

## A Framework Study Going Toward Green Hospital

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**ABSTRACT:** Environmental pollution from hospitals and healthcare facilities has become a critical concern globally, leading to the introduction of the Green Hospital concept. These facilities aim to mitigate the harmful environmental impacts of healthcare activities by implementing sustainable practices, including energy conservation, hazardous waste management, and green purchasing. This study examines the existing challenges and progress toward achieving the benchmarks of a Green Hospital. A two-phase research approach was employed: (1) a comprehensive review of existing literature, databases, and studies to define the standards for Green Hospitals, and (2) interviews and questionnaires to gather insights from healthcare professionals involved in green initiatives. Results indicate that frameworks such as Leadership in Energy and Environmental Design (LEED) and ISO 14000 play pivotal roles in setting sustainability criteria, prioritizing energy efficiency, waste management, and environmentally friendly procurement practices. This research underscores the importance of these standards in guiding hospitals toward greener operations and highlights the ongoing need for innovation to ensure both environmental sustainability and improved public health outcomes.

**Keywords:** Green Hospitals, Green Hospital's Indicators, Sustainable Development

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## Sürdürülebilir Yeşil Hastane'ye Dönüşüm için Çerçeve Yapılanma

**ÖZ:** Environmental pollution from hospitals and healthcare facilities has become a critical concern globally, leading to the introduction of the Green Hospital concept. These facilities aim to mitigate the harmful environmental impacts of healthcare activities by implementing sustainable practices, including energy conservation, hazardous waste management, and green purchasing. This study examines the existing challenges and progress toward achieving the benchmarks of a Green Hospital. A two-phase research approach was employed: (1) a comprehensive review of existing literature, databases, and studies to define the standards for Green Hospitals, and (2) interviews and questionnaires to gather insights from healthcare professionals involved in green initiatives. Results indicate that frameworks such as Leadership in Energy and Environmental Design (LEED) and ISO 14000 play pivotal roles in setting sustainability criteria, prioritizing energy efficiency, waste management, and environmentally friendly procurement practices. This research underscores the importance of these standards in guiding hospitals toward greener operations and highlights the ongoing need for innovation to ensure both environmental sustainability and improved public health outcomes.

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### 1. INTRODUCTION

Hospitals and healthcare institutions play a crucial role in healthcare delivery. These institutions try to bring advanced medical technology and compassionate healthcare together to provide a lifeline during times of illness or injury. From routine check-ups to critical interventions, hospitals offer a range of medical services. Beyond their role as healthcare providers, hospitals are integral to our communities, supporting health education, research, and innovation. They can be considered guardians of our well-being and dedicated to improving the quality of life for individuals and society at large. Environmental pollution and carbon footprint are major concerns in modern society. Hospitals, especially those that rely on non-renewable energy, are significant contributors to these issues. They are responsible for emitting greenhouse gases and causing air pollution, which makes them a major source of environmental pollution.

Hospitals also produce a large amount of medical waste, hazardous materials, and disposable medical supplies leading to waste production. Medical equipment and supplies often contain chemicals such as disinfectants and sterilant, which can release harmful pollutants into the environment. In addition, hospital equipment like diagnostic machines, surgical tools, Heating, Ventilation, and Air Conditioning (HVAC) systems consume considerable energy. Addressing these issues and taking necessary steps towards reducing the environmental impact of hospitals and healthcare facilities are vital.

The concept of the sustainability revolution was introduced to prioritize a healthy and friendly ecosystem, sustainable economic activities, and social justice. It emerged to protect the environment from degradation and reduce the resource depletion caused by the Industrial Revolution. The sustainable revolution is an effort to confront issues such as climate change, water scarcity, ocean pollution, diversity gaps, health and safety, income equality, inclusion,

and human rights. Hospitals worldwide are trying to maintain high-quality standards while considering the ecological impact of their activities. As a result, the goal of this project is to create a comprehensive framework that encourages traditional hospitals and healthcare facilities to transform into sustainable and environmentally responsible institutions. This is why the concept of Green Hospitals was introduced (Norozi et al., 2020; Kamath et al., 2019).

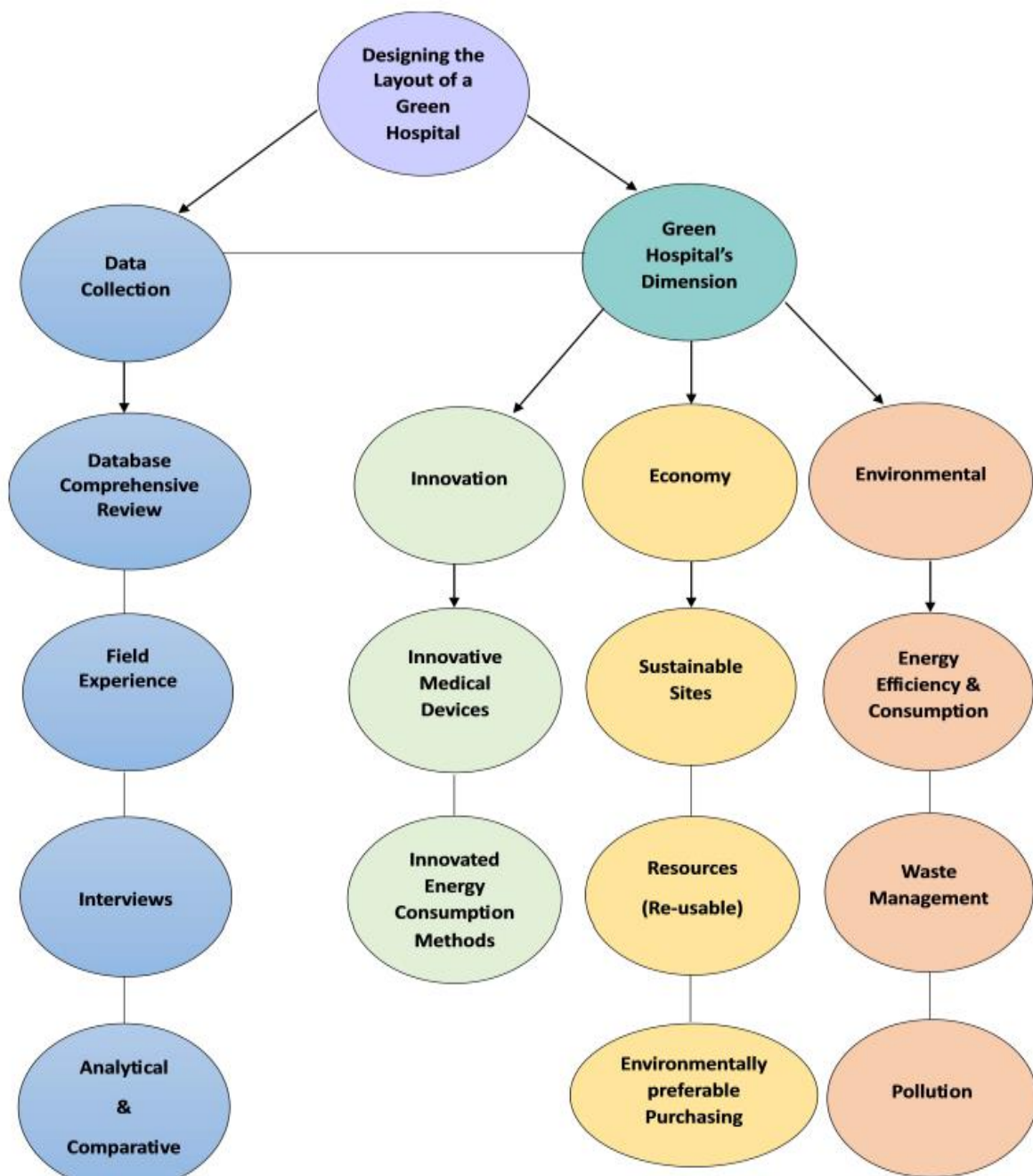
The primary aim of this project is to minimize the harmful environmental impact caused by healthcare institutions and hospitals, which are among the major contributors to environmental pollution. These institutions are implementing various measures to protect the environment from the adverse effects of human activities. For instance, they promote healthy nutrition, maintain a green ecosystem, manage hazardous chemicals, safely dispose of waste, control infections, and utilize alternative energy sources to reduce energy consumption and air pollution. Additionally, the location of the hospital and the use of Smart Hospital tools are considered to ensure the safety of the environment and people (Hoosmand et al., 2020).

The contribution of medical engineers towards creating and maintaining environmentally friendly and sustainable healthcare facilities cannot be ignored. In the establishment phase of a Green Hospital, biomedical engineers collaborated seamlessly with architects, healthcare administrators, and environmental specialists to create energy-efficient buildings that use sustainable materials and green technologies. They significantly contribute to the development of innovative medical devices and equipment that prioritize energy efficiency and waste reduction. Biomedical engineers take the lead in implementing measures to ensure optimal utilization of resources. This includes the implementation of smart monitoring systems, waste recycling programs, and sustainable water and energy management practices. With their interdisciplinary approach, biomedical engineers play a key role in promoting the transformation of hospitals into ecologically conscious institutions, ensuring that healthcare advancements are aligned with environmental responsibility.

The creation of a Green Hospital framework requires a multifaceted approach that prioritizes sustainability, optimal resource utilization, and a healthcare practice perspective. This project aims to identify criteria and standards for Green Hospitals by conducting a comparative-descriptive and qualitative analysis in two phases. In the first phase, a comprehensive review of various databases, information sources, and studies related to Green Hospitals was conducted to obtain a general understanding of the topic. A comprehensive literature review was carried out on Google and Google Scholar to gain foundational knowledge on current challenges, best practices, and emerging trends in Green Hospitals. Advanced AI technologies were also utilized to collect up-to-date information and emerging concepts to ensure that the project stays modern and innovative. In the second phase, three interviews were conducted to differentiate between a Green Hospital and a regular one based on a set of predetermined questions, two of them were in-person and the other was an email form. The purpose of these interviews was to clarify the primary responsibilities of biomedical engineers, and the specific medical devices used in hospitals. Moreover, the interviews aimed to clarify some unknown aspects of this concept and gather some practical experiences. Furthermore, the criteria for Green Hospitals were identified, highlighting the differences between true Green Hospitals and those that simply label themselves as environmentally friendly due to their surroundings.

To design a layout for a Green Hospital, two main categories were considered: data collection and Green Hospital's dimensions. Data was gathered by reviewing articles, conducting interviews, gaining field experience about the Green Hospital concept, and analyzing and comparing data. The Green Hospital dimensions, based on the collected and selected articles, are divided into environmental, economic, and innovative classifications. According to the articles based on the American Leadership in Energy and Environmental Design (LEED) method, sustainable sites, water and energy efficiency, materials and resources, waste management, innovation in medical devices, and energy consumption methods are described as dimensions of Green Hospitals (Noroz et al., 2020). (Figure 1)

Figure 1. Determining criteria of Green Hospital



## 2. METHOD

This research utilizes a two-phase methodology. In the first phase, a comparative and descriptive analysis of existing literature, databases, and case studies on Green Hospitals was conducted to establish a comprehensive framework for evaluation. Reputable databases, including PubMed, Scopus, and Google Scholar, were used to review existing models and standards for Green Hospitals. To ensure transparency and reproducibility, the literature review was conducted using predefined search criteria. The search was performed in PubMed, Scopus, and Google Scholar databases using combinations of keywords such as “Green Hospital,” “Sustainable Healthcare Facilities,” “Hospital Sustainability,” “Green Building in Healthcare,” and “Environmental Management in Hospitals.”

Peer-reviewed journal articles, review studies, and international reports published in English between 2000 and 2023 were considered for inclusion. Studies focusing on sustainability frameworks, environmental performance indicators, energy and waste management, and green building certification systems in healthcare settings were included.

Articles unrelated to healthcare facilities, non-academic sources, opinion pieces, and studies lacking relevance to environmental sustainability in hospitals were excluded. After initial screening based on titles and abstracts, full-text reviews were conducted to determine final eligibility.

In the second phase, a qualitative research approach was employed through structured interviews and questionnaires distributed to healthcare professionals working in hospital management, sustainability, and facility operations. Participants were selected based on their involvement in environmental management, biomedical engineering, or sustainability-related decisionmaking processes within healthcare institutions. In the qualitative phase of the study, interviews were conducted with two participants who were actively involved in hospital management and sustainability-related practices. The participants were selected using purposeful sampling based on their professional experience in biomedical engineering and healthcare facility operations. The interview questions were developed based on the findings of the literature review and focused on key themes such as environmental sustainability, energy efficiency, waste management, and the role of biomedical engineering in Green Hospital implementation. The questions were designed to explore both practical experiences and institutional perspectives related to green initiatives in hospital settings. The qualitative data collected were analyzed using thematic analysis to identify recurring patterns, key challenges, and emerging opportunities related to the implementation of green initiatives in hospital settings.

This two-phase approach enabled the integration of theoretical frameworks with practical insights, strengthening the reliability and applicability of the proposed Green Hospital framework.

This study includes studies that do not require ethics committee approval; data collection from data obtained through surveys, group studies, focus studies, observations, experiments, interviews, all kinds of research conducted with qualitative or beautiful treatments, humans

and animals (including material data) are used with universal or scientific data, parts performed on humans are not within the scope of those performed on animals.

### 3. RESULTS

The research identified several critical frameworks essential for the success of Green Hospitals. Models such as LEED, ISO 14000, and the Global Green and Healthy Hospitals (GGHH) initiative were frequently cited in the literature and by interview participants. These models emphasize sustainable waste management, energy conservation, water efficiency, and the use of environmentally safe materials. Key challenges include the high cost of transitioning to green technologies, resistance to change within institutional structures, and the lack of comprehensive policies incentivizing green practices. However, hospitals that have adopted these standards have reported significant improvements in operational efficiency and reductions in their environmental footprint.

#### 3.1. Green Hospital Criteria

Green Hospital is a healthcare facility that prioritizes environmental sustainability and eco-friendly practices. These hospitals focus on energy efficiency, resource conservation, waste reduction, and overall environmental responsibility (Figure 2).

Figure 2. Green Healthcare Benefits



By integrating environmentally friendly technologies, practices, and infrastructure into their operations, Green Hospitals aim to minimize their ecological footprint and promote both human health and environmental wellbeing. To certify the eco-friendly attributes of these healthcare institutions, various green building assessment models such as ISO 14001, Green Building Index (GBI), World Health Organization (WHO), Leadership in Energy and Environmental Design (LEED), and Green Building Rating System (GBRS) are used (Noroz

et al., 2020). For instance, The Children's Hospital of Pittsburgh is a Green Hospital and succeeded in gaining LEED certification. This hospital practices landscape maintenance using recycled water and has transitioned to a paperless system where all test results, patient notes, and data are electronically stored. Amanjaya Hospital in Sungai Petani, Malaysia has achieved the GBI Gold rating for its eco-friendly features including rainwater harvesting, solar panels, natural ventilation, and energy-efficient lighting (Sahamir et al., 2017; Ali et al., 2022).

The following text describes different strategies for transforming hospitals into green buildings. Four main criteria for green hospitals are categorized.

### 3.1.1. Sustainable Waste Management

Healthcare organizations generate significant waste, which poses environmental risks due to inefficient management systems. Implementing well-organized waste management programs can reduce waste, lower costs, and improve patient and staff safety. A key step is shifting consumption patterns and adopting effective waste management practices to decrease handling and disposal costs, ultimately contributing to a cleaner and safer environment (Sahamir, Rozana, 2014; Singh et al., 2016). Hospital waste is classified into two categories: hazardous (risk) and non-hazardous (non-risk). Hazardous waste includes sharp, chemical, pharmaceutical, and radioactive materials, which can harm human health and the environment, while non-hazardous waste consists of everyday items like paper and food waste. Proper management of these waste types, as shown in Figure 3, is crucial for sustainability efforts.

Figure 3. Different Types of Hospital Waste



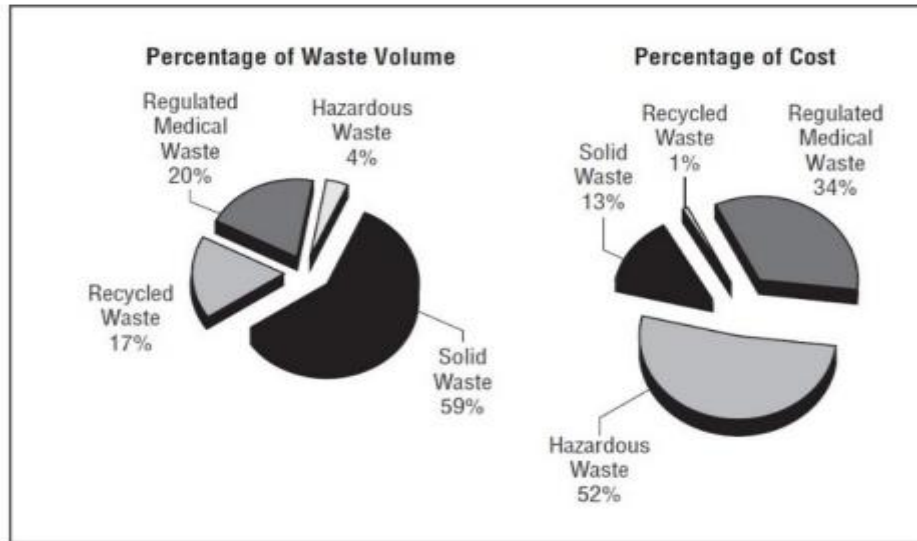
Figure 4. The Most to the Least Favorable Options of Waste Management



In Green Hospitals, sustainable waste management is a core focus. This involves reducing, recycling, and safely disposing of waste to minimize environmental impact. Figure 4 illustrates the hierarchy of waste management options, with prevention being the most favorable and disposal the least. Effective waste management also leads to a healthier environment for both patients and healthcare staff (Hooshmand et al., 2019).

Key strategies include proper waste segregation with clear guidelines and color-coded bins, which facilitate the correct handling of general, biomedical, recyclable, and hazardous waste. Biomedical waste involves steps like recycling, reducing transport needs, and segregating chemical and pharmaceutical waste. Despite hazardous waste making up only 24% of total medical waste, it accounts for 86% of disposal costs, underscoring the need for accurate segregation. (Kamath et al., 2019).

Figure 5. Comparison of Waste Volume and Cost



To minimize waste, hospitals can adopt policies like purchasing reusable glass and metals, sterilizing equipment, and partnering with recycling manufacturers. In Green Hospitals, it's also essential to prioritize the safe disposal of hazardous materials, including pharmaceutical waste (www.chp.edu ,2023).

Overall, integrating these waste management practices into Green Hospital standards is vital for creating a sustainable and eco-friendly healthcare system. Through waste reduction, recycling, and responsible disposal, Green Hospitals set an example for sustainability in the healthcare sector.

### 3.1.2. Innovative Medical Equipment

The healthcare industry is evolving towards sustainability, with hospitals increasingly adopting eco-friendly practices. Research highlights the role of innovative medical equipment in promoting environmentally conscious practices within healthcare. This section discusses key technologies that contribute to Green Hospitals:

#### 3.1.2.1. Digital Health Records (DHR) Systems

DHR systems are essential for sustainability, offering efficient data management, reducing paper use, and improving healthcare communication. Interoperable DHR systems minimize redundant testing and documentation, cutting down on waste generation. For instance, paperless ECG machines store data digitally, reducing costs and improving efficiency (GGHH,2024; USGBC, 2023; linkedin.com, 2023).

#### 3.1.2.2. Reusable Medical Instruments

Durable and sterilizable instruments are a key waste-reduction strategy. Reusable equipment like endoscopic devices and catheters reduce the environmental impact of single-use tools. This approach aligns with responsible resource utilization (Azmal, 2014).

### 3.1.2.3. Low-power Consuming Monitoring Devices

Energy-efficient monitoring devices, including patient monitors and wearable technologies, lower healthcare's energy consumption while providing effective patient care.

### 3.1.2.4. Smart Lighting Systems

Automated lighting systems, powered by sensors, reduce energy use in hospitals. These systems adjust lighting based on natural light, occupancy, and time of day, contributing to both sustainability and patient comfort.

### 3.1.2.5. Water-Saving Medical Equipment

Water-saving technologies, such as efficient dental chairs, reduce water usage during procedures. These devices optimize water flow and recycling, contributing to safe water management in healthcare settings.

### 3.1.2.6. Environmentally Friendly Anesthesia Machines

Advanced anesthesia machines with low environmental impact use efficient gas delivery methods and gases with reduced global warming potential. These innovations help hospitals lower their carbon footprint (Kwayke at al.,2021).

Figure 6. Avance CS2 with Eco flow Anesthesia Machine



### 3.1.3. Energy Conservation and Efficiency

Energy efficiency and water conservation are core principles for hospitals aiming for "green" recognition, with significant economic and environmental benefits. Hospitals are major energy consumers, with one in Brazil using 10% of the electrical energy from the domestic commercial sector. By adopting energy-efficient initiatives, hospitals can reduce utility costs and natural resource consumption, addressing environmental concerns. Programs like

ENERGY STAR and LEED recognize hospitals' efforts in sustainability, emphasizing their commitment to community well-being (Szklo et al., 2014).

Key energy efficiency initiatives include using separate electrical meters for different systems, optimizing natural light, improving ventilation, and reducing CO<sub>2</sub> emissions (Marshal, 2021). Hospitals like Great Ormond Street Hospital in the UK have implemented innovative systems such as underfloor heating, significantly reducing carbon dioxide emissions. Simple measures like switching to LED lights, adjusting thermostats, and purchasing energy-efficient equipment can lead to major cost savings (Figure 7) (Kamath et al., 2019; MHE, 2010; Energy Star, 2009). For example, New York-Presbyterian Hospital upgraded its lighting, air conditioning, and pumping systems in 2003, saving \$1.77 million annually (Kwakye, 2011; Energy Star, 2009; Techsmartfuture, 2023).

Figure 7. Energy Efficiency Programs

| Program   |
|---|
| <ul style="list-style-type: none"> <li>• Energy-efficient heating, venting and air -conditioning system designs</li> <li>• Energy-efficient lighting system designs</li> <li>• Energy-efficient sterilization, gas and water plants</li> <li>• Energy-efficient waste disposal systems</li> <li>• Energy-efficient housekeeping methods</li> <li>• Energy-efficient medical and nonmedical equipment</li> <li>• Thermal storage analysis systems and cooling analysis systems</li> <li>• Energy-efficient building infrastructure designs</li> <li>• Highly motivated and trained staff, including senior management, for initiating and implementing energy-saving protocols.</li> </ul> |

Shifting clean, renewable energy sources like solar and wind can also reduce greenhouse gas emissions, protecting public health by mitigating the effects of climate change. These efforts reduce hospital admissions and treatments for pollution-related illnesses like asthma and heart disease, improving both health and economic conditions (GGHH, 2024). Water conservation is another critical component. Reducing water use alleviates pressure on municipal supplies and lowers energy consumption for water treatment, benefiting both clinical operations and the environment (EPA, 2023). WHO's 2020 Guidelines for Environmentally Friendly Hospitals recommend monitoring water usage, implementing water-saving features, and using alternative water sources such as recycled and rainwater (Marshal, 2021). Hospitals like CIMS in India are setting an example with on-site sewage treatment, water reuse, and water-efficient landscaping practices (Kamath, 2019).

In summary, integrating energy efficiency and water conservation in healthcare addresses economic concerns while promoting sustainability, improving patient care, and fostering community health. These strategies highlight the transformative potential of Green Hospitals to reduce resource consumption and environmental impact while supporting sustainable healthcare practices.

### **3.1.4. Other Criteria of a Green Hospital**

#### **3.1.4.1. Green Building Design and Material Selection for Sustainable Hospitals**

Sustainable hospital design incorporates eco-friendly practices like energy efficiency, natural ventilation, and durable materials. Strategic site selection near public transportation minimizes emissions (MHE, 2008). Local materials and designs integrated with natural surroundings enhance sustainability and occupant well-being (GGHH, 2024; Szkło, 2004). Green building practices also emphasize reducing pollution, preserving biodiversity, and optimizing energy, water, and resource use. The adoption of these principles promotes environmental responsibility in healthcare infrastructure (Kwakye et al., 2011).

#### **3.1.4.2. Sustainable Transportation Strategies for Green Hospitals**

Hospitals can mitigate their transportation-related environmental impact by adopting green practices. This includes promoting public transportation, walking, and cycling while also transitioning fleets to hybrid or electric vehicles. These steps reduce emissions and air pollution, contributing to public health improvements. Encouraging greener commuting habits among staff and patients, such as carpooling or using bicycles, is essential in reducing the healthcare sector's carbon footprint (Azmal et al., 2014).

#### **3.1.4.3. Sustainable Food Management in Green Hospitals**

Hospitals are adopting green principles in nutrition by sourcing local, organic, and toxin-free ingredients. Food waste is a significant issue, and hospitals like University Hospital Galway have reduced waste through predictive ordering and efficient food management. A global shift toward eco-friendly menus, including composting and reduced meat consumption, is becoming more common. Some hospitals even produce food onsite or host farmers' markets, promoting sustainable food practices that improve patient health and reduce environmental impact (Marshall et al, 2021).

#### **3.1.4.4. Green Purchasing in Green Healthcare**

Hospitals, with their vast purchasing needs, have a significant influence over supply chains. By prioritizing environmentally friendly and socially responsible products, healthcare facilities can reduce their environmental footprint and promote ethical labor practices. Green purchasing policies focus on reducing packaging waste, eliminating harmful substances, and considering the entire lifecycle of products, ultimately contributing to a sustainable healthcare system (Marshall et al, 2021).

### 3.2. Case Study (Interviews)

A private hospital in Istanbul was an effective case study, offering invaluable insights into the qualitative aspect of the project. During the study the hospital is named Hospital A. The collaboration was initiated with the technical department, where the project's primary concerns were found through elucidation.

The Private Hospital A has been recognized as a Green Hospital since its establishment in 2019, having earned enough points to be awarded the gold LEED certificate. LEED certification does not expire for building design and construction projects. However, it is necessary to renew the certification every 3 or 5 years for building operations and maintenance projects.

The hospital's commitment to environmental responsibility is evident through several noteworthy actions:

**Water Management:** The Hospital A actively utilizes rainwater and greywater by collecting and storing them in a dedicated facility. This water is then exclusively employed for external usage, minimizing dependence on conventional water sources.

**Innovative Elevator System:** The Hospital A's elevator system is designed to optimize energy usage. Even in the event of a power outage, the elevators continue to function, harnessing gravity for downward movement. This innovative approach ensures continuous service while minimizing energy consumption. The picture taken in Figure 8 shows the innovative elevator system that is used in the Private Hospital's Clinic.

Figure 8. Innovative Elevator System



**Remote Control Systems:** Embracing advanced technology, the hospital remotely controls crucial systems such as electricity, computers, devices, and HVAC systems through tablets and mobile phones. This not only enhances operational efficiency but also allows for real-time monitoring and control. The pictures are captured in Figure 9 to illustrate HVAC and electricity remote control systems.

Figure 9. HVAC &amp; Electricity Remote Control System

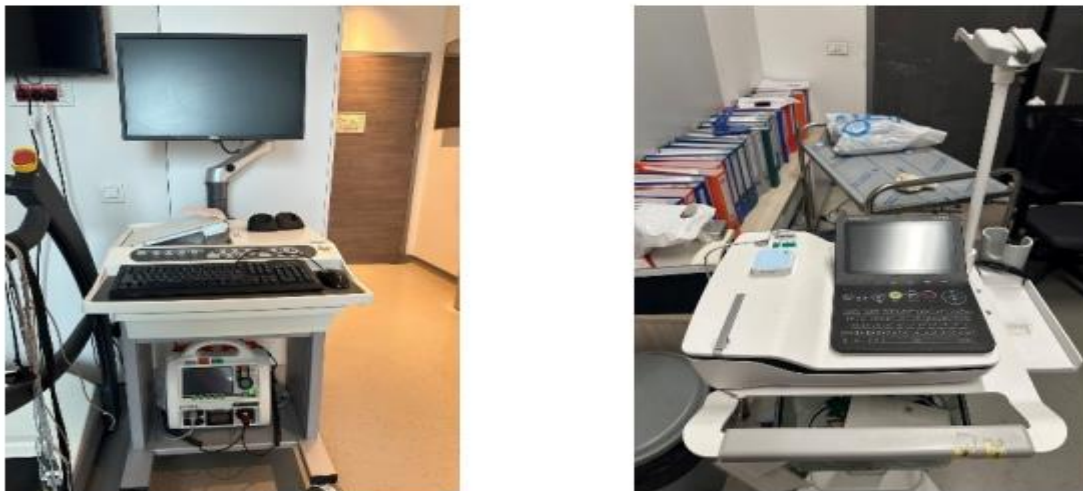


**Waste Management for Certification:** An integral aspect of their green initiative involves the meticulous separation of trash into different categories. These categorized waste items are then entrusted to specialized companies; a strategic move aimed at securing a LEED certificate. This partnership emphasizes the hospital's dedication to responsible waste management practices.

The integration of biomedical engineering at in the Hospital A not only emphasizes advancements in healthcare technology but also aligns with the principles of sustainability, promoting a healthier environment.

One notable biomedical engineering innovation is the digitalization of ECG processes. Rather than relying on traditional ECG paper, the hospital has implemented software that sends ECG results directly to mobile phones or computers, enhancing efficiency and reducing paper consumption. Pictures in Figure 10 were taken to show the ECG paperless machine.

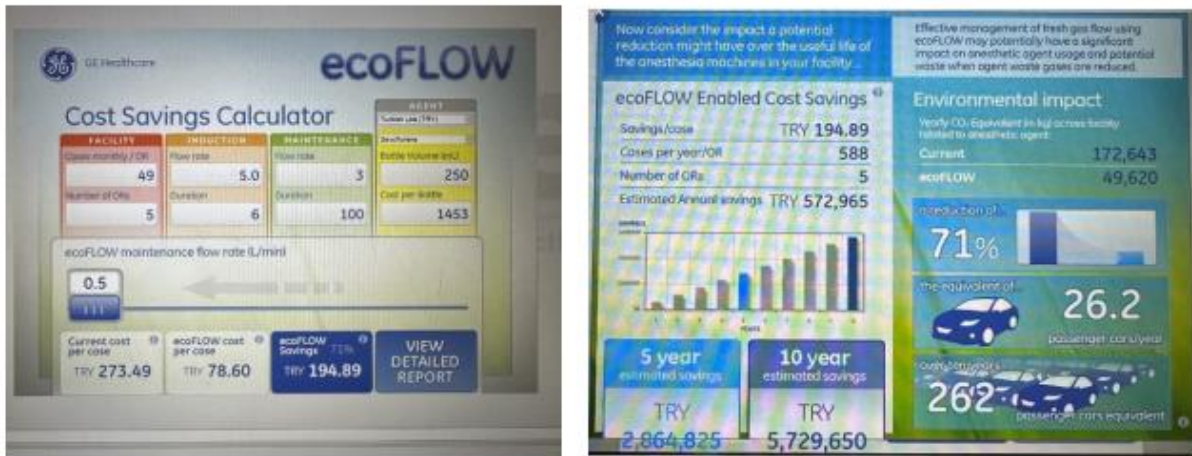
Figure 10. Paperless ECG Device



In the area of anesthesia, Hospital A stands out for its adoption of low-flow anesthesia technology. While traditional anesthesia devices consume 4-5 liters of anesthetic gases per

usage, the hospital utilizes a more efficient machine that requires only 0.5 liters. This not only ensures convenience but also significantly reduces the environmental impact associated with anesthetic gas consumption, aligning with the hospital's commitment to green practices. Additionally, the pictures in Figure 11 provide evidence of the significance of the ecoFLOW machine at the Hospital A.

Figure 11. Low-Flow Anesthesia Machine



Biomedical engineering further contributes to sustainability through innovations in sterilization systems. The hospital has replaced the central steam system for autoclave devices with generators, resulting in a remarkable monthly energy saving of 150,000 KW/h. This strategic shift not only eliminates the consumption of 150,000 KW/h but also utilizes the steam generated by the device itself, showcasing a dual commitment to energy efficiency and waste reduction.

These biomedical engineering initiatives at the Hospital A exemplify a conscientious effort to merge technological advancements with environmental responsibility. By embracing digital solutions, optimizing anesthesia practices, and reimagining sterilization processes, demonstrate that innovation can coexist with sustainable and eco-friendly healthcare practices. This dual focus on technological progress and environmental superintendence underscores the transformative potential of biomedical engineering in shaping the future of healthcare.

The fundamental principle of Green Hospitals is to use energy efficiently and wisely. The Hospital exemplifies this principle by prioritizing energy efficiency and minimizing consumption. The overarching goal is not merely to utilize energy sparingly but also to create avenues for its reuse, embodying a sustainable approach to energy management.

Furthermore, the hospital's dedication to energy efficiency extends beyond biomedical innovations. The Hospital A remotely controls electricity, allowing staff to monitor and manage electrical energy through their phones and computers. This proactive approach not only enhances operational control but also contributes to reduced energy consumption.

Highlighting the hospital's broader environmental impact, it is essential to consider its monthly energy consumption. The Hospital A consumes approximately 420,000 KW/h of electricity, 220,000-246,000 KW/h of natural gas, and 36,500 KW/h of water by the end of October 2023. Comparatively, the average energy consumption of hospitals in Turkey is approximately 572.6 kWh/m<sup>2</sup>/year which is significantly higher, emphasizing the hospital's success in optimizing energy usage. Table 4 displays information about the Hospital A's energy consumption as of the end of October 2023.

Table 4. BHT Clinic Istanbul Tema Hospital Energy Consumption 2023

| BHT CLINIC ISTANBUL TEMA HOSPITAL ENERGY CONSUMPTION TABLE 2023 |                    |                   |            |                    |                   |             |                    |                   |         |
|---|--------------------|-------------------|------------|--------------------|-------------------|-------------|--------------------|-------------------|---------|
| CONSUMPTION PERIOD  | ELECTRICITY 2023   |                   |            | NATURAL GAS 2023   |                   |             | WATER IN 2023      |                   |         |
|   | CONSUMPTION AMOUNT | CONSUMPTION PRICE | UNIT/TL    | CONSUMPTION AMOUNT | CONSUMPTION PRICE | UNIT/TL     | CONSUMPTION AMOUNT | CONSUMPTION PRICE | UNIT/TL |
| January   | 388766             | 11,742,019.71     | 466664     | 6753,727.28        | 3377              | 148,461.37  | 42,554,288.36      |                   |         |
| February  | 350,968            | 11,336,135.79     | 468468     | 4691,466.72        | 2897              | 142,325.17  | 42,069,957.68      |                   |         |
| March   | 344364             | 11,028,247.85     | 383455     | 4433,240.11        | 3016              | 144,049.15  | 41,505,537.12      |                   |         |
| April   | 315918             | 1022,741.35       | 288,216    | 4261,447.03        | 3691              | 163,925.51  | 41,138,113.90      |                   |         |
| May   | 371383             | 11,053,878.04     | 238,949    | 4216,656.08        | 3337              | 148,753.57  | 41,319,467.69      |                   |         |
| June  | 429706             | 1,021,331.79      | 156,165    | 4141,778.07        | 4000              | 164,720.00  | 41,227,629.86      |                   |         |
| July  | 552105             | 11,752,045.63     | 148,174    | 4134,894.61        | 4596              | 174,353.28  | 41,951,383.62      |                   |         |
| August  | 567759             | 11,877,981.64     | 163,153.00 | 4149,007.85        | 4000              | 164,720.00  | 42,091,789.49      |                   |         |
| September   | 478433             | 11,449,585.00     | 115,948    | 4105,069.30        | 4066              | 173,797.90  | 41,629,442.20      |                   |         |
| October   | 407877             | 11,373,832.00     | 23,719     | 425,950.43         | 3407              | 170,286.41  | 41,470,078.84      |                   |         |
| November  |                    |                   |            |                    | 2605              | 168,110.00  | 458,110.00         |                   |         |
| December  |                    |                   |            |                    |                   |             | 40.00              |                   |         |
| UNTTOTAL  | 4207269.00         | 113,457,798.82    | 2459630.75 | 42,924,457.48      | 39991             | 1643,512.36 | 417,025,778.65     |                   |         |
| GRAND TOTAL   |                    |                   |            |                    |                   |             |                    |                   |         |

Hospital A is a leader in sustainable healthcare, combining biomedical engineering innovations with energy-efficient and eco-friendly practices. Its initiatives, such as using

digital solutions and optimizing energy consumption, set an example for other hospitals. In contrast, the other interviewed private Hospital B, while eco-friendly in appearance due to its green landscape, does not meet the comprehensive criteria required for Green Hospital status, such as LEED certification and energy efficiency.

Karolinska University Hospital in Solna, Sweden, is a standout example of a true Green Hospital, meeting both LEED and Miljöbyggnad certification standards. With a focus on energy efficiency, sustainable materials, and waste management, Karolinska integrates environmental responsibility into its infrastructure through collaborations with various partners. This comparison highlights varying approaches to green healthcare, with Karolinska and The Private Hospital A excelling in holistic sustainability practices.

Table 5 illustrates a comparison of the three hospitals based on different criteria including certification for green hospitals, water and waste management, innovation, and energy efficiency.

Table 5- Comparison Between Three Hospitals

| <b>Criteria</b>                           | <b>Hospital A</b>  | <b>Hospital B</b>  | <b>Karolinska University Hospital</b>   |
|---|--|--|---|
| <b>Recognition as a Green Hospital</b>    | Recognized as a Green Hospital, awarded GOLD LEED certificate                        | Known as eco-friendly but does not meet Green Hospital criteria      | Established as a Green Hospital, holds GOLD LEED and Miljöbyggnad certification |
| <b>Water Management</b>                   | Active use of rainwater and greywater for external purposes                          | No specific details provided   | Not specified   |
| <b>Innovative Elevator System</b>         | Optimizes energy usage, utilizes gravity during power outage                         | Not specified  | Not specified   |
| <b>Remote Control Systems</b>             | Controls electricity, devices, HVAC systems through tablets and phones               | No information on remote control systems                             | Not specified   |
| <b>Waste Management</b>                   | Exact separation of trash for LEED certification                                     | Emphasis on visually green landscape, no details on waste management | Modern waste transport, sorting at source for material recycling                |
| <b>Biomedical Engineering Innovations</b> | Digitalization of ECG processes, low-flow anesthesia, efficient sterilization system | No information provided  | No information provided   |

|                                   |   |                                     |   |
|-----------------------------------|---|-------------------------------------|---|
| <b>Energy Efficiency</b>          | Prioritizes energy efficiency, monthly consumption data provided        | No information on energy efficiency | Established with Green credentials, complies with certification standards |
| <b>Monthly Energy Consumption</b> | Electricity: 420,000;<br>Natural Gas: 220,000–246,000;<br>Water: 36,500 | No data provided                    | No data provided  |

Hospital A, Hospital B, and Karolinska University Hospital showcase different approaches to green healthcare. Hospital A stands out with its comprehensive green initiatives, including innovative water management, remote control systems, and pioneering biomedical engineering innovations like digitalized ECG processes and low-flow anesthesia. Hospital B, while emphasizing a visually green environment, lacks the structured approach to meet Green Hospital criteria. In contrast, Karolinska University Hospital is a pioneer, established with green credentials, and holds GOLD LEED certification. The hospital's construction, guided by Miljöbyggnad and LEED systems, ensures energy efficiency, indoor environmental quality, and sustainable materials.

The waste management strategy, collaboration between stakeholders, and the pursuit of environmental excellence highlight Karolinska's commitment to holistic green practices. The monthly energy consumption data underscores the success of Hospital A in optimizing energy usage, emphasizing the hospital's notable achievements in sustainable healthcare.

#### 4. DISCUSSION

The findings suggest that the transition to Green Hospitals is both a necessary and feasible step toward mitigating healthcare's environmental impact. LEED and ISO 14000 certifications provide tangible benchmarks for achieving sustainability, but more work is needed to ensure that smaller hospitals and facilities in resource-limited settings can also adopt these measures. Stakeholder engagement, especially among healthcare professionals, is crucial for successful implementation. Hospitals that align themselves with green standards not only contribute to environmental sustainability but also enhance patient safety and community health outcomes.

#### 5. CONCLUSION

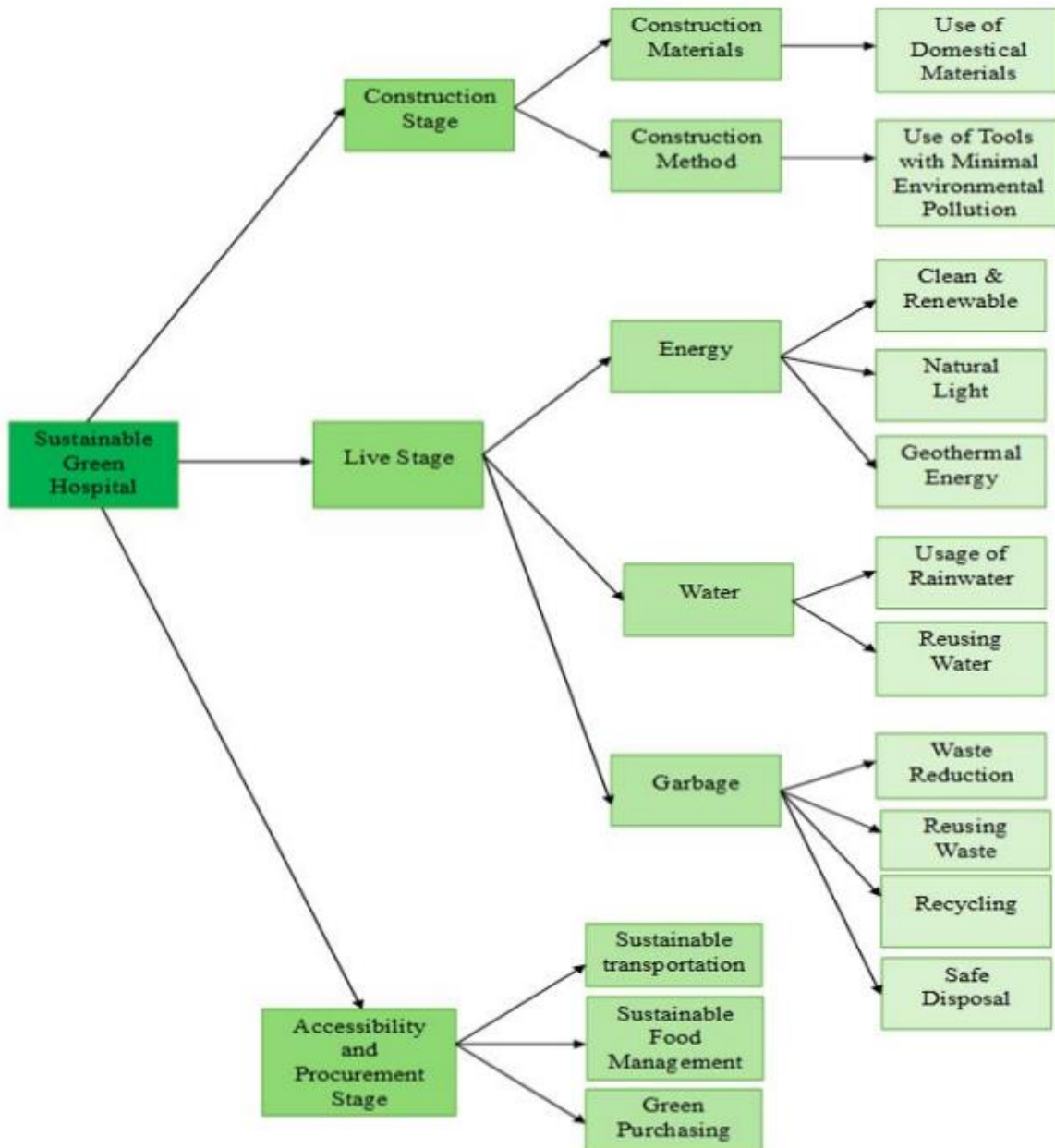
The concept of Green Hospitals has emerged as a response to the significant environmental impact caused by hospitals and healthcare facilities. This project focused on the existing challenges and the current state of achieving the benchmarks of a Green Hospital, emphasizing the importance of adopting measures such as sustainable waste management, innovative medical equipment, energy conservation and efficiency, and sustainable material selection. Green Hospitals play a vital role in improving human health and preserving the environment, contributing to a healthier and prosperous future for humans and the ecosystem.

The integration of environmentally friendly technologies, practices, and infrastructure into the operations of Green Hospitals aims to minimize their ecological footprint and promote both human health and environmental well-being. By prioritizing environmental sustainability and eco-friendly practices, these institutions focus on energy efficiency, resource conservation, waste reduction, and overall environmental responsibility. Furthermore, the certification of eco-friendly attributes of these healthcare institutions is facilitated through various green building assessment models such as ISO 14001, Green Building Index (GBI), World Health Organization (WHO), Leadership in Energy and Environmental Design (LEED), and Green Building Rating System (GBRS).

The project also illustrates specific areas of focus within the realm of Green Hospitals, including sustainable waste management, innovative medical equipment, energy conservation and efficiency, green building design and material selection, sustainable transportation, sustainable food management, and green purchase. These areas underscore the multi-faceted approach required to establish and maintain Green Hospitals, emphasizing the need for well-organized waste management, the integration of innovative and environmentally conscious medical equipment, and the implementation of energy-efficient initiatives to address both economic and environmental considerations.

This flowchart, represented in Figure 12, depicts the different stages and components involved in creating a sustainable Green Hospital. It highlights the importance of accessibility and procurement, construction methods, materials, energy usage, sustainable food management, transportation, renewable energy, and waste reduction. The flowchart emphasizes the utilization of tools, materials, and methods that have minimal environmental impact, as well as the implementation of green purchasing practices. Furthermore, the Green Hospital project employs renewable energy sources such as geothermal energy and natural light to reduce its carbon footprint. The hospital has also implemented sustainable food management practices to ensure that its food offerings are healthy and environmentally friendly. Overall, the flowchart provides a comprehensive overview of the sustainable practices that are being implemented in the hospital project to create a greener and healthier environment for all.

Figure 12. Main Stages of Sustainable Green Hospital



The implementation of the above-mentioned environmental strategies emerges as an essential factor in achieving true sustainability. It is not sufficient to merely understand these strategies; their integration is mandatory to realize sustainable practices. Aligned with the United Nations' Sustainable Development Goals (SDGs), this project emphasizes the significance of maintaining balance across various aspects, particularly in the realms of affordable and clean energy, innovation, and infrastructure.

The SDGs, which were adopted by the United Nations in 2015, determine the pivotal role of affordable and clean energy, innovation, and infrastructure leading to the development of a sustainable environment. Investment in infrastructure and innovation stands as a critical catalyst for economic growth and development. Since more than half of the global population resides in cities, prioritizing mass transport, renewable energy, and the advancement of new industries and information technologies should be increasingly magnified.

The strategic expansion of infrastructure and the adoption of cleaner and more efficient energy sources globally are identified as drivers which can affect not only economic growth but also environmental conservation. Keeping a balance between affordable and clean energy, boosting innovation, and enhancing infrastructure is the key to bridging the existing gap between current conditions and the expected sustainable environment. This holistic approach lays the foundation for a future where environmental sustainability is comprehended and additionally integrated into every facet of our global community profoundly (UNEP, 2021).

In conclusion, the pursuit of Green Hospitals represents a significant step towards mitigating the environmental impact of healthcare facilities and fostering a sustainable and eco-friendly approach to healthcare. By embracing the principles of environmental sustainability and integrating innovative technologies and practices, Green Hospitals can serve as beacons of responsible and conscientious healthcare, contributing to the well-being of both individuals and the environment.

**Conflict of Interest Statement:** There is no financial conflict of interest with any institution, organization or person related to this study and there is no conflict of interest between the authors.

**Ethics Statement:** This study includes studies that do not require ethics committee approval; data collection from data obtained through surveys, group studies, focus studies, observations, experiments, interviews, all kinds of research conducted with qualitative or beautiful treatments, humans and animals (including material data) are used with universal or scientific data, parts performed on humans are not within the scope of those performed on animals.

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