability of hospitals on different levels can be improved (Pantzartzis et al., 2017). For example, giving subsidies for energy-efficient improvements and renewable energy installations in healthcare institutions can effectively decrease their environmental impact and operating expenses.

Healthcare is a major contributor to carbon emissions and must mitigate its environmental impact (A. Hussain et al., 2024). The healthcare sector contributes around 4%–5% of worldwide net emissions, comprising direct and indirect greenhouse gas (GHG) emissions (Messmann et al., 2024). Meanwhile, in another study, it is reported that the healthcare sector globally is accountable for environmental impacts, ranging between 1% to 5% of the total global impact. In certain countries, these effects surpass 5% (Lenzen et al., n.d.). This study aligns with Ben Schiller (2012) that reported hospitals emit 2.5 times more greenhouse gases and consume 2.5 times more electricity compared to other commercial buildings Consequently, in the industrialized sector, healthcare service occupies one of the highest carbon footprint emissions (Priyan & Banerjee, 2022). Carbon emission and GHG will lead to climate change and global warming that will causes numerous health problem including heat stroke and other threat to ecosystem such as the disruption of biodiversity (Jiang et al., 2024).

Research has demonstrated that as the quality of healthcare services improves, there is an increase in the acquisition of medical equipment and consumables, such as medical supplies, reagents, and medications (Zamparas et al., 2019). This rise in resource utilization leads to an increase level of patient services provided, which in turn generates more healthcare waste. This trend underscores the growing significance of sustainability in healthcare, driven by factors such as patient influence, increased specialization, technological innovation, and the demand for more efficient care services (Wagrell et al., 2022).

Therefore, healthcare facilities need to implement sustainable practices to reduce their environmental impact. In addition, sustainability in healthcare encompasses several disciplines, such as medical science, operations management, and sustainable practices (Mehra & Sharma, 2021). Hospitals must integrate sustainable practices and diligently assess, track, and report their progress in sustainability initiatives (Messmann et al., 2024). By addressing these issues, Malaysia has the potential to establish a healthcare system that is more sustainable henceforth achieving the third (good health and well-being), ninth (industry, innovation and infrastructure) and thirteenth (climate action) Sustainable Development Goals (SDGs).

Research gap- Existing study towards sustainability in healthcare facilities

It is important to acknowledge that numerous studies have been conducted to highlight the issue related to environmental and sustainability challenge in healthcare facilities but there is a limited study focusing on sustainability in healthcare facilities (Tushar et al., 2023). In addition, previous studies only focused on specific topics and very few were discussed on broader sustainability strategies at different levels and comprised all sustainability domains (environmental, social and economic). To emphasize, Tarkar (2022) investigated the role of green hospitals in sustainable construction, Tushar et al. (2023) evaluated the elements that drive sustainable service management in the hospital sector, Chauhan et al. (2022) discussed regarding telemedicine services, M. Hussain et al. (2018) analyzed social sustainability in healthcare setting and some researchers examined indoor environmental quality (IEQ) (Gola et al. (2019);(Shen et al. (2023);Ackley et al. (2024)). By the same token, A. Hussain et al. (2024) stated that studies on sustainability in healthcare that primarily performed only assessed the correlation between sustainable advancements and their influence on different healthcare outcomes and organizational aspects. This gap highlights the need for additional research to explore possible strategies for implementing sustainability initiatives across all levels of healthcare operations and evaluate their impact. This study could provide significant insights into how healthcare institutions can effectively incorporate sustainable practices into their everyday operations, therefore improve health outcomes and minimizing environmental impact. Jiang et al. (2024) suggested to evaluate the key aspects that contribute to sustainable service management in the healthcare sector and three (3) critical factors in promoting sustainability namely Natural Resources (NTR), Renewable Energy (REC), and Healthcare (HLT).

This study will further discuss the implication of these strategies on the overall sustainability framework within healthcare facilities by analyzing how they can enhance operational efficiency while addressing environmental, social, and economic sustainability. It will assess the effectiveness of various sustainable approaches, such as waste management systems, energy-efficient technologies, and stakeholder engagement activities. Jiang et al. (2024) emphasized the need to integrate sustainability into legal frameworks and underscored the significance of economic strategies to prioritize environmental issues. This integration is crucial for establishing a comprehensive approach to sustainability in healthcare, as it aligns with regulatory measures and economic strategies that prioritize environmental issues.

This study aims to gain insight into efficient sustainable practice for advancing sustainability in healthcare facilities at different levels by focusing on aspects ranging from construction to operational management while considering not only environmental, but also social and economic sustainability. This study will explore innovative strategies that integrate technical advancements and evidence-based research to facilitate a comprehensive approach to sustainability. Therefore, SDG 3, SDG 9 and SDG 13 can be achieved.

METHODOLOGY

The review protocol-ROSES

This study follows ROSES (Reporting Standards for Systematic Evidence Syntheses review protocol that are strive to improve transparency and guarantee quality control with accurate information (Singam et al., 2024; Mafarja et al., 2023). This method is suitable with this study since it is specialized in conducting systematic reviews and systematic mapping in the conservation and environmental management field (Haddaway et al., 2018). Previously, many researchers used ROSES in their early research stage of study. To clarify, Shaffril et al. (2020) performed ROSES to analyze Asian natives population adaptation regarding climate change impacts. Similarly, Singam et al. (2024) used ROSES in their study to investigate carbon emission of light duty vehicles in urban setting. The first step is developing suitable research question for the analysis) using PICo technique (Shaffril et al., 2020; Singam et al., 2024). Then, a comprehensive three-stage document searching procedure consists of identification, screening and eligibility is implemented. Before finalizing the articles to be reviewed, each selected article undergoes quality assessment to ensure it met the required standard of quality and suitable for the review purpose. Lastly, The selected articles undergo multiple processes, including data extraction, analysis and the validation of the collected data (Shaffril et al., 2020).

Formulation of Research Question

The research question for this study was formulated using Population or Problem, Interest and Context (PICo). It is a tool that aids authors in formulating appropriate research questions for their review (Mohamed Shaffril et al., 2020). In this study, population refers to healthcare facilities, advancing sustainability as interest and the context corresponds to global evidence. Therefore, the main question is: What are the strategies that can be implemented to enhance sustainability in healthcare facilities? Then, from the initial research question, the second one was developed: What is the existing research gap with respect to this issue that may lead to a possible guidance for future research.

Systematic Searching Strategy

Three main stages of systematic searching strategies procedure including identification, screening, and eligibility. Refer figure 1.

Identification: Identification is the systematic procedure of exploring synonyms, complementary concepts, and alternatives for the primary keywords used in the study which are sustainability and healthcare facilities. The purpose is to get more choices for the specified database to perform more comprehensive searches for the article review. This study utilized ScienceDirect and Web of Science (WoS) as two primary search engines to obtain article sources that are relevant to the study's focus as Scopus had limited access due to some articles being unavailable for download. The ScienceDirect website is available with features that encourage users to explore the scientific publications fields (Tober, 2011) while WoS is a research and academic search engine provided by Clarivate Analytics that comprises many databases and indices that encompasses a wide range of journals, articles, papers, and conference proceedings from numerous fields (McNicholas et al., 2022). Furthermore, ScienceDirect and Web of Science is widely used by the researchers such as Jaušovec & Gabrovec, (2023), Anudjo et al. (2023), and Shaffril et al. (2020). Google Scholar (GS) was selected as an additional database especially when the main database cannot access the related article since the percentage of citation found in GS that overlapping by another database is high. GS discovered the highest number of citations, encompassing the majority of citations identified by WoS and Scopus. WoS and Scopus accounted only 6% of total citations, excluding those discovered by GS (Martín-Martín et al., 2018). The searching procedure using these 3-databases yielded in a total of 170 articles. Table 1 shows the search string employed by ScienceDirect, and WoS,

Table I The Search String

Database	Search String
ScienceDirect	TITLE-ABS-KEY ((“Sustainability” OR “Sustainable OR “Feasible” OR “Environment” OR “Environmental” AND “Healthcare Facility” OR “Healthcare” OR “Hospital” OR “Clinic”))
Web of Science	TS = ((“Sustainability” OR “Sustainable OR “Feasible” OR “Environment” OR “Environmental” AND “Healthcare Facility” OR “Healthcare” OR “Hospital” OR “Clinic”))

1) Screening: Screening can be define as the author's criteria to choose or exclude papers from the analysis (Nisa & Abdul, 2022). The 170 selected articles were filtered in this study by using the criteria for article selection, which was done automatically through the filter function provided in the database. Then, the duplicate articles from different databases were removed, and only articles written in English were chosen. The timeline for the article was limited from 2018 to 2024 to make sure that the data in the study remained valid and up to date. A total of 87 articles were excluded from this procedure due to their failure to meet the inclusion standards and 14 duplicated articles were removed. The balance of 69 articles were utilized for the third procedure, which involved assessing their eligibility.

2) Eligibility: The eligibility stage involves the authors personally monitoring the retrieved articles to ensure that all the remaining articles, following the screening procedure meet the specified criteria (Mohamed Shaffril et al., 2020). In this stage, the titles and abstract of the selected article were reviewed to make sure it is aligned with the study's topic and fulfilled the criteria. The article that related to healthcare facilities but did not mention sustainability were removed. In this process, a total of 24 articles were excluded, leaving 55 articles to be included in the final analysis.

Quality Assessment

By referring to Shaffril et al. (2020), to ensure the quality and validity, the remaining articles were submitted to two professionals for quality evaluation.

Data extraction and analysis

Mixed-method technique was utilized in the review for the purpose of providing thorough understanding on the current strategies implemented in advancing sustainability in healthcare facilities worldwide. Besides, it allows for integration of different types of evidence. Hence, the research question can be address properly. The remaining 55 article were read in detail with a focus on the abstract, results, discussions and conclusion parts to extract relevant data and insight based on the research question. In this study, atlas.ti software was utilized to facilitate the data extraction process, while thematic analysis was employed to analyze the collected data. Thematic analysis is an approach to identifying, analysing and presenting the data within the themes (Braun & Clarke, 2008). To create a theme and sub-theme, the data linkages and similarities that identified throughout the analysis were combined into a single subtopic. The themes that were formed from the raw data that reflected the whole dataset (Thana Singam et al., 2024). To ensure the theme validation, the themes and sub-themes were presented to two (2) expert panels that have experience in environmental and project management. As a result, both of them were agree that the themes and sub-themes were appropriate and valid for the scope of this systematic review. Fig.1 shows the systematic searching strategy that employed in this study.

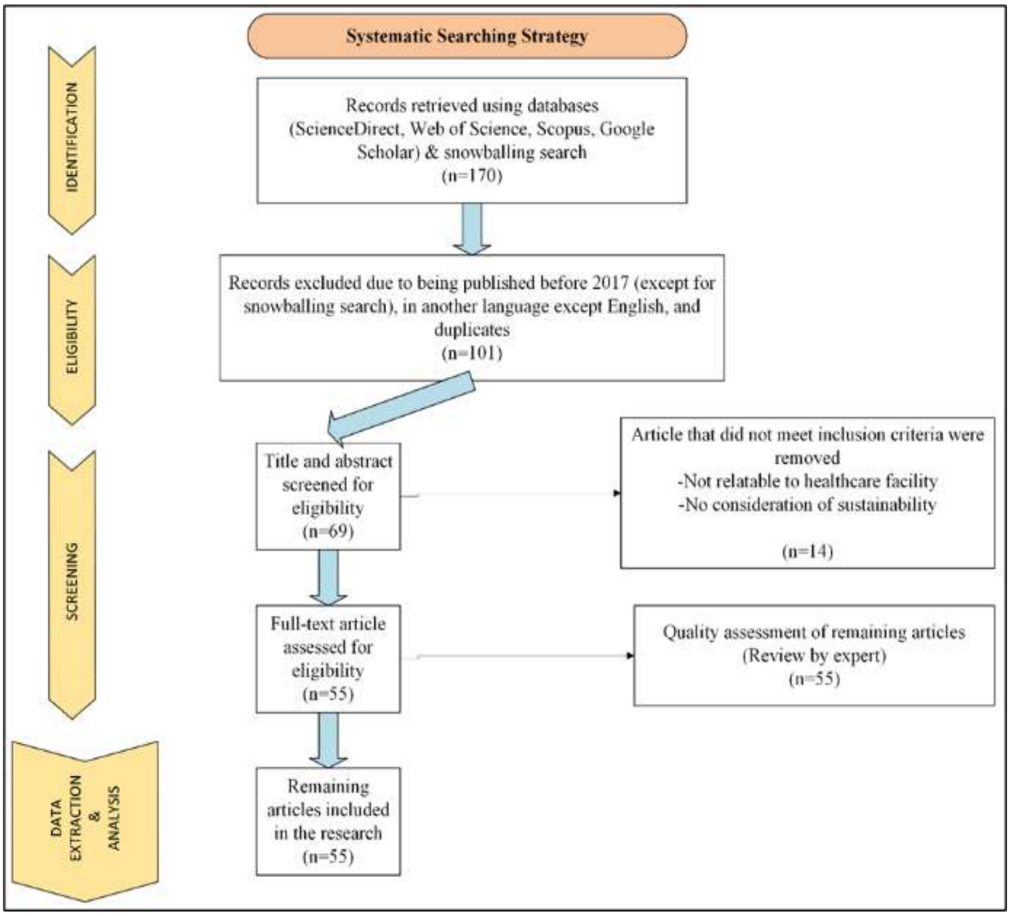

Fig. 1 The Searching Strategy

RESULTS

Themes and sub-themes

In this section, the practical strategies for implementing sustainability in healthcare facilities will be analyzed. The studies from past researchers will be reviewed to extract key insight and the best practice. By combining practical approaches and ideas from previous study, a comprehensive guideline for healthcare facilities to effectively implement sustainability practices can be achieved.

Sustainable Healthcare Operation: Sustainable healthcare operations involve a range of comprehensive strategies to enhance both the productivity and efficiency of healthcare management as well as environmental performance in healthcare facilities while ensuring high-quality patient care. High-performing hospitals will accomplish sustainability by providing hospital accreditation (Tushar et al., 2023). Under this theme, the study finds 3 sub-themes which are sustainable healthcare waste management, involves all the stakeholder engagement and government initiatives.

Healthcare facilities produce different types of waste such as food waste, biomedical waste, plastic waste and hazardous waste. Healthcare organizations are accountable for a significant amount of hazardous chemicals and non-recycled solid waste, contributing to up to 5% of worldwide greenhouse gas (GHG) emissions (Rajagopalan et al., 2023). Developing a comprehensive waste management strategy in healthcare facilities is crucial to effectively segregate various types of waste. Since COVID-19, the increased demand for healthcare services and the global acceleration of vaccination initiatives have resulted in large quantities of biomedical waste that need to be properly managed (Sharma et al., 2021). Examples of biomedical waste including Personal Protective Equipment (PPE), needles, pharmaceutical and chemical waste. PPE is the primary contributor of medical waste during the pandemic and is expected to continue increasing even after the outbreak ends (Mohan et al., 2022). A study conducted by Zamparas et al. (2019) in the Rio University Hospital, Western Greece, found that the classification of medical waste generated in healthcare activities was as follows: municipal waste (79%), infectious waste (17%), hazardous (chemical, pharmaceutical) waste (3%), and other waste (1%). Establishing a safe and reliable system for separating, handling and disposing the biomedical waste is crucial due to its higher potential for causing infection and harm to individual health. In addition, it also poses significant threats to the environment and socio-economic sustainability. Healthcare facilities must systematically organize medical waste management to ensure the optimum health and safety of all those involved in hospital operations (Tushar et al., 2023). Filho et al. (2023) highlighted the need for investment in medical waste disposal capacity, recycling and recovery. Clinicians have a crucial role in selecting supplies with lower emissions, such as reusable medical equipment instead of disposable ones, and minimizing unnecessary usage of supplies and medications in their practice (Soares et al., 2023). Due to that, researchers have increasingly encouraged the implementation of Circular Economy (CE) principles and investigated the challenges for applying CE in healthcare in order to improve waste reduction by preserving materials and resources inside a closed-loop system (Ahmed, 2023; Ogunmakinde et al., 2022; Mahjoob et al., 2023).

Adu et al. (2022) designed a gas filter system for hospital incinerators to clean the smoke from medical waste treatment. The incinerators are installed in healthcare facilities to dispose infectious clinical waste, but the chimneys of incinerators emit hazardous compounds in the smoke. Therefore, they integrate powdered activated charcoal that acts as an adsorbent material in the filter unit to minimize the release of hazardous pollutants into the environment. Similarly, (Dixit & Dutta (2024) suggested establishing a comprehensive medical waste management system to quantify the amount of waste generated and impact on various catastrophe areas while Mohan et al. (2022) went a step further, proposing the creation of composite construction materials using waste from PPE together with sand fillers. Finally, Anna et al. (2022) gathered the review and examine the existing knowledge of Health Lean Management (LM) implementations and expand the scope to include the undiscovered context of Local Health Networks (HNs). Implementing lean concepts in healthcare facilities is crucial for improving sustainable service quality by efficiently allocating resources, reducing process waste, and promoting continuous improvement (Tushar et al., 2023).

The next sub-theme is stakeholder engagement. The diverse viewpoints from numerous stakeholders regarding sustainable service and the cause-and-effect relationship of elements enable them to get a deeper comprehension of the complex environment of healthcare facilities. As an illustration, nurse perception regarding indoor thermal condition is different from patient perception. Multiple studies have investigated the differing perception of stakeholders, especially between staff and patient (Nourozi et al., 2024). This comprehensive understanding allows stakeholders to accurately assess the current situation and make wise decisions regarding the implementation of sustainable measures (Tushar et al., 2023). In their study, Tushar et al. (2023) involved all the stakeholder in healthcare facilities to get their viewpoints regarding sustainability. By employing a mixed-methods approach, the level of sustainable service according to stakeholder interest were able to determine and the study's findings highlighted the importance of integration of environmental, social, and economic aspects of hospital services to achieve a holistic and effective sustainability strategy. Furthermore, by involving stakeholders, healthcare executives and professionals may find strong direction and guidance in employing circular practices, waste reduction and management, integrated facilities design, sustainable procurement, employee happiness, and green growth to help them achieve their sustainability objectives (Mehra & Sharma, 2021). Comparatively, Filho et al. (2023) suggests the development of a strategic plan that emphasizes the exchange of experience and international partnerships, dissemination of information, and worldwide collaboration to accomplish the United Nation SDGs (Leal Filho et al., 2023). These strategies can enhance the overall sustainability of healthcare institutions and the communities they serve when implemented holistically.

Finally, it is recommended that governments also consider social policy measures (A. Hussain et al., 2024), legal structures, and implementation method to foster sustainable healthcare practices. Liu et al. (2024) conducted a study on government environmental attention (GEA) in China and it is found that the correlation between social responsibility and cost-effectiveness is shown by a normalized path coefficient of 0.18. The verified result showed that social policy initiatives can promote environmentally sustainable medical procedures. Furthermore, social policy initiatives may help underprivileged communities have better access to healthcare. In China, the Chinese government has undertaken an organized and coordinated initiative to combat environmental issues by gradually incorporating environmental governance into evaluation parameters for government officials at various levels (Liu et al., 2024). The aim of this initiative is to encourage government officials to prioritize environmental protection and sustainability in their decision-making and policy implementation, thereby contributing to the country's overall environmental goals. Government also should offering incentives such as tax rebates for the healthcare facilities that integrate environmentally friendly technology and procedures (Mostepaniuk et al., 2023). Liu et al. (2024) agreed that the government must increase its financial assistance, by offering green financing and innovation subsidies, to help lessen the financial burden experienced by companies in transitioning towards more sustainable practices since the government environmental subsidies are crucial for supporting the sustainable development process (Zhang et al., 2023). On the contrary, another study found that in Bangladesh, the government does not provide health insurance coverage for the citizens (Tushar et al., 2023). Lastly, raising community knowledge of environmental issues is commonly seen as an essential aspect of environmental sustainability (Mostepaniuk et al., 2023). Another study suggested enhancing staff awareness through the implementation of training programs that promote environmental sensitivity and responsibility, as well as increasing the number of green purchasing suppliers to support the adoption of sustainable products and services within healthcare facilities (Zamparas et al., 2019). Therefore, government should establish funding mechanisms that connect environmental sustainability science with health services research to effectively apply understanding toward sustainable clinical practices (Sherman et al., 2020).

Optimizing Indoor Environmental Quality for Improved Health Outcomes: The influence of IEQ, especially indoor air quality (IAQ), lighting, thermal comfort, and acoustics, has beneficial effects on patient rehabilitation, lowering stress levels, reducing hospital stays, and improving staff efficiency in providing care (Ackley et al., 2024).

IAQ can be improved by implementing the proper heating, ventilation and air condition (HVAC) system that ensures thermal comfort and humidity regulation for occupants. HVAC systems play a crucial role in maintaining indoor air quality (IAQ) by supplying adequate fresh air, removing excess heat, and diluting or removing airborne pollutant (Ilić et al., 2021; Gola et al., 2019). It plays a vital role in preserving the health and welfare of patients, staff, and visitors (Silva et al., 2024). Similarly, another research offers valuable insights into the potential for cross-contamination in different hospital ward configurations and emphasizes the crucial role of the ventilation system in reducing the negative impact of infection risks (Nourozi et al., 2024). (Silva et al. (2024). suggest to develop HVAC based on hospital region and taking into consideration several variables such as user comfort, energy savings, and reducing carbon emission The use of air purifiers along with the ventilation system decreases the concentration of indoor pathogens (Nourozi et al., 2024). The strict standards for indoor air quality and the need for minimal contamination levels in hospital settings, particularly in hospital wards and patient rooms, prioritize the perceived thermal comfort of both healthcare workers and patients (Nourozi et al., 2024).

Next is lighting. Multiple studies have emphasized the positive impacts of adequate lighting, especially daylighting and window views in healthcare facilities (Ackley et al., 2024). The impact of lighting not only influences patient comfort, affects patient sleep, perception of the surroundings, and pain levels but also on the nurse satisfaction through job productivity. Furthermore, better lighting can lower the risk of patient falls (Shen et al., 2023). In addition, there is a positive correlation between the availability of natural lighting in healthcare facilities and improvements in physiological and psychological aspects (Englezou& Michael, 2020). Daylight should be utilized in waiting rooms, staff lounges, and corridors as well while artificial lighting is necessary to achieve a harmonious balance with natural lighting. Additionally, it is necessary to evaluate the control of the lighting system concerning occupancy (Silva et al., 2024). To ensure the smooth operation and appropriate indoor environmental quality (IEQ) of healthcare facilities, it is essential that all components stay functional (Silva et al., 2024). In a case study conducted in Cyprus, the research findings highlighted the significance of acknowledging various elements that may impact daylight performance in common patient rooms in healthcare facilities. These factors encompass the spatial dimensions of the space, the proportion of windows to walls, and the utilization of shade mechanisms (Englezou & Michael, 2020).

Acoustics is also an important component of Indoor Environmental Quality (IEQ) to guarantee the physical and psychological well-being of both patients and staff. After reviewing past research, Auckley et al. suggested several strategies to improve acoustics in healthcare facilities. These includes utilizing noise-absorbing building materials, installing privacy curtains to improve conversation privacy, aiming for a design objective of a noise level less than 45 dB(A), allowing doors and windows to be closed flexibly, and incorporating signs to remind individuals to remain quiet (Ackley et al., 2024).

Sustainable Infrastructure for Resilient Healthcare: Under this theme 3 sub-theme were discussed which are green building, water resilient healthcare infrastructure and sustainable construction.

The Green Building Concepts are a necessity for all healthcare facilities, as the issue of Global Warming is rapidly evolving (Setyowati et al., 2013). Green building rating tool are aimed to provide architects, engineers, contractors, and building owners with standardized techniques and principles for promoting sustainable building practices and reducing the environmental impact of buildings. The U.S. Green Building Council (USGBC) created a rating system named "The Leadership in Energy & Environmental Design (LEED)" to certify green buildings. These rating systems provide a foundation for designers to incorporate environmentally friendly principles into building construction, thus contributing to the reduction of environmental degradation. The government has the authority to provide various types of incentives and compensation to promote the development of environmentally friendly building construction. Alternatively, government agencies might adhere to the specified guidelines when developing different types of incentives and compensation for each phase of green building development (Saka et al., 2021). Simultaneously, the Ministry of Health Malaysia has implemented a policy that mandates all hospitals to obtain green building certification, in accordance with global commitment to conserve the environment (Abd Rahman et al., 2021). To emphasize, in Langkawi, Hospital Sultanah Maliha has been awarded Leadership in Energy and Environmental Design (LEED) green building certification due to their commitment to developing a sustainable practices (Ministry of Health, 2023). In India, the first green building was constructed in Hyderabad, known as the CII-Sohrabji Godrej building (Tarkar, 2022). (Eti et al. (2023), in their study determined the key factors that are most important in the process of transforming buildings into green building. The results indicate that the utilization of renewable energy is the most crucial determinant and the grants towards renewable energy projects should be made. Three viable methods for carbon emission reduction in both new and renovated buildings consist of solar photovoltaic systems, energy storage using prosumer batteries, and heat pumps (Sovacool et al., 2023). Another study suggested the construction of green hospital buildings prioritizes the importance of energy efficiency and a sound surroundings as an essential elements for guaranteeing the sustainability of healthcare services (Tushar et al., 2023). Silva et al recommend to utilize BIM to accurately determine the carbon emissions during the whole lifespan of a building and provide a comprehensive analysis of the energy usage for HVAC, lighting, and water supply systems and the use of equipment throughout the operating stage of the healthcare facilities (Silva et al., 2024). By embracing these green building alternatives, healthcare facilities can significantly reduce their environmental impact, lower operating costs, thus provide healthier and more sustainable environments for patients and staff (Abd Rahman et al., 2021).

Next sub-theme is water resilient healthcare infrastructure. Since healthcare facilities consume a substantial volume of water, water conservation strategy need to be taken (Tarkar, 2022). This can be reduced by implementing efficient water usage practices, including the application of flow restrictors, the inspection for leakage, and the proper maintenance (Soares et al., 2023). Besides, an innovative hydroponic green roof system (HGRS) was created with the purpose of mitigating urban stormwater runoff and fulfilling the need for on-site collection, treatment, and reuse of grey- and rainfall in green buildings (Xu et al., 2020). Prada et al. recommended placing the sanitary installations system. For instance, the current washbasin batteries should be replaced with sensor batteries, using toilet vessels that have a recessed tank and a double flap (allowing for the selection of a water-efficient flushing method), and replacing urinals with sensor-activated flushing to conserve hot and cold domestic water (Prada et al., 2020). Rainwater harvesting system (RWHS) also can be implemented since it has the potential to enhance water supply security and lessen the burden on urban wastewater drainage systems and water resources (Almeida et al., 2023). Almeida at el. explored the integration of rainwater harvesting systems and green roofs in university buildings under varying climate conditions (Almeida et al., 2023). This integrated system seems highly applicable to healthcare facilities, where it could provide significant water savings, cost reductions, and environmental benefits.

Lastly, sustainable construction. Sustainable practices must start from the construction phase of healthcare facilities, where environmentally friendly materials and methods can be integrated into the building design and construction process. During the manufacture of construction materials, 11% of global carbon dioxide (CO_2) emissions are produced (Balinee et al., 2022). Cement is a significant contributor to the release of greenhouse gas emissions, particularly carbon dioxide (CO_2). Due to this, many researchers conducted several study to replace cement with waste material such as palm oil fuel ash (POFA) (Al-Hokabi et al., 2021), egshell waste (Ngayakamo & Onwualu, 2022) and PPE waste (Mohan et al., 2022). Another research indicates the projects that utilized modular integrated construction methodology (MiC) as the main construction approach had the best level of sustainability performance (Wong & Loo, 2022). Researchers also emphasized the importance of implementing circular economy and lean construction concepts during the construction phase to reduce waste (Ogunmakinde et al., 2022); Aristizábal-Monsalve et al., (2022). Subsidies from government have the potential to motivate contractors to replace outdated, high-emitting construction equipment. However, it may cause an economic strain on the government (Xie et al., 2023).

Leveraging Technology: Sustainable healthcare technologies have the potential to enhance healthcare equality by reducing gaps in healthcare access, outcomes, and quality among various social groups. Under this theme, 2 sub-theme were identified and discussed further which are telemedicine and digital technology and smart healthcare.

Utilizing digital technology is an effective approach, as digital health platforms have the potential to enhance patient involvement and self-care, while telemedicine and remote monitoring can decrease the need for in-person appointments (A. Hussain et al., 2024). Several key digital technologies can be incorporated into healthcare facilities to advance sustainability, including the Internet of Medical Things (IoMT), cloud computing, and artificial intelligence (AI) (Rowan, 2024). IoMT devices can be utilized for remote patient monitoring and robotic surgery that will enable healthcare providers to deliver care more efficiently and reduce the need for in-person visits. Cloud computing platforms can increase patient data accessibility and facilitate secure data sharing among healthcare providers as well as improving care coordination and reducing paper waste. AI can be applied for early detection of health issues, allowing for timely interventions and better patient outcomes. In addition, the government and public have benefited from telemedicine services during COVID-19 pandemic. Telemedicine services offer patients the convenience, safety, and flexibility to receive proper consultations from clinicians while staying at home, despite the difficult circumstances caused by the COVID-19 pandemic (Chauhan et al., 2022). Many researchers conducted a study to explore about digital health technology. To illustrate, a study conducted in Ethiopia revealed that the utilization of mobile health technology for parental and child health resulted in better outcomes and enhanced healthcare accessibility for women and children residing in rural areas (A. Hussain et al., 2024). Another study emphasizes the potential for transformation by integrating digital twin technology with extended reality technologies to improve efficiency in medical device design, supply chain, and training processes (Rowan, 2024). According to Wahab et al. findings, constant government encouragement and support are essential to drive market acquisition, promote cost-cutting measures, and incentivize profit-maximizing strategies. It is proven that the adoption of Internet of Things (IoT)-based devices and platforms is crucial for building a comprehensive and efficient telemedicine network (Wahab et al., 2023). Man et al. (2024).emphasis on digital transformation in the healthcare industry holds great promise for minimizing inefficiency and waste.

Next is smart healthcare. Smart healthcare employs sensors to adjust room temperature according to human heat, therefore conserving energy through efficient cooling systems. Smart healthcare also saves energy by reducing the need for artificial lighting. When the room is unoccupied, the system automatically switches off the lights (Tarkar, 2022). By installing various sensors in a Smart Building, the system for monitoring of the entire building can be enhanced (Plageras et al., 2018). Henceforth, Plageras et al. designed and implemented a topology architecture system that enables smart buildings to offer an energy-efficient solution by incorporating sensor data (Plageras et al., 2018). However, Plageras et al. (2018)recommended the integration of the Internet of Things (IoT) combine with Monitoring technology regardless of the usage of sensors to produce optimal outcomes in a Cloud environment. In a study conducted in Italy, Zini & Carcasci (2024) introduced a methodical approach to create a reliable monitoring technique using predictive models based on machine learning. This approach aimed to minimize the need for user expertise and applied to the electricity demand of various components within the healthcare facility. Another study proposed a smart hospital digital twinning framework with systematic information and enabling technologies. Then, the technology was tested in Shanghai municipal hospital. The results show that digital twinning allows real-time control of associated operational activities and enhances healthcare digitalization, automation, and intelligence in hospital operation (Han et al., 2023). By converting energy-inefficient buildings into intelligent buildings along with renewable energy, greenhouse gas emissions and primary energy consumption successfully reduced (Prada et al., 2020). In Malaysia, the Ministry of Health (MoH) developed strategic plans and roadmaps including the Green Technology Master Plan (GTMP) 2030, which prioritizes the areas of buildings, energy, and waste management, in conjunction with the Malaysia Renewable Energy Roadmap (MYRER) (Ministry of Health, 2023). Healthcare facilities also can enhance building functionality using a Building Management System (BMS). BMS is construct as a network between a central server and a specific number of automation controllers (Prada et al., 2020). In the terms of ‘‘smart’’ healthcare structures, stakeholders engaged with processes of decision-making should include not just technical stakeholders but also patients, visitors and staff (Silva et al., 2024).

Carbon Neutral Healthcare Facility: The first sub-theme under this theme is renewable energy transition. Healthcare facilities are the primary energy consumers among government facilities, which necessitate substantial energy reduction to reduce their annual operational expenses. By implementing renewable energy sources such as solar energy, wind energy, hydropower and bio-energy , healthcare organizations may reduce carbon emissions, thus contribute to the more ecologically sustainable future (Al-Rawi et al., 2023). The findings from Jiang et al. (2024) clearly illustrate the advantages of Renewable Energy Consumption (REC) such as reduced greenhouse gas emissions, improved air quality, and lower energy costs in promoting environmental sustainability. Renewable energy sources create clean energy intermittently or variably. The availability and productivity of these renewable energy sources are reliant upon climate factors and environmental circumstances, which may vary throughout the day and across different seasons of the year (Morales Sandoval et al., 2023). Yakub et al. (2022) constructed a hybrid energy system (HES) by integrating several different types of renewable energy sources into a rural healthcare centre in northern Nigeria and performed a techno-economic analysis to determine the viability of implementing such systems. The result shows that the PV-Diesel and Wind-Diesel system HES designs are the only viable options due to the ample solar energy, affordable diesel cost, and adequate wind energy potential. Likewise, Al-rawi et al. (2023) examined the effects of incorporating multi-solar collector and photovoltaic systems into healthcare facilities. The findings indicate that the solar thermal system supplies around 12% of the entire energy required for the hot water system, while the solar PV system contributes around 29.6% of the total demand for the HVAC system. Besides, a solar-assisted system designed to generate clean steam in hospitals was also developed to minimize greenhouse gas emissions. The system was tested in Danish and Swedish hospitals, and the study revealed that after incorporating the system, the Danish and Swedish hospitals were able to prevent 67.8 tons and 75.5 tons of CO_2 emissions each year, respectively (Jamshidmofid et al., 2024). Therefore, policymakers must expedite the transition from non-renewable energy sources to renewable alternatives such as solar, wind, and hydropower to enhance the role of REC (Jiang et al., 2024). To achieve this goal, it is necessary for government to allocate significant funds to improve renewable energy infrastructure, provide tax incentives to promote the use of clean energy solutions and develop a skilled workforce in the renewable energy industry (Jiang et al., 2024).

The second sub-theme is energy efficiency measures. Energy efficiency is an important component in every green building rating tool because of its high potential on point scoring (Abd Rahman et al., 2021). There are a variety of engineering services needed by healthcare facilities. These services, which use a lot of energy, have a great chance to implement renewable energy sources, thereby lowering healthcare facilities' carbon footprint (Al-Rawi et al., 2023). As & Bilir (2023) conducted a study to improve the energy efficiency of hospital buildings in Turkey at the design stage and create a model for an energy-efficient hospital. The study found that the adoption of building parameters supported by renewable energy sources resulted in a 57.5% reduction in energy consumption, a 16.24% decrease in overall expenses, and a 26.3% decrease in CO_2 emissions (As & Bilir, 2023). Conserving energy plays a crucial role in the collective efforts to safeguard the world from the impacts of global warming, especially concerning the energy usage of current buildings (Prada et al., 2020). In that case, another study recommended to upgraded the existing system (air conditioning, hot water system, and intelligent control system and generate photovoltaic power for the current buildings, considering the specific features of the local climate (Yu et al., 2023). In the same manner, Prada et al. (2020) highlighted the need to incorporate measures to encourage the redevelopment of existing buildings and improve their energy efficiency in national policies. Sandoval et al. (2023) agreed that the effectiveness of an upgraded energy system and the subsequent financial benefits heavily rely on the accessibility and excellence of the implemented low-carbon technology and may be improved by implementing renewable energy sources. By implementing retrofitting measures such as improving insulation, replacing windows, and installing green roofs, it is possible to achieve energy savings of up to 89% in the current building stock (Silva et al., 2024). Lastly, replacing the current lighting with LED technology can also increase the energy efficiency of healthcare facilities. LEDs offer advanced features, an affordable initial cost, and substantial long-term savings (Abd Rahman et al., 2021).

Table 2 provides a comprehensive synthesis of key themes and sub-themes derived from an extensive review of literature focusing on sustainability in healthcare facilities. This tabular representation categorizes and maps the contributions of various studies across five overarching themes: Sustainable Healthcare Operations, Indoor Environmental Quality, Sustainable Infrastructure for Resilient Healthcare, Leveraging Technology, and Decarbonizing Healthcare Operations. Each theme is further delineated into specific sub-themes, reflecting diverse yet interconnected strategies aimed at enhancing sustainability.

The table serves as a crucial reference for identifying trends and gaps in existing research, illustrating the evolution of sustainable practices in healthcare. By categorizing studies according to their thematic focus and year of publication, this compilation not only highlights the progression of scholarly contributions but also provides insights into areas requiring further exploration. This systematic approach underscores the multifaceted nature of sustainability in healthcare, encompassing environmental, social, and technological dimensions.

Table 2 The Themes And Sub-Themes

Studies	**Years**	**Sustainable Healthcare Operations**			**Indoor Environmental Quality**			**Sustainable Infrastructure for Resilient Healthcare**			**Leveraging Technology**		**Decarbonizing Healthcare Operations**	
		WM	SE	G	IAQ	D	A	GB	WR	SC	DT	SH	RES	EE
Tushar et al.	2023	/	/	/				/						
Rajagopalan et al.	2023	/												
Bhakta et al.	2021	/												
Mohan et al.	2022	/								/				
Zamparas et al.	2019	/		/										
Filho et al.	2023	/	/											
Soares et al.	2023	/							/					
Ahmed, 2023	2023	/												
Ogunmakinde et al.	2022	/												
Mahjoob et al.	2023	/												
Adu et al.	2022	/												
Dixit & Dutta	2024	/												
Anna et al.	2022	/												

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Nourozi et al.	2023		/		/									
Mehra & Sharma	2021		/											
A. Hussain et al.	2024			/							/			
Liu et al.	2024			/										
Mostepaniuk et al.	2023			/										
Zhang et al.	2023			/										
Sherman et al.	2020			/										
Ackley et al.	2024				/	/	/							
Ilić et al.	2021				/									
Gola et al.	2019				/									
Silva et al.	2024				/	/		/				/		/
Shen et al.	2023					/								
Englezou & Michael	2020					/								
Ministry of Health	2023							/						
Saka et al.	2021							/						
Abd Rahman et al.	2021							/						/
Tarkar	2022							/	/			/		
Eti et al.	2023							/						
Sovacool et al.	2023							/						
Xu et al.	2020								/					
Prada et al.	2020								/			/		/
Pessoa et al.	2023								/					
Balinee et al.	2022									/				
Al-hokabi et al.	2023									/				
Ngayakamo & Onwualu	2022									/				
Wong & Loo	2022									/				
Aristizábal-Monsalve et al.	2022									/				
Xie et al.	2023									/				
Rowan	2024										/			
Chauhan et al.	2022										/			
Wahab et al.	2023										/			
Man et al.	2024										/			
Plageras et al.	2018											/		
Zini & Carcasci	2024											/		

Han et al.	2023											/		
Al-rawi et al.	2023												/	/
Jiang et al.	2024												/	
Morales Sandoval et al.	2023												/	/
Yakub et al.	2022												/	
Jamshidmofid et al.	2024												/	
As & Bilir	2023													/
Yu et al.	2023													/

WM = Waste management	IAQ = Indoor environmental quality	GB = Green building	DT = Digital technology	RES = Renewable energy sources
SE = Stakeholder engagement	D = Daylights	WR = Water resilient	SH = Smart healthcare	EE = Energy efficiency
G = Government Initiatives	A = Acoustic	SC = Sustainable construction		

DISCUSSIONS

From thematic analysis, five (5) themes and fourteen (14) sub-themes were developed. This section will further discuss the themes and recommendations for future research will be provided. The findings show that the themes discussed are aligned with the SDG's. The provided theme, Sustainable Healthcare Operation and Optimizing Indoor Environmental Quality for Improved Health Outcomes, along with its sub-themes are aligned with SDG 3: Good Health and Well-Being.

Sustainable management operation is one of the effective strategies to enhance organizational efficiency, reduce environmental impact, and promote social responsibility. The objective can be fulfilled through improving national policies, supervision of law enforcement, budget and supply revisions, ongoing training, the establishing an assessment system, eco-friendly procurement, and improved communication (Alighardashi et al., 2024). To advance healthcare facilities, engaging diverse stakeholders such as patients, healthcare staffs, and policymakers is crucial for advancing healthcare facilities and building systems that are environmentally friendly, sustainable and socially equal in-patient care. By involving multiple stakeholder viewpoints that has different perspectives and interests on sustainable practices, healthcare organizations could develop a more holistic comprehension on the complex healthcare environment. Government investments in sustainable practices can ensure that all communities benefit from enhanced healthcare services. For example, healthcare delivery in underserved regions can be improved when rural hospitals receive grants for implementing renewable energy systems. Besides, most healthcare facilities have problems in managing their waste. Poor waste management in healthcare facilities may spread disease transmission and provide substantial risks to healthcare workers and the public. Hence, healthcare professionals should engage in training programs to acquire knowledge on sustainability. For instance, a comprehensive training program could educate healthcare workers on the importance of proper waste segregation, which would result in a decrease in the total volume of waste produced. By tailoring training programs to the specific needs and learning styles of different healthcare staff roles, organizations can foster a culture of sustainability throughout the organization since the training begins with an assessment of the skills and knowledge that employees need to improve (Alighardashi et al., 2024). Moreover, M. Hussain et al. (2018) stated that the absence of staff training limits the effective integration of social sustainability within the healthcare supply chain.

This study examines both environmental and social aspects of IEQ. Maintaining excellent IEQ is crucial as it can directly affect the safety and health of occupants, which is vital for enhancing patient recovery rates. Social responsibility, cost-effectiveness, and inventive capacity was identified as essential factors that enhance management efficacy and patient satisfaction (A. Hussain et al., 2024). It is important to consider patients' health issues throughout their hospitalization and to create an enhanced rehabilitation environment for vulnerable groups (Wu et al., 2023). The findings from Wu et al. (2023). demonstrated significant impacts of environmental elements on occupants' viewpoints, indicating factors such as air quality, lighting, acoustic levels, and temperature are important in shaping their overall experience and satisfaction. Engaging patients, staff, and other stakeholders in the design process ensures that IEQ measures align with the specific requirements and preferences of facility users. To successfully evaluate feedback from the users, surveys and focus group interviews can be conducted. While IEQ offers numerous benefits, healthcare facilities nonetheless encounter specific challenges in achieving and maintaining it, including financial constraints and ongoing maintenance requirements. To emphasize, budget constraints often inhibit hospitals from investing in energy-efficient HVAC systems or conducting regular maintenance on air filtration units, which negatively impact thermal comfort inside hospital environments while escalating yearly consumption costs (Ackley et al., 2024). Healthcare facilities should find alternate financing sources such as government grants or commercial partnerships to deal with these challenges.

The third and fourth themes align with SDG 9: Industry, Innovation, and Infrastructure. This alignment underscores the critical role of sustainable infrastructure in enhancing healthcare building while effectively delivering healthcare services. The primary advantage of green building in healthcare is the mitigation of environmental impact. Green healthcare offers environmental, economic, and social advantages. For example, it facilitates reductions in energy and water consumption. A study indicates that water usage in green hospitals can decrease by 20 to 30 percent, while energy consumption could decrease by approximately 30 to 40 percent. Additionally, green hospitals provide benefits such as enhanced daylight exposure, rapid patient recovery, improved natural connectivity, and increased hygiene and wellness (Tarkar, 2022). However, they face several constraints and problems such as difficult to fulfill the requirements for accreditation and licensing, safety and health regulations, and the operating hours of the hospitals disregard any interference in healthcare services (Tarkar, 2022). Conventional healthcare facilities significantly contribute to carbon emissions and waste production. A significant correlations occur between environmental management techniques and various sustainable construction technologies (Nebrida & Gomba, 2023). For instance, implementing a circular economy approach and using waste material as cement replacement in construction can significantly reduce waste generation, promote resource conservation and lower CO_2 emissions. The integration of sustainable infrastructure within healthcare not only mitigates environmental impacts but also ensures long-term viability and resilience of healthcare systems.

Technologies such as telemedicine, health information systems, and smart hospital have been implemented to optimize operations and reduce environmental impact. By focusing on technological innovations together with sustainability initiatives, healthcare organizations can establish a more efficient and environmentally responsible approach for healthcare delivery. During the COVID-19 pandemic, telemedicine services assisted non-critical patients with chronic conditions such as hypertension and diabetes while significantly reducing the number of new infections by avoiding physical contact (Chauhan et al., 2022). Post-pandemic, this technology can be employed to complement traditional in-person care that allows healthcare providers to offer remote consultations thus improving access to care for patients in rural or underserved areas. This transition from face-to-face interactions to virtual consultations has significantly changed the dynamics between patients and medical professionals that set a benchmark for future healthcare delivery models that prioritize accessibility and convenience. Similarly, Artificial intelligence (AI) that is widely used nowadays holds potential in expanding personalized care programs to remote and home based settings (Mennella et al., 2024). This situation benefits both sides. Healthcare providers can save on overhead costs associated with in-person visits while patients can reduce travel time and associated costs. Besides that, smart healthcare implementation offers some benefit including allows for early detection of health issues through continuous monitoring via IoT devices, and monitor the real-time status of diverse entities inside the healthcare system to deliver safer, quicker, and superior healthcare to patients through the utilization of digital twinning (Han et al., 2023). This shift towards smart healthcare not only enhances operational efficiency but also supports better decision-making and resource management in healthcare facilities.

The fifth theme aligns with SDG 13: Climate Action. Since the healthcare industry contributes around 5% of global carbon dioxide emissions, the transition of healthcare to carbon neutrality is essential for mitigating climate change and their associated health impacts (Al-Rawi et al., 2023). This underscores the urgent need for healthcare facility to prioritize sustainability initiatives and reduce their environmental impact, including transitioning to renewable energy sources and implementing energy efficiency measures such as utilizing solar power and replacing the current lighting with LED to reduce cost. Governments can implement policies, regulations, and incentive schemes to encourage healthcare facilities to adopt sustainable practices. For example, providing subsidies for energy-efficient advancement, renewable energy installations, and other sustainability-focused investments. Similarly, Jiang et al. emphasize the necessity of formulating economic policies prioritizing environmental concerns (Jiang et al., 2024). Minimizing carbon emissions helps in global climate change reduction efforts which is vital for maintaining public health. By reducing their carbon footprint, healthcare facilities can reduce the growing number of climate-related health problems, especially asthma that worsened by poor air quality and heat-related illnesses due to rising temperatures. Moreover, the shift towards carbon neutral healthcare facilities also offers numerous benefits that enhance operational efficiency and foster positive community relations.

RECOMMENDATIONS

In accordance with the pattern observed in previous research, this study agrees with Pantzartzis et al. (2017) that it is important to identify and assessing various sustainability indicators to improve hospital performance at multiple levels. This study presents several limitations that should be considered in future research. Although multiple elements of sustainability have been addressed, they may not encompass all critical measures or indicators that are essential for a comprehensive understanding of sustainability in healthcare. For instance, the scope of sustainable healthcare operation concept can be explored more deeply by examining specific strategies and the best practices for implementation within multiple healthcare facilities. Strategies employed, challenges faced, and negative impact of neglecting sustainability in healthcare facility should be focused, thereby it will serve as a guide for future implementations. Furthermore, future research should evaluate the impact of different government initiatives and identify which policies are the most effective. For example, conducting a comparative analysis between regulatory frameworks and government subsidies. This may comprise analyzing the impact of strict laws on compliance and innovation in contrast to the financial incentives offered through subsidies. Then, the strategy that achieves better outcomes for environmental sustainability and public health can be identified. Lastly, comparative research across various healthcare facilities such as public versus private hospitals or urban versus rural clinics should be conducted. This approach may be useful in identifying optimal practices that are appropriate to specific settings and can guide policy recommendations that consider geographical variations. Furthermore, it will ensure that every community's demands are fulfilled, ensuring that no one will be left behind.

CONCLUSION

The main purpose of this study is to analyze the strategies that can be implemented to enhance sustainability in healthcare facilities. The findings from this research directly contribute in achieving several key SDGs, specifically SDG 3 (Good Health and Well-Being), SDG 9 (Industry, Innovation and Infrastructure), and SDG13 (Climate Action). It provides a strong foundation for future studies to build upon and further advance sustainability in healthcare facilities. This study underscores the urgent need for sustainable healthcare solution in the context of increasing population and the rising demand for healthcare services. Several comprehensive strategies that are essential for enhancing sustainability in different healthcare facilities were identified from the review. The results acknowledged the significant gaps in existing literature regarding specific strategies and the best practices for implementing sustainability in healthcare facilities. The implementation of these strategies has the potential to reduce the environmental effect of healthcare operations while enhancing patient outcomes, elevating staff happiness, and promoting a more sustainable healthcare ecosystem. Moreover, the findings guide researchers on the specific themes and topics related to sustainability in healthcare facilities that require more attention. The review concluded that social and economic sustainability are equally important for achieving sustainable development. To achieve harmonious balance, every stage of healthcare, from construction and decision making to management and operations must be carefully evaluated. Involving various stakeholders, especially policymakers, healthcare staff and patients are critical to provide various perspectives and insight that improve decision-making processes; hence the healthcare sector can lead the way in creating a more sustainable and resilient future.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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