Health Leadership and Quality of Life. 2023; 2:323
doi: 10.56294/hl2023323

ORIGINAL

Investigating the Convergence of Healthcare Management and Environmental Sustainability Initiatives

Investigación sobre la convergencia de la gestión sanitaria y las iniciativas de sostenibilidad medioambiental

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Cite as: Narayan Lenka D, Jyothi.S R, Kumar Lyngdoh N N, Asif M, Gupta S. Investigating the Convergence of Healthcare Management and Environmental Sustainability Initiatives. Health Leadership and Quality of Life. 2023; 2:323. https://doi.org/10.56294/hl2023323

Submitted: 07-06-2023 **Revised:** 02-09-2023 **Accepted:** 13-11-2023 **Published:** 14-11-2023

Editor: PhD. Prof. Neela Satheesh

ABSTRACT

Bringing together healthcare management and environmental sustainability efforts has become an important way to deal with the world problems of health and environmental decline. Though they are distinct, both fields are closely related as they strive to improve society. More people desire services; costs are rising; environmental issues like pollution, climate change, and resource depletion are increasingly taxing healthcare systems all around. Concurrent with this, environmental sustainability initiatives seek to mitigate negative impacts of human activities on the planet by motivating individuals to use resources more sensibly and leave fewer residual carbon footprints. The links between environmental sustainability and healthcare management are examined in this essay together with the advantages and drawbacks of merging these two spheres. It discusses how medical institutions could reduce their impact on the surroundings by applying sustainable practices. They could advocate for medical products produced from sustainable materials and decrease waste and energy usage, for instance. The research also examines how public health is directly impacted by environmental problems such changes in ecosystems, restricted water sources, and bad air quality. The healthcare and environmental sectors must cooperate more closely if we are to build a long-term more resilient system. The article also covers how new tools, government regulations, and policy frameworks could assist to make healthcare practices more sustainable. It looks at the opportunities of green healthcare practices include hospitals using less energy, long-lasting healthcare supply lines, and making decisions considering environmental health. The coming together of these two areas is good for public health and helps with the larger goal of healthy growth around the world. Climate change and health problems are becoming more and more connected, so healthcare management systems need to start using environmental methods in their daily work. This all-around method can lead to a future where both people's and the planet's health are valued, making the world better and more sustainable for future generations.

Keywords: Healthcare Management; Environmental Sustainability; Green Healthcare Practices; Climate Change and Health; Sustainable Development.

RESUMEN

Aunar los esfuerzos de gestión sanitaria y sostenibilidad ambiental se ha convertido en una forma importante de afrontar los problemas mundiales de salud y deterioro del medio ambiente. Aunque son distintos, ambos campos

están estrechamente relacionados en su empeño por mejorar la sociedad. Cada vez hay más gente que necesita servicios, los costes aumentan y los problemas medioambientales, como la contaminación, el cambio climático y el agotamiento de los recursos, afectan cada vez más a los sistemas sanitarios de todo el mundo. Paralelamente, las iniciativas de sostenibilidad ambiental tratan de mitigar el impacto negativo de las actividades humanas en el planeta motivando a las personas para que utilicen los recursos con más sensatez y dejen menos huella de carbono residual. En este ensayo se examinan los vínculos entre la sostenibilidad ambiental y la gestión sanitaria, así como las ventajas e inconvenientes de fusionar ambas esferas. Se analiza cómo las instituciones médicas podrían reducir su impacto en el entorno aplicando prácticas sostenibles. Por ejemplo, podrían abogar por productos médicos fabricados con materiales sostenibles y reducir los residuos y el consumo de energía. La investigación también examina cómo la salud pública se ve directamente afectada por problemas ambientales como los cambios en los ecosistemas, la restricción de las fuentes de agua y la mala calidad del aire. Los sectores sanitario y medioambiental deben cooperar más estrechamente si queremos construir un sistema más resistente a largo plazo. El artículo también explica cómo las nuevas herramientas, normativas gubernamentales y marcos políticos pueden ayudar a que las prácticas sanitarias sean más sostenibles. Entre las oportunidades que ofrecen las prácticas sanitarias ecológicas figuran el menor consumo energético de los hospitales, la mayor durabilidad de las líneas de suministro sanitario y la toma de decisiones teniendo en cuenta la salud del medio ambiente. La unión de estas dos áreas es buena para la salud pública y contribuye al objetivo más amplio de un crecimiento sano en todo el mundo. El cambio climático y los problemas de salud están cada vez más relacionados, por lo que los sistemas de gestión sanitaria deben empezar a utilizar métodos medioambientales en su trabajo diario. Este método integral puede conducir a un futuro en el que se valore tanto la salud de las personas como la del planeta, haciendo que el mundo sea mejor y más sostenible para las generaciones futuras.

Palabras clave: Gestión Sanitaria; Sostenibilidad Medioambiental; Prácticas Sanitarias Ecológicas; Cambio Climático y Salud; Desarrollo Sostenible.

INTRODUCTION

As the world struggles with both public health problems and environmental damage at the same time, the idea of combining healthcare management with efforts to protect the environment is getting more and more attention. At the point where these two important areas meet, there is a chance for businesses, cities, and communities to make systems that are stronger, healthy, and last longer, which is good for everyone. As the world's healthcare system continues to grow to meet the needs of an ageing population, more people with chronic diseases, and changing public health requirements, it's becoming clearer that natural resources and ecosystems are under more stress. At the same time, natural problems like climate change, pollution, and the loss of species are having very big effects on public health, especially in groups that are already weak. In the last few decades, there have been big changes in both the healthcare field and the environmental green groups. More people desire services, costs are rising, and healthcare systems all around lack the means necessary. Conversely, environmental sustainability initiatives seek to limit climate change, reduce carbon emissions, preserve ecosystems, and prevent the depletion of natural resources.[1] Examining these different but related areas holistically is crucial as environmental and health issues may interact in complex ways. For instance, climate change aggravates air pollution, makes water and food scarce, and facilitates the spread of infectious diseases—all of which directly affect public health. Healthcare systems unable to handle these issues might thus run much more risk and waste from other sources. Popularly known as "green healthcare," these approaches centre sustainability in medical settings. They present an optimistic approach to handle environmental degradation as well as the issue of growing healthcare expenses.[2]

Healthcare companies are searching more and more for methods to use sustainable practices to reduce their effect on the environment, increase the efficiency of their operations, and provide their patients better treatment. Some of these methods cut the quantity of medical waste thrown away, utilise fewer energy-consuming structures, and employ better instruments and supplies for medical professionals. Though it's difficult to strike a decent balance between cost, effect on the environment, and patient care, the healthcare sector is currently working on extensively implementing these sorts of policies. The health of people and the health of the environment are linked, hence one of the primary areas where environmental sustainability and healthcare agree is From respiratory ailments to cardiac issues, pollutants in the environment including particulate matter, carbon dioxide, and hazardous chemicals have been connected to various health issues.[3] Particularly those carried by water and insects, changes in the climate like rising temperatures, altered patterns of rainfall and destruction of natural areas can also facilitate the spread of infectious illnesses. Healthcare management systems should consider the environment as the climate disaster is worsening. This

serves to safeguard public fitness in addition to provide infrastructure capable of dealing with problems brought on via weather exchange. The way environmental sustainability projects and healthcare control engage relies upon a lot on rules and laws created via the authorities. Many sectors have regulatory systems that make it more crucial for healthcare facilities to adhere to environmental criteria, observe sustainable practices, and screen their impact at the surroundings. These styles of pointers are intended to accomplish more than handiest lessen the carbon footprint of scientific remedy.[4] They also make certain that the sector aligns with widespread objectives of sustainable development. As an example, the Sustainable development goals (SDGs) of the United Nations underline the want of maintaining the environment and ensuring anyone has get admission to first-class healthcare.

Healthcare structures might not be capable of reach those worldwide objectives if they fail to recognise how environmental sustainability and health results are related. Moreover essential for both environmental friendliness and ease of improvement of healthcare is technology. New strategies for inexperienced power resources, waste management, communication, and strength-efficient systems would possibly substantially lessen the environmental harm caused by medical operations. furthermore, era include far off tracking structures, artificial intelligence, and information analytics help to streamline healthcare services thereby lowering the want for actual assets and waste. It also uses these technologies to help guess and lessen environmental health risks, like disease attacks caused by changes in the environment. In the end, bringing together environmental sustainability and healthcare management is a complicated task that needs a systems-thinking approach.[5] It requires people who work in health care, the environment, making policy, and the public to work together. Organisations can make healthcare systems that not only provide good care but also help with world efforts to be more sustainable if they think about how their choices will affect both health and the environment. Moving forward, it will be important to use sustainable medical practices that are based on both environmental science and medical knowledge. This will help us reach our long-term health and sustainability goals for future generations. The coming together of these two important areas gives us a great chance to rethink healthcare as a way to improve society and protect the earth.

Literature review

Key concepts in healthcare management

At its core, healthcare management tries to provide good care while making the best use of resources, better patient results, and staying profitable. Some of the most important ideas in healthcare management are cost-effectiveness, quality certification, organisational leadership, and allocating resources. Leadership that works is very important in healthcare management because it forms the culture of care and affects how well healthcare organisations do generally. To get through the complicated healthcare system, leaders in this situation need both strategic vision and practical experience. Another important idea is resource sharing, which is about how to best use limited resources like money, medical staff, and tools to meet the needs of all patients. Quality assurance is a big part of managing healthcare. It uses methods and rules to make sure that services meet certain standards.[6] This includes efforts to keep evaluating and making things better by looking at things like how satisfied patients are, how well treatments work, and how quickly care is delivered. Quality assurance, which makes sure that healthcare settings are free of mistakes, infections, and bad things that could have happened, is closely linked to patient safety. Cost-effectiveness is an important part of managing healthcare, especially now that prices are going up around the world. Managers have to find a way to keep costs down while still providing excellent care. Healthcare management systems also have to deal with rules and regulations, healthcare data, and a wide range of parties, such as doctors, patients, insurance, and government agencies.[7] Because people are living longer, more people are getting chronic diseases, and technology is getting better, healthcare is becoming more complicated and needs new ways to be managed. As healthcare systems become more linked, it's important to know how management practices, patient care, and operating efficiency are all related. This will help improve healthcare service and make it last longer.

Key concepts in environmental sustainability

To protect the health and happiness of future generations, environmental sustainability means using and protecting natural resources in a smart way. It is based on the idea that natural health shouldn't be sacrificed for economic growth. Protecting species, lowering waste, controlling carbon footprints, and sustainable development are a few of the most vital concepts in environmental sustainability. Using natural resources such as water, energy, and raw materials in a way that does not damage them over time is the approach known as resource conservation. People may assist to extend resources by recycling, reusing, and cutting down on consumption, therefore helping to minimise garbage. By reducing the quantity of greenhouse gases, harmful chemicals, and particle matter expelled into the air, water, and land, pollution reduction seeks to minimise environmental damage. Among the most crucial things one can do for the preservation of the environment is monitoring carbon footprints. Individuals, companies, and organisations are realising how they influence

climate change and are working to reduce their carbon emissions by utilising green energy, thereby optimising their energy consumption, and implementing other ecologically good behaviour. Maintaining biodiversity entails ensuring that species do not become extinct and preserving ecosystems in their whole.[8] Maintaining the equilibrium of the environment and ensuring the functionality of ecosystems depend on this, so it is rather crucial. A more all-encompassing concept is sustainable development, which calls for environmental preservation, economic growth, and equal rights protection. It advises us to satisfy current needs without sacrificing the ability of next generations to do the same. The Sustainable Development Goals (SDGs) established by the UN enable one to be sustainable in many spheres, including climate action, clean energy, responsible expenditure, life on land and in the sea.

Previous studies on healthcare and sustainability convergence

Table 1. Summary of Literature Review

Application	Key Findings	Challenges	Scope
Energy Efficiency in Hospitals	Hospitals can achieve significant energy savings through efficient HVAC systems and lighting.	High initial costs of energy-efficient infrastructure.	Energy efficiency can be scaled across multiple healthcare facilities.
Waste Reduction Programs	Effective waste management leads to a reduction in landfill waste and lower disposal costs.	Compliance with regulations on waste management can be complex and costly.	Waste reduction programs can be adopted by healthcare systems globally.
Renewable Energy Adoption[11]	Renewable energy systems like solar power reduce reliance on fossil fuels and lower operational costs.	Limited availability of renewable energy solutions in certain areas.	Renewable energy adoption can be expanded to cover a larger portion of healthcare energy needs.
Green Building Certifications	Green buildings improve patient and staff satisfaction due to better air quality and lighting.	Green building certifications can be costly and time-consuming to obtain.	Green building certifications can be applied to new healthcare constructions and renovations.
Sustainable Procurement	Reduces the environmental impact of healthcare products and services.	Resistance from suppliers and lack of sustainable product options.	Sustainable procurement can be implemented in hospitals, clinics, and pharmaceutical companies.
AI for Resource Management[12]	AI optimizes resource allocation, reducing waste and improving efficiency.	Integration of AI systems into existing healthcare management practices can be challenging.	AI can be applied in hospitals and healthcare management globally.
Telemedicine for Reducing Travel	Decreases the need for patient travel, reducing emissions and improving accessibility.	Barriers in rural areas due to limited internet access.	Telemedicine can be implemented in both developed and developing regions.
Smart Waste Monitoring Systems	IoT systems enable hospitals to track and manage energy consumption, leading to cost savings.	Real-time monitoring systems require constant updates and maintenance.	IoT-based energy monitoring can be expanded across various healthcare facilities.
Sustainable Medical Device Design	Reusable devices reduce waste and lower costs associated with single-use items.	Designing reusable devices that meet strict medical safety standards.	Reusable medical device design can be adopted globally.
Pharmaceutical Waste Management[13]	Prevents contamination of water sources and reduces environmental harm.	Proper disposal and recycling of pharmaceutical waste requires specialized facilities.	Pharmaceutical waste management can be applied globally.
AI for Predicting Resource Demand	Improves forecasting of resource demand, preventing overuse of materials and energy.	Requires large, high-quality datasets, which can be difficult to obtain.	AI resource demand forecasting can be applied in hospitals and clinics.
IoT for Real-Time Energy Monitoring	Reduces energy consumption by providing real-time insights.	Setting up IoT systems can require significant investment.	IoT systems can be used across multiple healthcare environments.
Green Supply Chain Management	Reduces the environmental footprint of medical product sourcing.	Establishing sustainable supply chains requires collaboration across stakeholders.	Green supply chain management can be expanded globally.
Circular Economy in Healthcare	Encourages the reuse of medical equipment and reduces waste.	Overcoming institutional inertia to adopt circular economy practices.	Circular economy practices can be adopted across the healthcare industry.

The way environmental sustainability and healthcare management could cooperate interests more and more researchers. This is especially true given the increased evidence of how environmental harm and climate change affect human health. Previous studies have examined several facets of this union, primarily how to make healthcare systems more sustainable, how to make them more resistant to climate change, and how to include environmental issues into healthcare systems.[9] Research on the concept of "green healthcare," or the application of environmentally friendly practices by healthcare institutions, has been especially intense. Studies have indicated that by utilising technologies that consume less energy, improving rubbish management systems, and converting to green energy sources, hospitals and other medical centres could have less of an impact on the surroundings. To lower their carbon footprints, healthcare facilities have been moving, for instance, to buildings with reduced energy use and incorporate green roofs and solar panels. The connection between public health and the availability of healthcare has also been quite important in the debate. Public health is directly affected by environmental elements such air pollution, water pollution, and climate change, therefore individuals are more prone to acquire infectious diseases, heart disorders, and lung ailments. More than one study has called for a more unified method where environmental sustainability goals are linked with healthcare management strategies to deal with these health risks where they start.[10] The literature study is summed up in table 1, which shows the main results, obstacles, and range of possible healthcare uses. A common theme in the research is how important it is for policies to connect natural preservation and health care.

Environmental impact of healthcare systems

Healthcare's carbon footprint

It is thought that the healthcare industry is responsible for about 4–5 % of all greenhouse gas pollution in the world. This means that healthcare systems release a lot of carbon into the atmosphere. Healthcare leaves a carbon impact through many actions, such as using energy, transporting medical supplies, making and throwing away medical supplies, and using drugs. Mostly for lights, climate control, and medical equipment, hospitals, clinics, and other medical facilities need a lot of energy—mostly power. Since many of these transportation uses fossil fuels, patient, worker, and products transit also significantly contributes to the carbon footprint of the industry. In the medical profession, the pharmaceutical industry is a major contributor to carbon pollution. Making, transporting, and disposal of medications[14] require several energy-intensive actions. Furthermore adding to the carbon burden is the manufacturing of medications used in medicine. Since many of these products demand energy and resources to manufacture and aren't always easy to recycle, the usage of medical disposables and single-use plastics also greatly affects the carbon footprint of healthcare. More and more individuals are advocating ecologically friendly methods such developing more energy-efficient buildings, employing green energy sources, and improving the supply chain to help to reduce the carbon effect of healthcare. Additionally there is a desire to reduce waste and promote medical items to be recycled and used again.[15] To meet their carbon-neutral targets and become more ecologically friendly, healthcare systems are also striving more and harder to measure and document their carbon emissions. Healthcare providers, governments, and companies must cooperate to create policies, give incentives for green technology, and include sustainability into the management of healthcare.[16]

Energy consumption and waste in healthcare

Using a lot of energy and producing a lot of rubbish are two of the main environmental issues healthcare systems bring about. Medical institutions include hospitals, medical centres, and others must have a consistent source of energy for things such heating, cooling, lighting, and powering medical equipment. Many times, staff members at healthcare institutions are on call seven days a week, twenty-four hours. They thereby make great use of fuel and electricity. Apart from their energy consumption, healthcare facilities sometimes make extensive use of water for purposes like maintenance of instruments, cleaning, and patient care. Constant power sources are required for life-saving technologies such dialysis machines, imaging equipment, and ventilators, so the demand of energy is even more important. It is possible to lessen the damage that healthcare energy use does to the environment by designing buildings that use less energy, using green energy sources, and taking other steps to save energy. To cut down on energy use, for example, hospitals are adding more energy-efficient lights, solar panels, and better insulation. Also, more and more people want to use green building standards like LEED (Leadership in Energy and Environmental Design), which encourages using less energy and more environmentally friendly building methods. Figure 1 shows how healthcare organisations use energy and create trash, showing where they are inefficient and having an effect.

Taking care of healthcare waste is another issue that needs attention. A lot of garbage is made in healthcare centres, such as medical waste, paper, plastic, medicine waste, and food waste. A lot of healthcare trash doesn't break down and includes dangerous things like drugs, needles, and used medical equipment that needs to be thrown away in a way that is safe for the environment and doesn't harm it. When people throw away trash in the wrong way, it can pollute the land and water and help diseases spread.

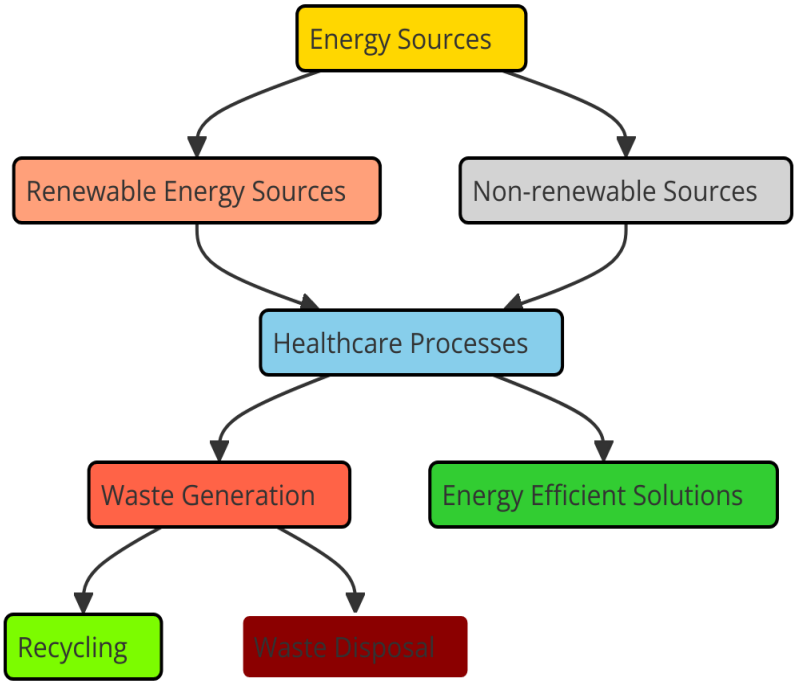

Figure 1. Illustrating energy consumption and waste in healthcare

Healthcare organisations are focussing more and more on waste reduction strategies like sorting trash, reusing, and safely getting rid of dangerous materials in order to lessen the damage that trash does to the environment. There is also a growing trend to use less single-use plastics and look for options, like recyclable materials or medical products that can be used more than once. A more environmentally friendly way of dealing with trash not only helps the earth but also helps healthcare organisations save money and work more efficiently.

Health outcomes related to environmental degradation

Pollution, cutting down trees, and climate change are all examples of environmental damage that has serious effects on public health. As the world gets worse, more sicknesses and health problems are likely to happen, especially to people who are already weak. Getting lung diseases like asthma, chronic obstructive pulmonary disease (COPD), and lung cancer has been linked to things like air pollution. GI diseases like diarrhoea and cholera can be spread by polluted water sources, and foodborne illnesses can be caused by contaminated food supplies. Many of these health risks are getting worse because of climate change. Extreme weather events like heatwaves, floods, and storms also have direct and secondary effects on public health. As temperatures rise, more people get sick and die from the heat, and storms can spread diseases that are carried by water. Changing weather trends have also changed where vector-borne diseases like malaria and dengue are found. These diseases are now spreading to places they weren't before. Also, damage to the environment has an effect on people's mental health, especially when they go through the stress and pain of natural disasters, being forced to move, or losing species. Natural resources are being used up faster because of the loss of forests and wildlife. This affects food security and access to clean water. There is more and more pressure on healthcare services to deal with the health effects of environmental damage. This includes both healing diseases that are caused by the environment and taking steps to stop them from happening in the first place, like making people more aware of the health risks that come from the environment and supporting laws that protect the environment. Taking care of environmental health is important to lessen the effects of environmental damage on health and get healthcare systems ready for the difficulties that climate change and environmental damage will bring in the future.

Sustainable healthcare practices

Green building and sustainable architecture in healthcare

A growing trend in healthcare is green building and sustainable design. The goal is to make healthcare centres less harmful to the environment while also making patients and workers healthier and more comfortable. Due to their 24/7 activities, the use of energy-intensive equipment, and high levels of waste production, healthcare buildings use a lot of energy and leave big environmental effects. The main goals of green building are to use

less energy, release fewer greenhouse gases, save water, and make living settings healthy. There are a number of design methods used in sustainable building in healthcare that put an emphasis on saving energy, resources, and being environmentally responsible. Passive design features, like natural airflow, sun optimisation, and high-performance insulation, are being used more and more in hospitals to cut down on the need for artificial heating and cooling. It is also becoming more usual for healthcare buildings to have renewable energy sources like solar panels and wind mills. This helps facilities use less nonrenewable energy. In addition, healthcare centres are using building products and methods that have less of an effect on the environment. As part of this, non-toxic, environmentally friendly, and locally sourced building products should be used to lower the carbon impact of development. Green roofs, rainwater collection systems, and energy-efficient windows are also becoming more common. These features help the environment and people's health while lowering costs.

Waste management and recycling in healthcare facilities

Healthcare facilities make a lot of waste, and a lot of it is dangerous, doesn't break down, or is hard to get rid of properly. Waste management and recycling are important parts of sustainable healthcare practices. Healthcare waste includes medical waste (like needles, bandages, and medicines), non-medical waste (like food, paper, and plastic), and toxic waste (like chemicals and dirty needles). To manage this trash in a way that is good for the earth and people's health, we need big plans that focus on reducing trash, throwing it away properly, and recycling. This helps keep things clean so that recyclables can be handled correctly and dangerous materials can be thrown away or treated safely. A lot of healthcare facilities are getting trash cans with different colours that make it clear where to put each type of trash. For instance, pharmaceutical trash, medical sharps, and contaminated materials should be thrown away in certain bins. Plastics and paper that are not contaminated can be recovered. Healthcare recycling programs are also important for cutting down on the amount of trash that ends up in dumps and the damage that healthcare activities do to the environment. More and more healthcare centres are putting money into recycling programs that sort paper, cardboard, plastics, glass, and metals. Some hospitals are also looking into ways to recycle medical items like surgery tools that can be cleaned and used again instead of being thrown away. Also, medicines that are no longer needed or have passed their expiration dates can usually be returned and thrown away properly, which keeps water sources from getting contaminated and limits the damage to the environment.

Energy-efficient technologies and renewable energy adoption

Hospitals and other healthcare facilities use a lot of energy, which hurts the earth and makes running costs go up. Hospitals and clinics use a lot of energy because they are open 24 hours a day, seven days a week, and their medical equipment is very energy-hungry. To fix this problem, using energy-saving tools and green energy has become an important part of sustainable healthcare. These methods can help lower costs, cut down on energy use, and lessen the damage that healthcare systems do to the environment. Advanced building management systems (BMS) are an example of an energy-efficient technology. These systems handle HVAC, lights, and ventilation to track and make the best use of energy in healthcare centres. For example, LED lighting is being used more and more in healthcare areas because it lasts a long time and uses little energy. Similarly, better HVAC systems, like variable refrigerant flow (VRF) systems, save a lot of energy by adjusting to different parts of a healthcare facility's shifting needs. Renewable energy sources, like solar, wind, and geothermal, are also becoming more popular in the healthcare field. To use less nonrenewable energy, many hospitals and other healthcare organisations are putting solar panels on their roofs or adding geothermal systems. By lowering the amount of electricity bought from the grid and offering a more sustainable energy source for day-to-day activities, solar power in particular can save a lot of money. Renewable energy can also be used to power backup systems in hospitals, which will keep important medical equipment running when the power goes out. Figure 2 shows tools that use less energy and how green energy is being used in healthcare systems.

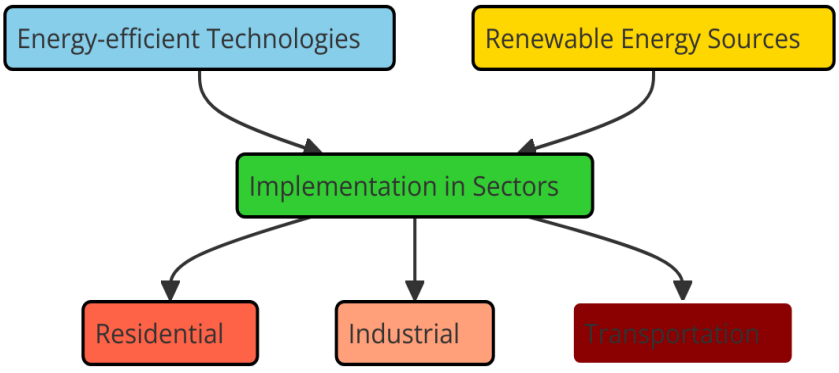

Figure 2. Energy-efficient technologies and renewable energy adoption

https://doi.org/10.56294/hl2023323

Healthcare centres are also using tools that use less energy to control how much energy each patient uses. Using low-power imaging tools and other medical equipment that uses less energy, along with teaching staff and patients how to be more energy-conscious, can help lower total energy use. Using energy management systems and doing regular energy audits are two more ways to help reach the goal of energy efficiency. These help healthcare facilities find and fix inefficient practices. When healthcare systems use these energy-saving tools and green energy sources, they can lower their carbon output and help the environment in important ways.

Sustainable procurement and supply chain in healthcare

For healthcare systems to have less of an effect on society and the environment, they need to use sustainable purchasing and supply chain methods. An important part of a healthcare facility's environmental impact is the buying of goods and services, like medical tools and office supplies. Choosing products and services according on how they impact people, the environment, and the economy across their complete lifetime from manufacture to disposal by means of sustainable buying practices is Sustainable procurement in the context of healthcare refers to purchasing goods produced from environmentally friendly resources, therefore minimising waste, and ensuring that vendors apply fair employment standards. This entails choosing products that run on less energy, can be recycled, or are created using resources repeatedly available. Healthcare systems can decide, for example, on medical devices with little packaging or drugs with little to no impact on the environment when manufactured, transported, and disposed of. A significant component of sustainable procurement is ensuring that the supply chain is open and ethical. Businesses in the healthcare sector may demonstrate their environmental consciousness by collaborating with suppliers certified in fair trade or ISO 14001. This guarantees that products originate from businesses who value the environment and endeavour to guarantee fair treatment of employees. Reducing the carbon effect of the supply chain is yet another crucial aspect of sustainable procurement. This implies enhancing the delivery procedures so that less pollution is emitted during transportation. Healthcare facilities can focus on local buying to lessen the damage that long-distance shipping does to the earth and work with logistics providers to use cars that use less energy. When healthcare facilities buy things, they are also using a circular economy method and looking for things that can be returned, used again, or fixed up. As an example, some hospitals are now buying medical equipment that can be fixed up and sold again. This cuts down on the need for new materials and trash. By using environmentally friendly buying methods in their supply lines, healthcare systems can greatly lower their effect on the environment, help make the world a better place to live, and encourage a more moral and responsible healthcare industry.

Policy and regulation

Government policies on environmental sustainability in healthcare

Leading the healthcare sector towards environmentally friendly methods depends much on policies created by the government. Over years, several national and regional policies have been developed to address environmental sustainability in the healthcare sector. These rules guarantee that, even if they offer first-rate treatment, healthcare facilities preserve the surroundings. These regulations aim to manage healthcare operations, promote environmentally friendly resource usage, and minimise the harm healthcare activities do to the surroundings. Governments in several nations mandate that healthcare facilities reduce their carbon footprint, use less energy, and appropriately dispose of waste. Healthcare facilities, for example, are expected to set up garbage sorting systems, follow guidelines on energy consumption, and, where it makes sense, apply green energy sources. Some countries provide tax incentives or money to those who purchase energy-efficient technology, place solar panels, or design green buildings, thereby motivating individuals to change to more environmentally friendly lifestyles. Simultaneously, guidelines are being developed to handle how medicinal products impact the environment. For instance, laws are being implemented all over to inspire people to properly dispose of medications and use less single-use plastics, including those used in medical packaging. Governments are also driving green buying rules. These rules guarantee that healthcare institutions choose goods and services that satisfy sustainability criteria and benefit the environment.

International frameworks and initiatives

Leading healthcare systems all throughout the world towards more environmentally friendly approaches has been greatly aided by international norms and initiatives. Many times, these models centre on cooperating globally to address environmental issues and support the development of legislation and initiatives aiming at increasing the sustainability of healthcare by means of global solutions. One of the most significant worldwide agendas, the Sustainable Development Goals (SDGs) are part of the 2030 Agenda for Sustainable Development of the United Nations. Particularly, SDG 3 states that everyone should have a healthy life and be happy; SDG 13 advises us to act immediately to halt the consequences of climate change. Linking these objectives reveals the need of safeguarding public health by including environmental sustainability into

hospital systems. Furthermore significantly changing the scene is the World Health Organisation (WHO), which publishes recommendations on sustainable healthcare. These rules include methods to make healthcare facilities more climate change resistant and health systems less detrimental to the surroundings. With WHO's "Health and Climate Change: A Policy Action Framework" nations may better manage the health hazards associated with climate change. It underlines how crucial healthcare is for preserving the environment and people's health as well as for reducing the hazards of climate change. International organisations such as the Global Green and Healthy Hospitals (GGHH) network also provide tools and knowledge to assist with environmental friendliness for hospitals and other medical facilities. Working together, GGHH a collection of health groups and environmentalists shares best practices, creates environmental goals, and lessens the impact of healthcare services on the surroundings. These initiatives centre on using less energy, cutting waste, shopping in ways that minimise environmental damage, and pushing the use of green resources in medical settings.

Integration of healthcare and environmental sustainability strategies

Strategies for healthcare institutions to promote sustainability

Because they employ techniques that minimise their impact on the environment while also offering high-quality treatment, healthcare facilities are quite crucial for promoting sustainability. With an eye towards garbage, resource conservation, energy economy, and environmentally friendly purchase behaviour, there are several strategies to make healthcare operations more sustainable. One of the key strategies is using less energy in adopted tools. Healthcare facilities may reduce their energy use by converting to LED lights, automating lighting and HVAC systems, and running fewer medical equipment running less energy consumption. In order to reduce their usage of fossil fuels and greenhouse gas emissions, healthcare institutions can also make investments in sustainable energy sources as solar or wind power. By revaluating their construction, hospitals and clinics may also increase the ventilation of their facilities, let in more natural light, and employ less energy-intensive heating and cooling systems. Promoting ecological also depends critically on waste management. Separating medical waste from recyclables and ensuring correct disposal of hazardous items help healthcare institutions reduce waste. Reducing waste by a significant degree may be achieved with less single-use plastics and medical instruments with many use. In order to acquire energy from garbage that cannot be recycled, hospitals can also burn their biological waste, recycle paper and plastic, and engage in waste-to--energy projects. One method healthcare companies may reduce the impact of their supply chains on the environment is through sustainable procurement.

Benefits of an integrated approach to healthcare and sustainability

Sustainable practices can help healthcare organisations care for their patients better, run more efficiently, have less of an effect on the environment, and improve the health of their communities as a whole. One of the best things about it is that it might save you money. Using less energy, cutting waste, and purchasing items in a way that doesn't damage the environment will help healthcare institutions drastically lower their running expenses. Install waste-to- energy systems, renewable energy, and less-energy-consuming lighting to help hospitals cut their energy costs. Hospitals that concentrate on reducing medicine waste might also help to cut the expenses of disposal of it. New medical instruments, better patient care, or improved healthcare services can all be purchased with the savings money. Along with saving money, a combined approach to sustainability improves patient care. Better indoor air quality, more natural light, and less noise all of which green healthcare facilities offer all of which can help patients feel better and get well. Furthermore promoted by sustainable healthcare methods are the usage of superior, non-toxic materials. Patients are therefore less likely to come into contact with the hazardous substances often included in common medical products. Combining sustainability with healthcare also helps to minimise the negative impacts on health resulting from environmental harm. Running out of resources, pollution, and climate change aggravate many health issues including lung ailments, heart disorders, and infectious diseases.

Technological innovations for sustainable healthcare

Role of AI, IoT, and big data in sustainable healthcare management

By enabling smarter judgements, more effective use of resources, and less of an impact on the environment, the Internet of Things (IoT), artificial intelligence (AI), and big data are altering the management of sustainable healthcare. These instruments enable medical practitioners to use less energy and waste while nevertheless providing better treatment for their patients. Predictive analytics which lets doctors estimate what their patients will require and maximise their resources is mostly dependent on artificial intelligence. Looking at a lot of data on every patient, artificial intelligence can estimate the medical services individuals will demand. This helps to prevent misuse of resources and wastefulness. AI systems may, for example, determine when hospitals will be busiest so that staff numbers and energy use can be adjusted to prevent waste of funds not

needed. By reducing the demand for repairs or replacements, artificial intelligence may also be used to monitor the condition of medical equipment, therefore saving time and money. IoT devices allow healthcare procedures be seen in real time, therefore benefiting the environment even more. Smart gadgets can monitor, for example, the waste, water, and energy use of medical buildings. These instruments can provide hospitals with data enabling them to discover ecologically friendly solutions and consume less water and energy. By let doctors monitor patients from distance, IoT-enabled medical devices also help to enhance patient care by reducing hospital visits and the carbon footprint associated with them.

Innovations in medical devices and pharmaceuticals with environmental impact reduction

New technology-based medicines and medical tools are much less detrimental to the environment than their predecessors. Manufacturers are concentrating more on producing things with less harmful components, less waste generation, and less energy use. These fresh concepts enable the healthcare system to be more ecologically friendly, thereby enabling doctors to do their duties better without so much harming patients. One area of great advancement in medical technology is the creation of less energy-consuming equipment. Imaging tools, ventilators, and tracking systems are among the things that are being remade to use less power while still working well. For example, new models of MRI machines and X-ray machines are made to use less energy, which means hospitals use less electricity. In the same way, medical gadgets that use renewable cells don't need as many throwaway batteries, which helps reduce medical trash. Another important change is the move towards medical gadgets that can be used more than once. A lot of healthcare trash comes from single-use medical items like needles, tubes, and surgery tools. But more and more money is being put into making goods that can be safely used again after being sterilised. For example, materials that are easy to clean, sturdy, and long-lasting are being used to make reusable medical tools. This helps cut down on waste and costs. There are also steps being taken by pharmaceutical businesses to lessen their impact on the earth.

The future of telemedicine and its role in reducing environmental strain

Using digital technologies for telemedicine that is, healthcare services available at a distance could help to significantly minimise the harm that conventional healthcare delivery does to the surroundings. Telemedicine may reduce carbon emissions connected to transportation, minimise the harm hospital facilities do to the environment, and promote better healthcare practices by allowing individuals conduct discussions from home and cut travel. Reducing travel for patients and healthcare professionals helps telemedicine to be one of the main environmental advantages. Patients sometimes have to drive a great distance on conventional in-person visits to medical institutions, which generates a lot of carbon dioxide into the atmosphere. Telemedicine enables consumers avoid travel by speaking with doctors from distances. This lessens the environmental effect of healthcare and saves money and time. In rural or underdeveloped locations where health care facilities might be far apart and attending meetings can take a lot of time and harm the surroundings, this is very important. Telemedicine can also serve to relieve the burden on healthcare institutions by lowering the need for actual room and resources. Virtual conferences reduce the demand for medical facilities, therefore enabling healthcare institutions to run fewer energy-consuming lighting, heating, and cooling systems. Less people having to drive to hospitals allows healthcare professionals to work faster, therefore reducing building energy consumption and waste. Furthermore promoted by telemedicine is more tailored treatment and health maintenance. By facilitating the access to consultations and monitoring services, telemedicine can let individuals with chronic diseases take ownership of their treatment and obtain help early on. This helps to reduce the demand for costly emergency care as well as the environmental harm more aggressive therapies cause.

Case studies

Successful integration of sustainability in healthcare systems globally

Many healthcare systems all throughout the world have effectively included sustainability into their everyday activities. These case studies demonstrate how healthcare facilities could employ sustainable practices without sacrificing first-rate patient care. One well-known instance is Stockholm, Sweden's Karolinska University Hospital. The hospital has a comprehensive sustainability strategy meant to reduce energy consumption, increase the usage of green energy, and generate less rubbish creation. Karolinska has lessened environmental impact by employing solar panels, energy-efficient building designs, and more sophisticated heating and cooling systems while still offering first-rate medical treatment. The hospital also employs waste management technologies that separate recyclables and guarantee correct disposal of hazardous garbage, therefore reducing the total quantity of waste dumped. Another effective case study comes from the US Cleveland Clinic. It has moved several measures to reduce its environmental effect. Using renewable energy, following green building guidelines, and reducing its carbon footprint by purchasing items in a more ecologically responsible manner helps the clinic to be more environmentally friendly. Thanks to its whole sustainability approach which has helped the Cleveland Clinic lower its water consumption by 20 % and its energy use by 30 %—the institution is leading in sustainable

healthcare in the United States. The Kyoto University Hospital in Japan has also become more environmentally friendly by focussing on saving energy, cutting down on medical trash, and using clean energy sources.

Lessons learned from leading sustainable healthcare practices

Sustainability has been successfully added to healthcare systems around the world. This has taught us a lot that other healthcare institutions can use to become more eco-friendly and improve patient care. One of the most important lessons is that healthcare managers need to be great leaders who are dedicated to their jobs. Sustainability must be a top priority at all levels of decision-making, and leaders must make sure that it is built into the institution's main goal. For long-term change to happen and a mindset of sustainability to grow, leaders must make this promise. Another important lesson is how important it is for government agencies, nature groups, and healthcare workers to work together. Making long-term survival strategies that consider the particular issues healthcare systems confront depends on these interactions. Working with environmental groups helps healthcare institutions obtain the knowledge and resources required to have less impact on the surroundings. Likewise, cooperation across government departments can enable sustainability initiatives to acquire the funds and backing required from legislators. Another crucial lesson is on technological use. Many healthcare systems have effectively implemented technologies using less energy, green energy sources, and systems that reduce garbage to lessen their carbon footprint. Hospitals using artificial intelligence, IoT, and big data to monitor how their resources are being utilised, for instance, can discover waste, reduce energy use, and improve general performance. These instruments can also let healthcare organisations ensure they fulfil their sustainability objectives and monitor how their activities impact the surroundings.

Comparative analysis of healthcare models that prioritize both health and sustainability

Examining healthcare models that prioritise sustainability and health reveals the many approaches taken by nations and organisations to make their healthcare systems more ecologically friendly while nonetheless delivering first-rate patient care. Healthcare systems in nations like Sweden and Denmark now heavily rely on sustainability. Using green building methods, renewable energy sources, and well-performing garbage management systems, these nations are trying to reduce the carbon footprint of their healthcare systems Swedish hospitals, for instance, are meant to utilise a variety of techniques to reduce waste, use green energy sources like solar and wind power, and use as little energy as feasible. These nations' healthcare systems demonstrate the need of building sustainability from the ground up by means of fewer energy-consuming healthcare systems that improve the environment, can adapt to new environmental challenges, and thus contribute to Conversely, the U.S. healthcare system which include establishments like the Cleveland Clinic focusses on achieving little but consistent progress towards sustainability by means of innovative instruments and modified approaches of operation. The Cleveland Clinic has done a lot to save energy, eliminate waste, and make ecologically responsible purchases of goods. In the United States, however, sustainable practices are more haphazardly adopted by individual hospitals or healthcare networks rather than a national policy demand.

RESULT AND DISCUSSION

Bringing together environmental sustainability efforts with healthcare management has shown a lot of promise for lowering healthcare's impact on the environment and making operations run more smoothly. Case studies of successful hospitals, like Karolinska University Hospital in Sweden and the Cleveland Clinic in the United States, show how energy-efficient tools, trash management techniques, and the use of green energy can work. Using AI, IoT, and big data to make the best use of resources and cut down on waste is even better. Using green building standards and environmentally friendly buying habits can also save you money and protect the earth in the long run. But there are still problems, such as the high cost of sustainable technologies at first and the need for steady policy support.

Table 2. Evaluation of Healthcare Sustainability Initiatives in Various Hospitals

Hospital Name	Energy Efficiency (%)	Carbon Footprint Reduction (%)	Waste Reduction (%)	Renewable Energy Adoption (%)
Karolinska University Hospital	30	40	25	50
Cleveland Clinic	25	35	28	45
Kyoto University Hospital	28	32	30	48
Mayo Clinic	22	30	23	40
Singapore General Hospital	26	33	27	43

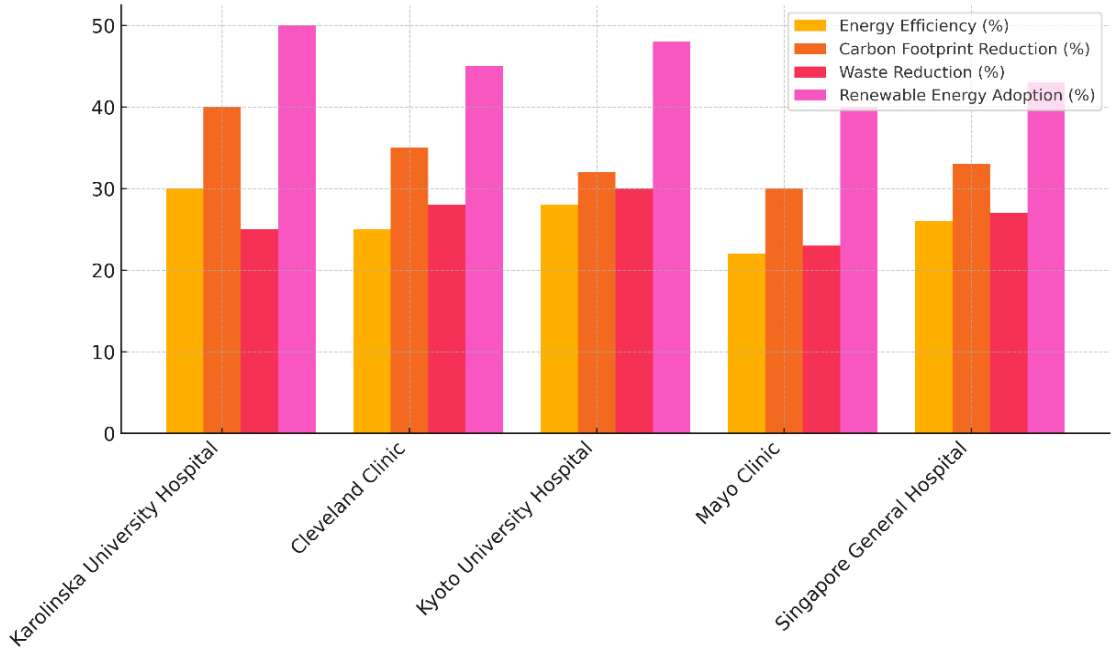

Figure 3. Comparative Analysis of Hospital Sustainability Metrics

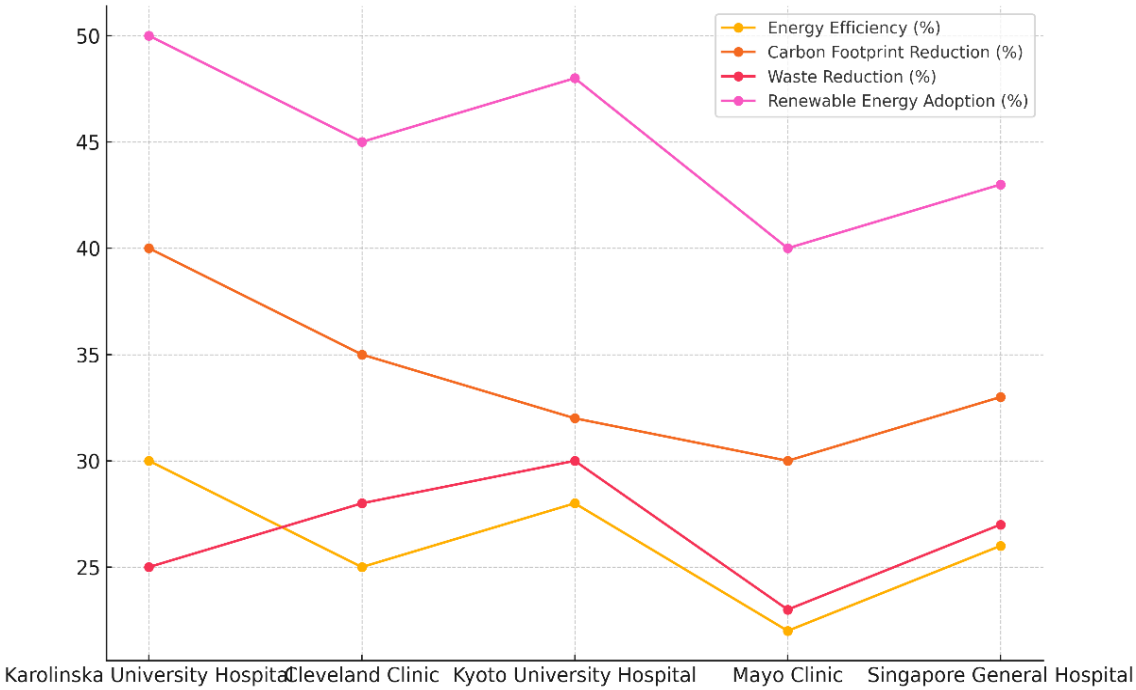

Figure 4. Trends in Hospital Sustainability Metrics Across Institutions

In table 2, we look at five well-known hospitals around the world and their efforts to be more environmentally friendly. We look at how they use energy, cut down on trash, and use green energy. The data shows that the Karolinska University Hospital has the best energy efficiency (30 %) and the most green energy use (50 %). Figure 3 shows a comparison of hospital sustainable measures, with trends and key performance factors standing out.

It has also cut its carbon footprint by a significant 40 %. This shows that they are really committed to being environmentally friendly and saving energy. The Cleveland Clinic also does good things for the environment; their carbon footprint has gone down by 35 % and their waste has gone down by 28 %. Figure 4 shows how hospital sustainability metrics have changed over time at different institutions, revealing both success and problems.

When compared to Karolinska, though, its energy economy and use of green energy are a little lower at

https://doi.org/10.56294/hl2023323

25 % and 45 %, respectively. Kyoto University Hospital does a great job of reducing trash (30 %) and using green energy (48 %), which shows that they care about managing resources in a way that doesn't harm the environment. Mayo Clinic has lower levels of energy economy (22 %) and carbon impact reduction (30 %), which means these areas could use some work. Finally, Singapore General Hospital takes a measured approach. They have cut their carbon footprint by 33 % and their trash by 27 %, and they use green energy 43 % of the time, which is a good number.

Table 3. Performance of Sustainability Technologies in Healthcare Facilities

Technology	Reduction in Energy Consumption (%)	Waste Reduction Efficiency (%)	Cost Savings from Sustainable Technologies ($)	Carbon Emission Reduction (%)
AI for Energy Optimization	15	18	500 000	20
IoT for Resource Monitoring	12	20	400 000	15
Big Data for Waste Reduction	10	22	350 000	18
Green Building Designs	18	15	600 000	25

Table 3 displays how well different technologies for sustainability work in healthcare facilities. These technologies include AI for improving energy efficiency, IoT for keeping an eye on resources, big data for cutting down on waste, and green building designs. Figure 5 looks at how well and how much sustainable technologies improve the performance of the healthcare system.

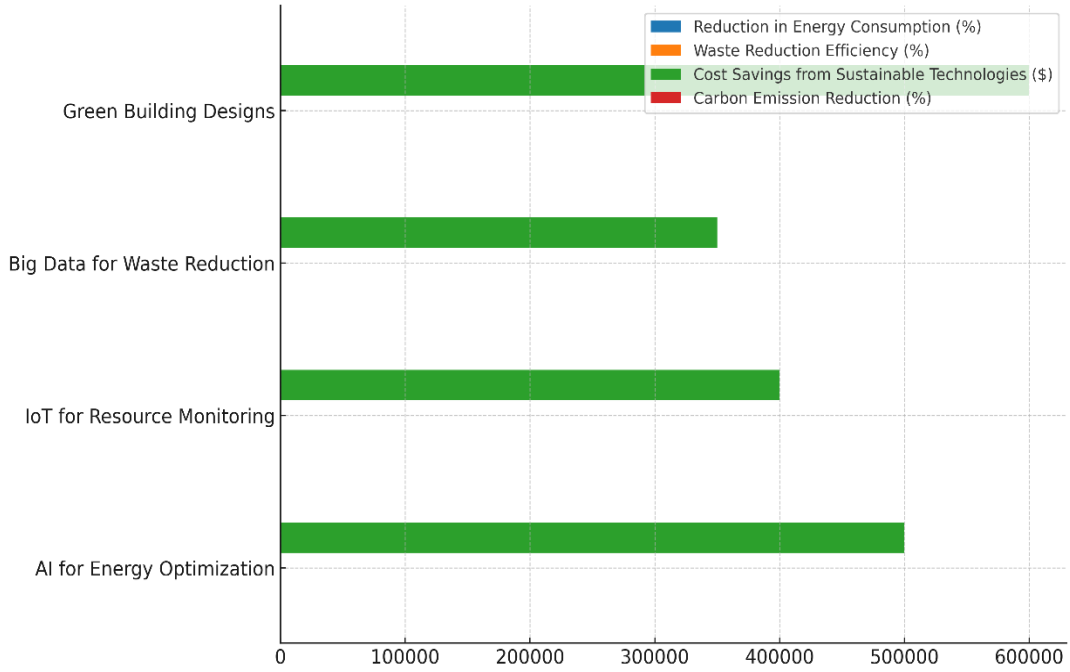

Figure 5. Efficiency and Impact of Sustainable Technologies

These systems are judged by how much energy they use, how much waste they create, how much money they save, and how much carbon dioxide they release. With the AI for Energy Optimisation system, both energy use and carbon pollution can be cut by 15 % and 20 %, respectively. With an 18 % waste reduction effectiveness, it saves a lot of money—$500 000 worth—showing that it could be used to better effect in healthcare situations. When IoT is used for Resource Monitoring, energy use drops by 12 % and carbon emissions drop by 15 %. Figure 6 shows the combined benefits of sustainable technologies, with a focus on how they will make healthcare more efficient over time.

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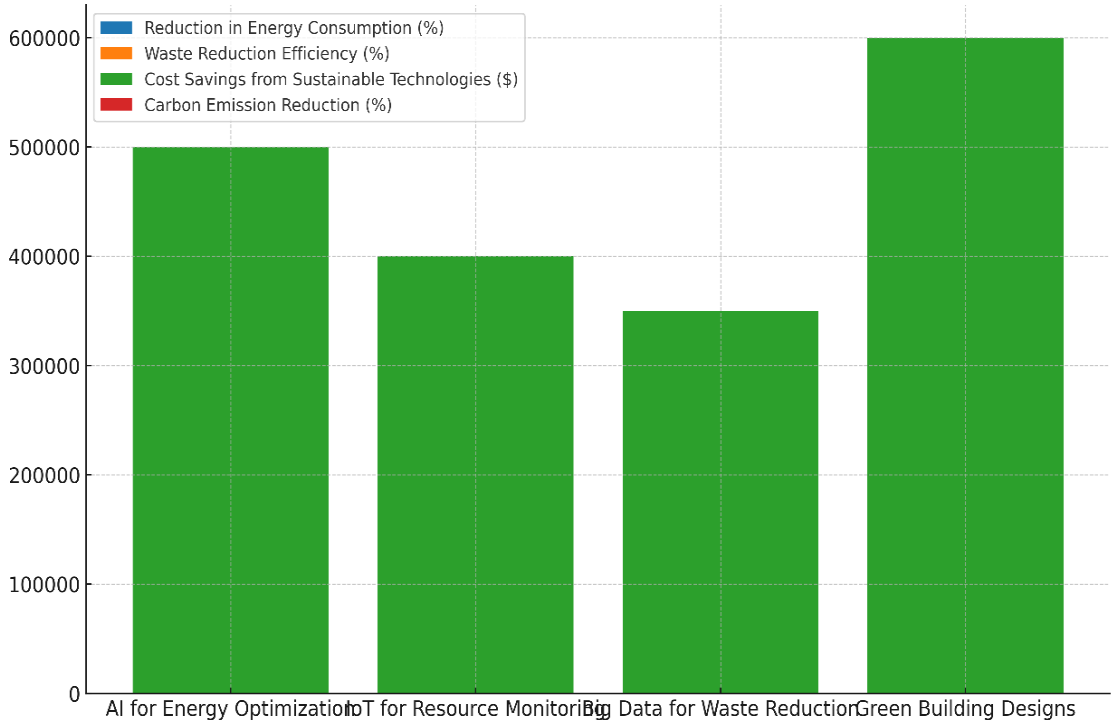

Figure 6. Cumulative Benefits of Sustainable Technologies

There is 20 % less trash, and the company saves $400 000 in costs. IoT systems allow tracking in real time, which helps healthcare centres make choices based on facts that are better for the environment. It takes 10 % less energy to use Big Data for trash Reduction, which also cuts trash the most (22 % is the best efficiency). Not only does it save money ($350k), but it also cuts carbon emissions by 18 %. At 18 % less energy use and 25 % less carbon pollution, green building designs show the biggest drop in energy use. With a cost savings of $600 000, this technology is also the most effective way to build a sustainable healthcare system.

CONCLUSIONS

Not only is the merger of environmental sustainability and healthcare management projects a new trend, but it's also necessary to deal with the twin problems of better public health and reducing environmental damage. By their very nature, healthcare systems use a lot of resources and make a big difference in carbon emissions, trash production, and environmental damage. The world's health is at greater risk because of things like climate change, pollution, and a lack of resources. Because of this, healthcare organisations must make sustainability a central part of their work. Sustainable practices in healthcare, like using tools that use less energy, managing trash better, and switching to green energy, can greatly lower the sector's impact on the environment without lowering the level of care, as this study shows. Also, using cutting edge technologies like AI, IoT, and big data has been very helpful in making healthcare management more efficient, cutting down on waste, and making better decisions. Leading healthcare institutions around the world, like the Karolinska University Hospital in Sweden and the Cleveland Clinic in the U.S., have successfully adopted these tools. This makes the case for wider use very strong. Even with these wins, it will still be hard to spread these methods across the whole world's healthcare system. High start-up costs, unwillingness to change, and a lack of policy benefits are some of the things that are still getting in the way of progress. But there is no denying that incorporating sustainability into healthcare has many benefits, including lower running costs, better patient results, and a more secure healthcare infrastructure.

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FINANCING

The authors did not receive financing for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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