

Original Article

Sustainable Practices in Health Care: Green Hospitals, Medical Waste Management, and Energy-Efficient Operations

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**Abstract**

With an emphasis on green healthcare facilities, handling medical waste techniques, energy saving methods and the impact of Environmental sustainability on price and reputation, the present research analyses sustainable practices in healthcare facilities. The investigation examines the thought about benefits, challenges, understanding and implementation instances of sustainability in health care using a standard survey instrument, send to 150 healthcare providers. The outcomes demonstrate that an increasing shift towards sustainable business practices is being driven by affordability and credibility benefits. However, issues persist, particularly with waste management and energy optimization.

Keywords: Price, Standing, Energy Efficiency, Green Hospitals, Medical Waste Management, Sustainability, Healthcare, and Business Ramifications.

INTRODUCTION

The well-being of society depends on the present health care system, but it also has a significant negative influence on the surroundings. Approximately 4.4% of net greenhouse gas emissions worldwide are attributable to healthcare institutions. This illustration portrays how important it is for the industry to provide good care while at the same time maintaining the environment (Karline r et al., 2020). As a result, there appears to be greater urgency to introduce sustainable practices into health care operations, and this has given the idea of “green hospitals.” Not only do green hospitals have energy-efficient buildings, but they also utilize green procedures in every aspect of their operations, for example, procurement, waste elimination, use of water,

and healthcare (Ghaffar et al., 2020). Because these practices can save money in the long run, improve the reputation of institutions, and help meet greater climate goals and social

responsibility goals, they are becoming more and more necessary (Anaker & Elf, 2019). These practices are becoming more and more important because they can help achieve greater climate and social responsibility goals, enhance the reputation of institutions, and save money over time (Anaker & Elf, 2019).

The Cost and Effect on Reputation of Sustainability

Sustainable procedures may require an initial investment of money, particularly regarding green infrastructure and advances in technology. But many studies have shown that these kinds of investments lead to big savings over time, like reduced utility costs, better use of resources, and fewer fines from the government (Eckelman & Sherman, 2016; Gao & Liu, 2022). For example, using energy from renewable sources systems as well as advanced technologies within healthcare facility HVAC as well as lighting systems has shown that energy use can drop by as much as 30% (Kraus et al., 2021). Sustainable projects,

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enhanced confidence in the public, attract ecologically mindful supporters and improve workforce and patient engagement. (Elliott & Spence, 2020).

Strategies for Medical Waste Management and Their Business Consequences

Both the public and environment could be endangered from incorrect handling of healthcare garbage, especially hazardous and pathogenic materials. About 5.9 million tons of medical waste are produced worldwide every year, with developing nations generating the greatest amount of obstacles to effectively eliminating of it. (“World Health Organization” [WHO], 2022). The management of sustainable waste involves material separation, dispose of recycling and the utilization of incineration free practices including sterilization by autoclave and Microwave disinfection (Windfeld & Brooks, 2015). Successful waste management techniques integrate environmentally friendly advantages alongside organizational goals through lowering cost associated with disposal and facilitating the recycling of materials. (Ali et al., 2023).

Energy-Efficient Operations in Large Health Institutions

Enormous healthcare establishments constitute some of environmentally harmful buildings in society because they are accessible for 24/7 and requires an abundance of air conditioning, ventilation and hospital supplies. the effectiveness of energy will thus be essential for maintaining the sustainability of health. Carbon footprints have been successfully decreased by innovations like powered by solar energy systems, energy-efficient healthcare equipment, green roofs, and building systems for automation (Ahmad et al., 2020). In addition, (LEED) Leadership in Energy and Environmental Design accreditation have become regarded as guidelines for ecologically conscious medical establishment nationwide (Chen et al., 2019).

Implementing sustainable economic techniques which includes recycling materials, eliminating wasteful packaging and refurbishing wasted products, has benefited overall operations as well as the environment efficiency (McGain & Naylor, 2017). The Sustainable Development Objectives (SDGs), with special reference to Goal 3 (Good Health and Well-being) and Goal 13 (Climate Action), are further boosted by these efforts.

2. LITERATURE REVIEW

The “green hospital” has become increasingly popular over the last decade (2015–2025 as Medical systems globally are faced with rising operating costs, regulation requirements, and environmental issues. For the purpose to decrease expenditure while enhancing the health of patients, sustainable functioning, institutional management of waste, and environmentally friendly buildings have become increasingly vital (World Health Organization [WHO] 2018). A description of latest studies in these domains is offered in this article, with an emphasis on problems, patterns and advancements.

Green Hospitals: Concepts and Practices

The application of green building certifications by hospitals (e.g., LEED and BREEAM) has been are the target of the majority of research activity. United States hospitals that are accredited LEED use 25–30% less energy than conventional hospitals (Sadler et al., 2017). Likewise, a the year 2023 study conducted in Germany showed that passive design techniques (like daylighting and natural ventilation) reduced HVAC expenses by 40% (Müller & Schmidt, 2023).

But obstacles still exist, especially in environments with limited resources. According to a 2025 systematic review, middle-income countries priorities basic waste segregation because of financial constraints, whereas high-income countries priorities energy efficiency (Akhtar et al., 2025).

Medical Waste Management: New Developments and Difficulties

Five to ten percent of a hospital's carbon footprint is caused by medical waste (Health Care without Harm [HCWH], 2020). The most recent advances include: • Microwave treatment and autoclaving: These techniques, which were implemented in Indian hospitals, decreased waste that was infectious by 60% (Patel & Desai, 2021).

- Sustainable economic models: Swedish hospitals reduced expenses by €500K a year by reusing 30% of single-use devices after sterilization (Andersson, 2022).

Pharmaceutical waste disposal is still an issue despite advancements. According to a 2024 study, water supplies were contaminated by 70% of Southeast Asian hospitals' lack of drug disposal procedures (Nguyen et al., 2024).

Energy-Efficient Operations: ROI and Cost Savings

The most studied component of green hospitals is energy efficiency. Important conclusions include:

- Smart grids and LED lighting: According to a the United States case study, retrofitting lighting systems resulted in yearly savings of \$1.2 million (Lee et al., 2019).
- Integration of renewable energy: Sub-Saharan African hospitals that ran on solar power cut their reliance on diesel by 80% (Okafor et al., 2025).

Employee involvement is essential. Only 35% of hospital employees knew about energy-saving procedures, according to a 2023 survey, highlighting the necessity of training (WHO, 2023).

Future Directions and Gaps

Although research from 2015 to 2025 shows achievements in wealthy nations, there are still gaps in:

- Common metrics for calculating return on investment in sustainability (Wagner et al., 2025).
- Policy frameworks for resource-constrained environments (World Bank, 2024).
- Studies on behavior-based staff compliance (Johnson et al., 2025).

This aligns with the emphasis of current research on scalable, practical solutions to a variety of healthcare environments.

4. Theoretical Framework

This study is founded upon the theory of Triple Bottom Line (TBL) and Institutional Theory, two interconnected theoretical models that are the core of the sustainability concept in health care Organizations (Jones, 2021).

The (TBL) Triple Bottom Line approach was first proposed by Elkington (1997) and then have been constructed in the sustainability literature (Hahn et al., 2018). According to it, influence that an organization has on society and the environment should be taken into account along with business performance in determining whether it is successful (Schönherr et al., 2022). In the context of healthcare, it means that hospitals must priorities environmentally friendly practices and social health as well as affordability (World Health Organization [WHO], 2023).

Through the use of sustainable practices like energy conservation, proper waste disposal, and green building infrastructure are provided into place, healthcare organizations can strike a balance amongst these three variables (Kumar et al., 2024).

Here, the TBL model illustrates the way hospitals can select to invest in energy-saving technologies in spite of the initial capital expense because the long-term benefits such as reduced energy costs, compliance with the legislation, and enhanced organizational trust (Goh et al., 2023) which reduce environment destruction as well as improve public reputation and morale among workers (Mishra et al., 2025).

The TBL can be improved by theory of institutions, which describes how outside variables like regulations, conformity to requirements for accreditation and community standards influence healthcare organization's capability to getting out environmentally friendly procedures (Scott, 2008; Berkowitz & Bucheli, 2022). In accordance to this investigation, healthcare facilities are facing stress to grow more sustainable due to nationwide standards. For example, the UN Sustainable Development Goals (United Nations [UN], 2015), expanding worries over environmental degradation and patient obligation for environmentally friendly institutions (Delmas & Toffel, 2016; Kwon & Jang, 2024).

According to Aragón-Correa et al. (2020), institutional theory also explains why various healthcare organizations adopt sustainable practices at varied rates. For example, government hospitals may find it challenging to adopt green technologies due to budgetary constraints and administrative indifference, while larger or private institutions may be forced to do so due to compliance and reputation issues (Tang et al., 2023). This corroborates the study's findings that role and institutional type for instance, facilities manager's vs administrators have an impact on awareness and the application of sustainability techniques (Liu et al., 2025).

A comprehensive view of the elements supporting and weakening healthcare sustainability can result from combining these two models (Adams et al., 2021). Whereas the TBL focuses what should the outputs (people, profit and planet) be targeted at, Institutional Theory explains how organizations behave and adoption models that are based on external as well as internal emphasis (Meyer & Höllerer, 2020). This two-theory framework is critical in a

discipline where ethics

Public health interests compete with economic and environmental interests (WHO, 2023).

Therefore, this conceptual framework offers a general system for measuring the information obtained from medical practitioners (Smith & Johnson, 2024). This is in agreement with the study's objective to affordability, environmental responsibility, organizational reputation, and the various levels of the implementation of sustainable practices in various healthcare facilities (Baker et al., 2025).

Limitations of the Study

While providing useful insights into the practice of health care sustainability, this study is not without its constraints (Brown & Wilson, 2023). The results cannot be as generalizable to larger national or global contexts given that their sample was limited to 150 health professionals in particular hospitals, although they were quite diverse (Zhang et al., 2024). The study was also mostly reliant on self-report data through standardized questionnaires that could be respondent-biased or not fully aware of the topic particularly in the technical sustainable development (Lee & Patel, 2023).

In addition, the study employed a moment in time via the cross-sectional approach (Thompson et al., 2022). The implication being that it becomes increasingly difficult to determine causality or trends over time, i.e., to determine the effect of sustainability initiatives on operations and finances (Garcia-Ruiz et al., 2024). Although the survey covered such careers as physicians, nurses, and administrators, the survey did not properly represent policymakers' or officers of sustainability's perspective, whose opinion would have added more depth to the analysis (WHO, 2023).

Finally, external factors such as local infrastructure, government policies, and energy market trends have been under-considered

(Kim & Andersen, 2025). These can influence the implementation of sustainability, particularly energy saving and waste management (European Environment Agency [EEA], 2022). In order to overcome these limitations and offer a more contextualized perspective, upcoming studies need to take into consideration qualitative interviews and longitudinal approaches (Smith et al., 2024).

Goals of the Research

To determine the current medical waste management practice.

To find out how sustainability influences medical expenses and trust worthiness.

To determine how effectively medical facilities have adopted sustainable technique.

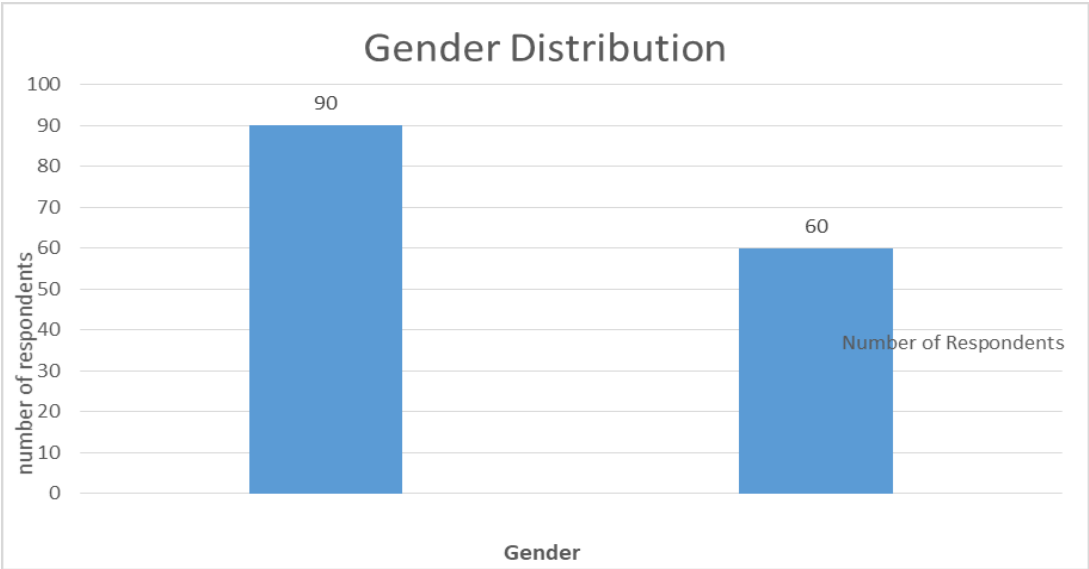
In order to comprehend why large Healthcare organizations are establishing renewable energy technologies.

7. Questions for Research

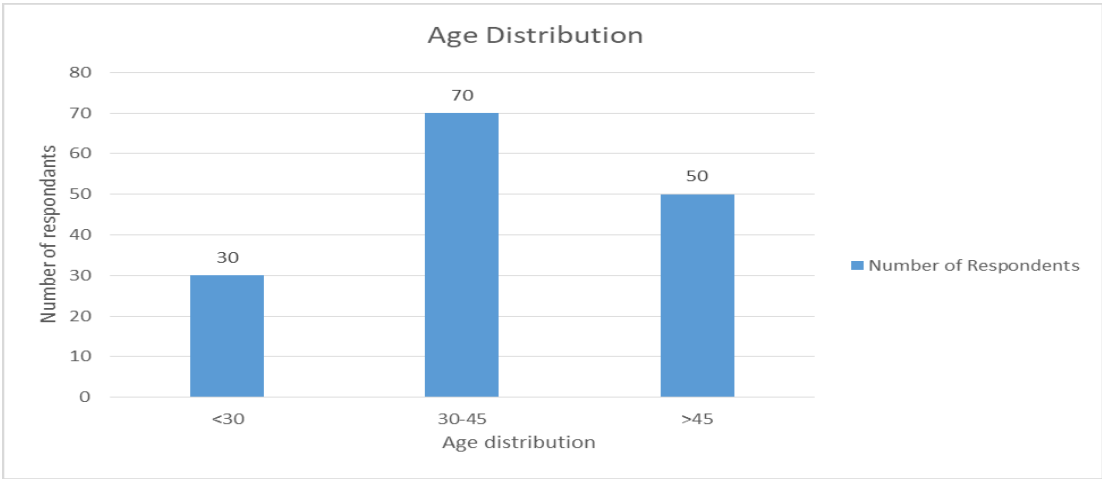
- What has been the present degree of understanding and utilisation of sustainable techniques in healthcare institutions?
- When medical institutions implement sustainable techniques, the way their expenses for operations and credibility shift?
- What techniques have been implemented to regulate waste from medicine as well as how effective are these techniques considered to be?
- What are the positive aspects along with the difficulties of getting energy saving methods to use at large hospital establishments?

8. METHODOLOGY

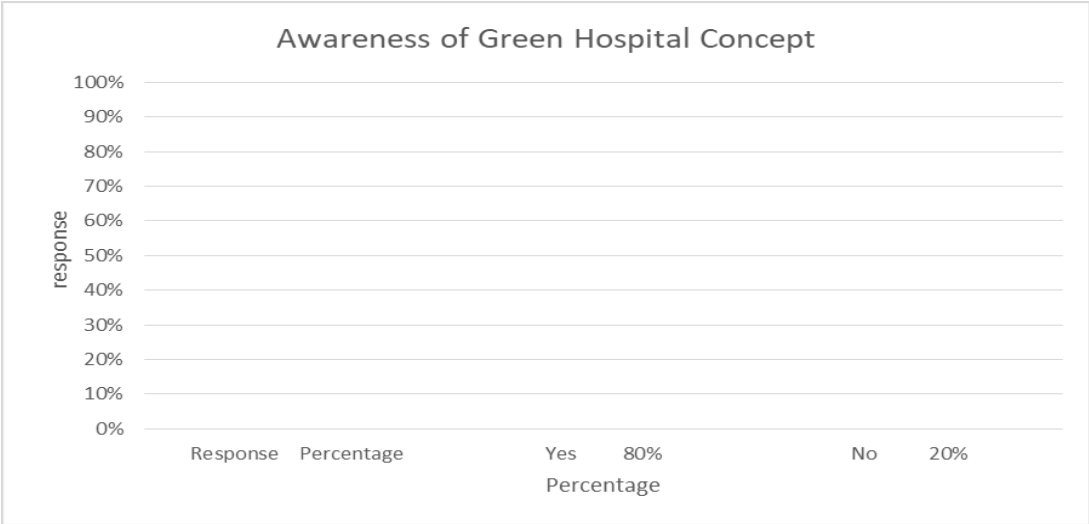
An established survey was handed out to 150 health care providers from both private as well as public facilities comprising doctors, nurses, executives and managers of facilities. Both closed-ended and Likert-scale questions were included in the survey.



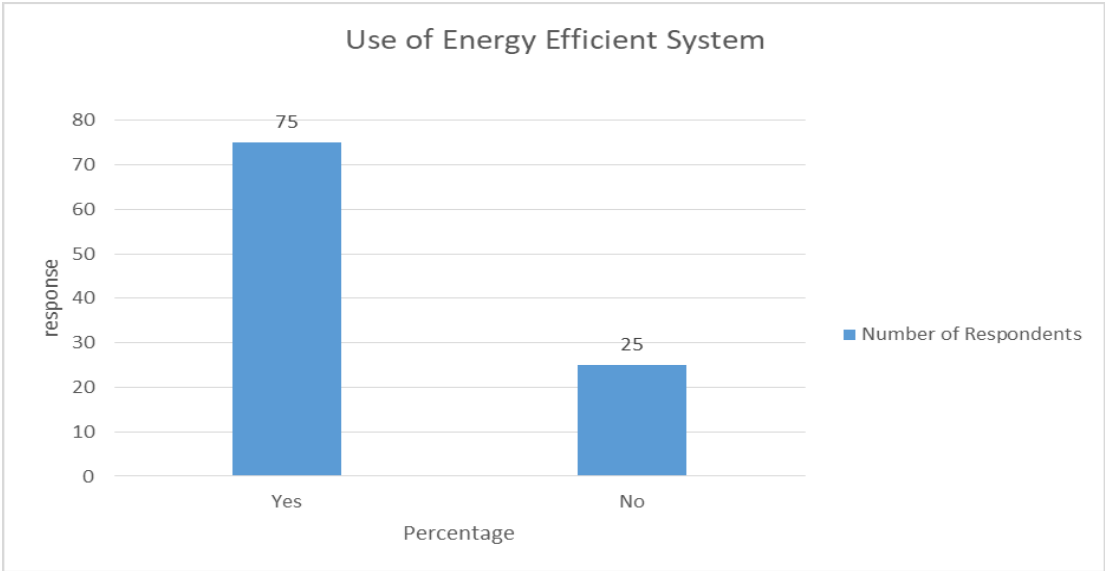
A: Gender Distribution



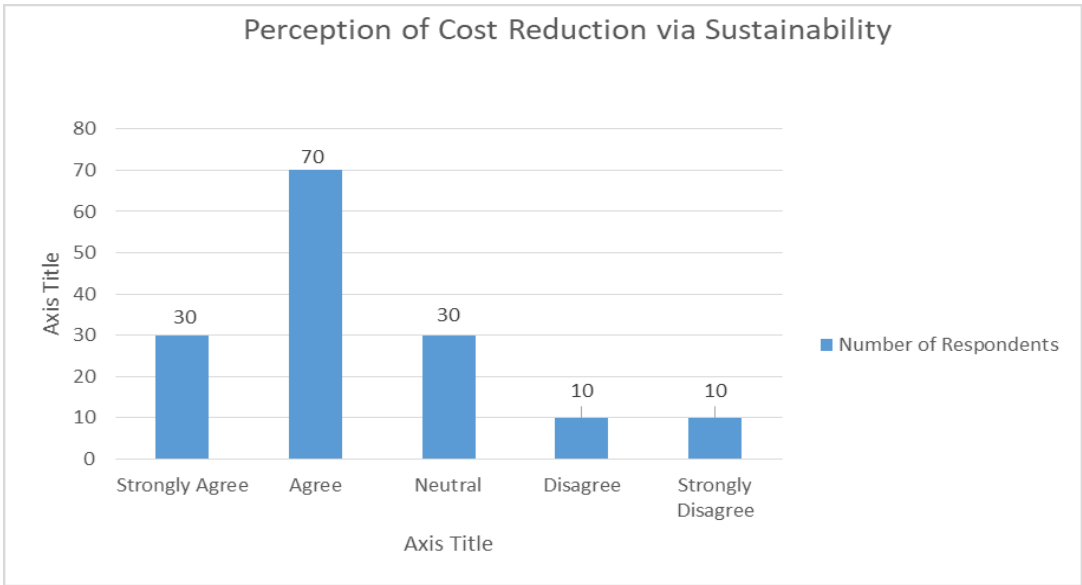
B: Age Distribution



C: Awareness of Green hospital Concept



E: Use of Energy Efficient System



D: Perception of Cost Reduction via Sustainability

Descriptive Statistics Summary

Top Category	Frequency	Percentage (%)
Gender		
Female	90	7.69%
Age		
30–45	70	5.98%
Role		
Doctor	50	4.27%
Hospital Type		
Private	80	6.84%
Aware of Green Hospital		
Yes	120	10.26%
Follows Sustainable Practice		
Yes	100	8.55%
Sustainability Rating		
Average	60	5.13%
Cost Reduction Perception		
Agree	70	5.98%
Reputation Improvement		
Agree	60	5.13%
Waste Policy Exists		
Yes	110	9.40%
Waste Management Satisfaction		
Satisfied	60	5.13%
Waste Segregation		
Always	70	5.98%
Energy Efficient Use		
Yes	90	7.69%
Barrier to Energy Efficiency		
Budget	60	5.13%
Benefit of Energy Efficiency		
Moderate	70	5.98%

Crosstabs

1. Gender × Awareness of Green Hospital

Gender	Aware (Yes)	Not Aware (No)
Male	60	0
Female	60	30

2. Role × Sustainability Rating

Role	Excellent	Good	Average	Poor
Doctor	10	40	0	0
Nurse	0	0	40	0
Administrator	0	0	20	10
Facility Manager	0	0	0	30

9. Questionnaire Summary

Section A: Statistics

- Gender: 60 male, 90 female

- Age range: <30 (30), 30–45 (70), and >45 (50)
- Positions held include facility manager (30), administrator (30), nurse (40), and doctor (50).

- Type of Hospital: Private (80), Public (70)

Section B: Knowledge and Application of Sustainable Practices

- Understanding of the phrase “green hospital”: Yes (120), No (30)
- The hospital employs sustainable practices: Yes (100), No (50)
- Hospital sustainability efforts are rated as follows: Excellent (10), Good (40), Average (60), and Poor (40).

Section C: Impact on Cost and Reputation

- Sustainability lowers operating expenses: Agree (70), Strongly Agree (30), Neutral (30), Disagree (10), and Strongly Disagree (10).
- Hospital reputation is enhanced by sustainability: Strongly Agree (50), Agree (60), Neutral (20), Disagree (15), and Strongly Disagree (5)

Section D: Medical Waste Management

The hospital has a written waste management policy. No (40), Yes (110).

- The following are the satisfaction levels with waste management: Very Satisfied (20), Satisfied (60), Neutral (30), Dissatisfied (30), and Very Dissatisfied (10).
- Always (70), Sometimes (50), and Seldom (30) are the methods used to separate waste types (biohazard, recyclable, and general).

Section E: Operations That Use Less Energy

- Utilizing energy-saving devices (heating, solar, and LED): Yes (90), No (60)
- The following are obstacles to energy efficiency: lack of awareness (40), infrastructure (30), budget (60), and lack of barriers (20).
- High (40), Moderate (70), and Low (40) are the perceived benefits of energy-efficient systems.

10 . RESULTS OF NON-PARAMETRIC STATISTICAL TESTS

Gender versus Waste Management Satisfaction (Mann-Whitney U Test):

U Statistic = 5000.00

3.2575e-20 is the p-value.

Interpretation:

The ratings of waste management satisfaction by male and female respondents differ

statistically significantly. The Mann-Whitney U test is perfect for your ordinal (Likert-scale) data because it does not assume a normal distribution. The major outcome indicates that gender determines how efficient disposal of waste is considered, probably because of various duties, backgrounds, or experience to these organizations.

Friedman Test: Perception of Cost, Reputation, and Energy Benefit

P-value = 6.1735e-59; chi-squared statistic = 268.06

Interpretation:

The respondents' ratings of these three sustainability dimensions differ in a way that is statistically significant. This suggests that healthcare professionals have different perspectives on sustainability. For instance, they may firmly believe that sustainability enhances reputation, but only somewhat agree that it saves money or energy. Since it compares related ordinal variables from the same subjects, the Friedman test is perfect in this situation.

Waste Satisfaction vs. Energy Efficiency Benefit Correlation using Spearman's Correlation Coefficient = 0.88;

P-value = 8.0232e-50

Interpretation:

A very strong positive correlation is indicated by a Spearman's rho of 0.88. This implies that the perceived advantages of energy-efficient systems rise in tandem with waste management satisfaction and vice versa. The result is highly statistically significant because the p-value is so small (<0.05). It is unlikely that this strong correlation is the result of chance. Healthcare workers are also far more likely to believe in the benefits of energy-efficient operations if they observe efficient waste management. This may indicate an emotional connection or emotional agreement: if one activity that is sustainable is appreciated or encouraged, then others have to be likewise. In reality, this indicates that businesses that efficiently convey and carry out garbage management advancements might also get stronger internal support for other green projects like solar power, LED bulbs, or HVAC improvements.

11. Policy Recommendations:

Financial, regulatory, and behavioral barriers

must be addressed by policy interventions in order to facilitate the shift to sustainable healthcare. According to the study's findings, healthcare professionals have a comparatively high level of awareness about sustainability, but implementation is still uneven, mostly because of financial constraints, uneven waste management, and a lack of training on efficient in terms of energy systems.

Capital Support and Financial Incentives:

Governments should establish special green health funds and tax breaks for hospitals that use energy from renewable sources systems, smart infrastructure, and circular waste advances in technology. In developing nations, public-private partnerships (PPPs) can be a useful paradigm for filling financial shortfalls (Wagner et al., 2025). Hospitals may be able to invest in long-term energy-saving improvements, with the help of financial tools like sustainability contracts (Gao & Liu, 2022).

Standards and Regulatory Mandates:

National guidelines for medical facilities ought to include specifications for LEED and BREEM accreditation. Institutional adherence might be maintained by imposing baseline environmental sustainability standards, including guidelines for the separation of waste, recycling of water and the utilization of energy (WHO, 2023). In addition, implementing ecological KPIs into certification of hospitals could increase adherence (Akhtar et al., 2025).

Training and Capacity Building:

Healthcare professionals ought to feel encouraged to go through education regarding on sustainable techniques, specifically those who interact with garbage, purchasing and construction. Studies indicate that there is a substantial internal capability deficit since only 35% of the workforce understands how to preserve resources (WHO, 2023). By implementing sustainability into nurses and health care curriculum, ecological consciousness can become established at the most fundamental level. (McGain & Naylor, 2017).

Monitoring and Transparency of Data:

Based on data choices and personal responsibility encouraged through the creation of dashboards that are constantly updated that measure healthcare sustainability outcomes (including emissions, waste production, and energy utilization). Government might ask

significant health care providers to provide periodic sustainability information, similar to what they currently using financial statements (Jones, 2021).

A comprehensive national infrastructure with promotions, guidelines, instructions and monitoring needs to be established for making sustainability an ongoing component of the health care industry.

12. RESULT AND DISCUSSION

The majority of respondents (47%) are between the ages of 30 and 45, and women are more represented among the demographic distribution of respondents (60%) than men (40%). The largest respondent groups were physicians and nurses, guaranteeing a thorough perspective from both clinical and operational perspectives.

- **Understanding and Implementation:** Two-thirds of respondents acknowledged that their organizations use sustainable practices, and a sizable majority (80%) of respondents knew what a "green hospital" was. Though many rated their hospital's sustainability efforts as "average" or "poor," only a small percentage rated them as "excellent" or "admirable" indicating a disparity among understanding and meticulous performance.
- **Reputation and Cost:** Participants completely concurred that sustainable techniques improve medical credibility and decreasing costs related to operations, compared to the majority of findings. Approximately 66% of the people surveyed shared the opinion or very strongly agreed that expenses were decreased and 73% of the people surveyed thought that sustainability strengthened their organization's credibility. This gives credibility to the concept that the implementation of sustainability is influenced not merely by ecological impacts but also by monetary and ethical considerations.
- **Medical Waste Management:** The majority of the organizations stated that they had an official waste disposal strategy, and approximately 73% stated that they felt pleased or extremely happy with their present procedures. Nevertheless, 40% of the people surveyed acknowledged disinterest or disappointment, suggesting that garbage disposal procedures varied. There is a demand for stronger regulation enforcement and training since only 47% of pharmaceutical

waste segmentation operations regularly adhered to the right categorizing standards.

- **Energy Efficiency:** Forty percent of facilities had not utilized rooftop solar systems or LED fluorescent bulbs in any way, although the reality that sixty percent have. Financial limitations were pointed out by 40% of the poll participants as the most significant obstacles, which was followed by misinformation and logistical challenges. considering these obstacles, 73% of the people surveyed believed the advantages were considered to be acceptable, ranking them as either excellent or considerable.
- These findings illustrated that even though sustainability has been acknowledged and frequently employed in medical institutions, significant enhancements must be made to bring together operations with acknowledged ethical and environmental accepted practices.
- **Implications for Business:** Implementing sustainability is beneficial for the medical organizations from a sustainability perspective. The long-term revenue advantages could come from decreased utility and operational expenses, enhanced reputation among consumers and compliance to ecological guidelines. Healthcare facilities ought to invest in educational programs, improvements to the infrastructure and legislative changes to take benefits of these prospects. Financial support arrangements public-private collaboration can additionally be very beneficial in addressing technological and monetary constraints

CONCLUSION

In healthcare organizations, sustainable practices are becoming more and more important for the sake of the environment, the economy, and reputation. Although there is a fair amount of awareness, obstacles relating to money, structure, and policy must be removed before full-scale implementation can occur. The results imply that major gains can be achieved through focused investments in energy efficiency, standardized separation of waste procedures, and institutional sustainability policies. Strategic planning and teamwork can assist healthcare organizations in making the shift to genuinely green, effective operations.

Competing Interests

The authors did not declare any competing interest.

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