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Sustainable Healthcare Practices: Advancing Eco-Friendly Laboratory Management, Integrating Green Initiatives in Nursing Education, and Promoting Value-Based Approaches in General Medicine.

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Abstract:

Background: The healthcare sector is a significant contributor to environmental damage, with 4.4% of global greenhouse gas emissions from healthcare and large quantities of waste such as single-use plastics and biohazardous waste. As the effects of climate change accelerate, health care systems need to implement sustainable health practices that use the least harmful and minimally damaging methods and still provide care for health and well-being. **Aim:** This review analyzed eco-friendly lab management, green initiatives in nursing education, and value-based general medicine to develop pathways to sustainable health practices in health care. **Methods:** A systematic review of the literature was completed using PubMed, Google Scholar, and CINAHL Ultimate. Inclusion criteria limited review to studies published within the past decade, from 2015-2025, and all peer-reviewed studies. Search terms included "sustainable health care", "Eco-friendly lab management", "nursing education green initiatives", and "value-based medicine". **Results:** Eco-friendly lab management modeled sustainability by reducing energy use by 20-30% and reducing waste by 20-40% using energy-efficient technologies and sustainable procurement. Nursing education modeled sustainability practices, introducing innovation to increase sustainability consciousness up to 35%, and trained nurses were 40% more likely to incorporate the newly introduced green practices into their nursing interventions. Models of value-based care, including telehealth and green-prescribing, improved sustainability and reduced emissions by 7-12%. **Conclusions**: Interdisciplinary collaboration, policy support, and education/processes are required to promote scalable practices for sustainable healthcare. Future research needs to work. Specifically, the research we need to conduct should focus on creating cost-effective technologies and emphasizing cross-culturally applicable technologies.

Keywords: eco-friendly laboratories, sustainable healthcare, value-based care, nursing education, environmental sustainability.

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Introduction

The health care sector is a foundational aspect of societal health and well-being, providing health care services that are vital to saving lives and or enhancing quality of life. These services are also creating substantial environmental changes due to the significant resource use and waste generation associated with the health care sector's environmental footprint. Hospitals, hospitals, clinics, and other forms of healthcare facilities are consuming considerable energy inputs when lighting and heating significant square footage, cooling large areas of space, and powering highly complicated medical machine outputs. Health care also consumes billions of liters of water for sterilization, cleaning, and patient care (Karliner et al., 2020). The health care sector produced millions of tons of waste each year which includes single-use plastics, biohazardous waste, and chemicals which may not always be treated before they are disposed of or released after waste treatments, and practitioners have serious doubts about how to dispose and manage them in secure and environmentally responsible ways (Seifert et al., 2021). Health care systems are estimated globally to produce approximately 4.4% greenhouse emissions, and in the U.S. health care sector alone, health care systems generate the 8.5% of the overall emissions in the U.S.A., putting the U.S. health care system among the highest of generators of GHG emissions when compared to developed nations (Eckelman & Sherman, 2016). The weight of that environmental footprint makes a strong case for the need to consider the health sector's impact on climate change and resource waste. As a global community, we are facing the damaging impact of climate change through changes to our climate, extreme weather events, and damage to ecosystems. This means that the requirement for change is increasingly feeling like a moral obligation for the healthcare sector to be more sustainable. In general terms, sustainable healthcare is about delivering high quality, patient-centered care with as little environmental damage as possible (Sharifi, A. Mohammed. 2025), while also contributing to global initiatives such as the United Nations Sustainable Development Goals (SDGs) and, in particular, SDG 13 (Climate Action) and SDG 12 (Responsible Consumption and Production) (Sharifi, A. Mohammed, 2025). Considering sustainability in healthcare is not only about environmental damage but is a means of achieving greater efficiencies in operations, improved cost efficiencies, improved public health, and reduction of health consequences associated with damaging and undeveloped social and environmental ecosystems, such as air pollution, water pollution (Weathers et al., 2020).

This review outlines three key areas where the opportunity exists to further advance sustainability in healthcare, including: sustainable and/or environmentally friendly management of laboratories; education about green initiatives; and value-based general medicine. Clinical laboratories might be the most resource-intensive aspect of health systems due to the enormous amounts of energy used and waste generated (Aljehani & Alhayek, 2024). Due to being the largest segment of the health care workforce, nurses can be significant frontline advocates for sustainability, and incorporating green practices in their education can result in systems change in the clinical practice of nursing (Álvarez-Nieto et al., 2022). At the same time, value-based general medicine that focuses on patient outcomes as opposed to volume of services is an approach to integrating environmental sustainability into effective care that is cost-effective and does not result in higher costs to healthcare systems (Barratt & McGain, 2021). This review aims to provide a detailed framework for healthcare

delivery systems to implement sustainable practices in their operations to address the sustainability challenges both environmentally and operationally in healthcare, by reviewing recent literature.

Methodology

This review takes a systematic literature review approach using Rodgers' evolutionary method of graduate research (Rodgers, 2000). This method is used explicitly to highlight that sustainability happens over time and is contextual to different people in various situations. A literature review was completed to review published literature on sustainable health care, eco-friendly lab management, nursing education, successful green initiatives, value-based medicine, and environmental sustainability published from 2015 to 2025. Various databases were used, including PubMed, Google Scholar, and CINAHL Ultimate. Study keywords used in this lit review included sustainable health care, eco-friendly laboratory management, nursing education green initiatives, value-based medicine, and environmental sustainability. Searching was also enhanced through the use of Boolean operators: ((Sustainable Healthcare OR Eco-Friendly Lab Management OR Nursing Education OR Value-Based Medicine) AND (Environmental Sustainability OR Green Initiatives)). Criteria for inclusion were peer-reviewed articles that were systematic reviews, qualitative studies, or case studies.

Eco-Friendly Laboratory Management

Clinical laboratories play an essential role in health care systems. Their diagnostic and research functions are necessary for patient care and advancements in clinical medicine. However, laboratories are also among the most resource and energy-intensive components of health care facilities. Laboratories consume and utilize vast amounts of energy, water, and materials while generating a substantial amount of waste, including hazardous waste and both single-use plastics and consumables (Aljehani & Alhayek, 2024). The environmental impact and footprint of laboratories is considerable because laboratories use energy-hungry ULT freezers and high-performance liquid chromatography systems (among many other types of equipment), which leads to high electricity consumption, while using poor waste management practices translates into increasing issues on land and in creating pollution (Seifert et al., 2021).

Eco-friendly laboratory management aims to reduce this resource use and waste production while benefiting from the practices that lead to sustainable, eco-friendly resource use. Moreover, eco-friendly laboratories are a natural fit with the United Nations Sustainable Development Goals (SDGs): for example, SDG 12: Responsible Consumption and Production, and SDG 13: Climate Action (Sharifi, A. Mohammed, 2025). Sustainable resource use and taking urgent action to combat climate change are two key focal points of the SDGs. Eco-friendly laboratory management fits fortuitously with a keen commitment to sustainability in health care, as it starts to realize this aim by reducing the environmental impacts of laboratories and increasing the potential impacts of eco-friendly management, with the further potential to provide effective and efficient clinical diagnostic services.

Key Practices

Clinical laboratories utilize energy-intensive equipment to perform the necessary work associated with sample handling, storage, analysis, and processing. ULT freezers that keep their samples at -80° C temperature and high-performance liquid chromatography equipment utilize a tremendous amount of electricity and contribute to the carbon

footprint of the health sector (Van Staalduinen et. al, 2022). Therefore, laboratories are looking to transition to energy-efficient replacements that will use less energy but will allow the laboratory (lab) to achieve similar results as the existing equipment. For example, ULT freezers that use natural refrigerants (hydrocarbons) have demonstrated 20 - 30% less energy use than traditional ULT freezers (Van Staalduinen et. al, 2022). Automated lab systems with sleep modes or timers are also available to reduce energy use by switching off during downtimes. For example, in a study by Al Atiyyah et al. (2024), they were able to reduce electricity usage by 25% in a tertiary hospital laboratory for a laboratory that utilized energy-saving upgrades with existing laboratory equipment. The upgrades were developmentally low-cost: LED lights, variable-speed motors, etc. They also demonstrated that by optimising ventilation systems in laboratories, they were able to reduce energy requirements by reducing the number of air changes in non-critical areas (Wang et al., 2020). These examples indicate that energy conservation can and should be a major consideration in environmentally friendly lab management.

Labs create enormous amounts of waste, much of it single-use plastics (like pipette tips and petri dishes, and sample tubes) or biohazardous materials that require disposal in a specific manner to not contaminate the environment in which we live. Poor waste disposal amounts are causing more waste in landfills and more opportunities for contaminants to enter an ecosystem (Alsharari et al., 2024). Implementing a strong waste separation and recycling program can reduce waste amounts significantly, and studies show that laboratories would, on average, reduce waste amounts by between 20 40% if they separate waste streams and recycle waste (Alsharari et al., 2024). Active work by some material science scientists has shown that it is possible (with bacterial cellulose) to create consumables that will reduce some single-use plastic impact (with studies showing a reduction in landfill amounts of up to 15% in pilot studies) and yield an alternative to traditional plastic. Laboratory practices are changing in sustainable ways, for example, using bacterial cellulose made from microbial/fermentation energy sources as consumables that are biodegradable and decompose, and can substitute most things made with plastic (for instance, packaged bacteria petri dishes) and maintain sterility. Another great glassware laboratory example is using reusable glassware and autoclaving reusable glassware (as opposed to trying to use disposable glassware every time!) has proven to reduce waste volume. A study by Martín-García et al. (2024) demonstrated that using reusable glassware protocols in laboratories or autoclaving reusable glassware decreased waste by 10% and met safety standards. Waste management is an essential element of any sustainable laboratory and is dependent on both technology and changes in behavior.

Sustainable procurement policies are vital for reducing the carbon footprint of lab operations through prioritizing suppliers and products that promote sustainability and environmental responsibility. These policies encompass finding non-toxic reagents, recyclable packaging, and durable/repairable equipment that minimizes waste and harms the environment (Lee et al., 2024). Altogether, the effort to substitute plastic pipette tips for recyclable or biodegradable pipette tips yielded findings of a 12% decrease in plastic usage when implemented in a university hospital laboratory (Musa et al., 2023). Likewise, finding products/reagents that have lower volatile organic compound (VOC) emissions results in lower emissions of toxic chemicals into the environment (Ketcherside et al., 2024). Lee et al.

(2024) reported an 18% decrease in hazardous waste by using green procurement policies in laboratories, alongside saving money in disposal costs. Further, laboratories should consider suppliers that commit to sustainability certifications like ISO 14001 in order to keep up their sustainability commitments downstream through their place in a supply chain. Incorporating sustainability into procurement will allow laboratories to look at environmental impacts upstream, which can have a significant impact downstream in the healthcare supply chain and effectively impact practice in general, otherwise not attainable.

Challenges

Despite the potential of eco-friendly lab management, several barriers need to be overcome before widespread adoption will take place. The high initial price is a challenge as energy-efficient equipment or sustainable materials usually require significant investments upfront. Smaller laboratories, especially in low and middle-income countries (LMICs), may lack adequate funds to adjust to these technologies, which will make scaling, not just on clean lab materials, but also sustainable labs, even more difficult (Al Atiyyah et al., 2024). Another barrier is the lack of awareness of staff or laboratory personnel, particularly if there is no formal education on sustainable practices, resulting in inconsistencies in execution and missed chances to impact the environment (Wong et al., 2024). If laboratory personnel are not trained on proper waste segregation, they may be actively working against a recycling program (wrongly segregating) and undermining sustainable efforts. Regulatory issues hinder sustainability; the safety and sterility regulations are often strict and dictate single-use materials to prevent contamination, which is in contrast to attempting to reduce material waste from the lab (Alsharari et al, 2024). The regulations are essential for patient safety, yet often the regulations restrict the usability of reusable or biodegradable alternatives, so it is imperative to find a creative way to meet compliance and sustainability.

Facilitators

Correspondingly, several facilitators of eco-friendly lab management encourage other laboratories to adopt green lab management strategies. Institutional support is a major culprit for many sustainability limitations among hospital workers. Dedicated sustainability officers' devotion in hospitals had an approximate 30% participation increase in green initiatives by other staff (Lee et al., 2024). Sustainability officers organize and build the framework for coordinating opportunities, as well as obtaining funding to leverage for projects, and work with the organization's capacity in determining what goals are sustainable, thereby initiating better laboratory practices and congruency throughout the organization. Technology and scientific innovation are significant elements since biodegradable materials have come a long way in developing energy-saving technologies, which have increased the availability and affordability of sustainable practices (Van Staalduinen et al., 2022). An example of this involves ULT freezers that are low-energy, requiring less energy and serving to lower the barriers for adoption in resource-limited situations. Education and training programs are also an important consideration since focused training can lead to 25% higher staff compliance in green initiatives (Martín-García et al., 2024). Not only do these training programs educate laboratory personnel on sustainable practices to use within their laboratories, but they also bridge the information gap by providing the essentials for long-term change in behavior. Overall, these facilitators provide the necessary components for laboratories wanting to adopt sustainable practices.

Case studies

My Green Lab Certification program is a prime example of how structured sustainability can impact a laboratory. The program has been adopted by more than 500 laboratories around the globe. The certification program works like a framework to analyze and create environmental improvements to the laboratory, which has led to a 25% reduction in energy use and a 30% reduction in waste among the participating facilities in the world (Freese et al., 2024). The certification requires auditing a laboratory's energy consumption, waste disposal, and purchasing policy to look for ways to improve. Another example is a pilot program in a European hospital laboratory where they replaced some of their plastic consumables with bacterial cellulose alternatives. As a result of the experimental program, they successfully replaced 10% of their plastic with bacterial cellulose out of environmental consideration, as opposed to waste or economic savings. The program ultimately reduced waste while maintaining sterile protocols, successfully implementing bio-based and biodegradable alternatives in a situation with strict protocols (Wong et al., 2024). These cases demonstrate the real benefits of implementing more environmentally friendly initiatives within laboratory or clinical settings, offering examples from which similar strategies may be implemented in various healthcare contexts (Table 1 & Figure 1).

Table 1: Examples of eco-friendly laboratory management and outcomes.

Strategy	Description	Environmental Outcome	Reference
Energy Conservation	Use of low-energy freezers and automated systems	20–30% reduction in energy use	Van Staaldui nen et al., 2022
Waste Management	Recycling and biodegradable consumables	20–40% reduction in waste	Alsharari et al., 2024
Sustainable Procurement	Eco-friendly suppliers and non-toxic reagents	12–18% reduction in hazardous waste	Lee et al., 2024

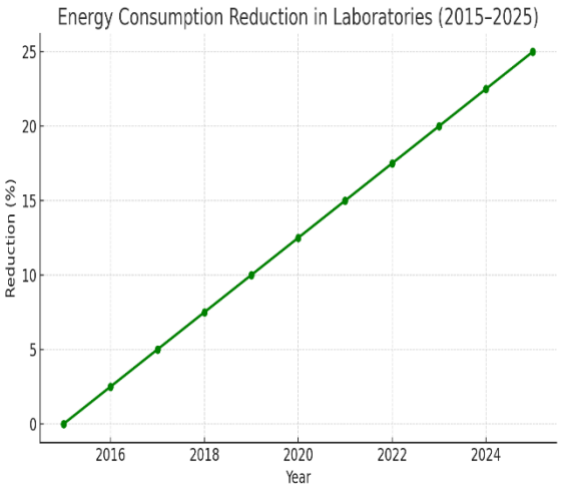

Figure 1: Energy consumption savings in laboratories 2015-2025.

Nursing Education in Green Initiatives

Nurses represent the largest discipline within the healthcare workforce and are uniquely positioned to lead change towards sustainable healthcare methods. As frontline providers, nurses are involved with patients, clinical situations, and initiate decisions regarding resource consumption, which gives them a unique vantage point to lead green initiatives (Álvarez-Nieto et al., 2022). The transition towards sustainability in healthcare is not possible without including green initiatives in nursing education to ensure future nurses develop knowledge, skills, and attitudes to enact environmentally sustainable practices within healthcare delivery. By including green initiatives in nursing courses, students promote a culture of environmental stewardship within the health care sector, aligned with other global priorities such as the United Nations Sustainable Development Goals, particularly SDG 3 Good Health and Well-being and SDG 13 Climate Action (Watts et al., 2021). Educational institutions can ensure nurses are prepared to navigate sustainability in their profession by embedding sustainability into the nursing curriculum. Nursing practice has enormous potential to incorporate sustainability and change the environmental impacts of the profession, such as the high amounts of waste and energy use that high-quality healthcare requires, while still providing patient care.

Sustainability-Focused Courses

Nursing programs across the world have started to recognize the relevance of environmental sustainability and are adding environmental health courses to the curriculum. These courses are intended to help students develop a deeper understanding of the healthcare sector's environmental footprint, including its contributions to greenhouse gas emissions and waste (Abdu Asiri et al., 2025). Linfield University's Master of Science in Nursing program has implemented modules on leadership in sustainable health care ecosystems that address waste, energy, and climate change health impacts (Rickerd, 2023). The outline of the modules includes an emphasis on practical interventions, including the reduction of single-use plastics and the promotion of energy-efficient practices in actual clinical settings. A study by Zoromba and EL-Gazar (2025) demonstrated that these courses enhanced students' sustainability consciousness by 35% based on survey results that modified students' levels of awareness about environmental issues and commitment to practice environmentally friendly practices and behaviors. Nursing programs are fostering a mindset that prioritizes environmental sustainability in theoretical coursework while considering patient care.

Practical Training

Sustainability practices are also being adapted in clinical skills laboratories with a practical clinical training component of theoretical knowledge, which allows nursing students to get first-hand practical experience using sustainable methods (Yeboah et al., 2024). For example, some programs are moving towards using reusable manikins and equipment in simulation labs, rather than disposable, which helps to decrease dependence on single-use plastics (Yeboah et al., 2024). A study by Chung and collaborators (2024) showed how using sterilizable products reduced waste by 10% compared to only using disposable gloves in simulation labs, and the training did not suffer in quality. These experiences are important for developing self-assurance with implementing green practices. Yeboah et al. (2024) described a 40% increase in nursing students' self-reported confidence levels for applying eco-friendly methods, such as segregation of waste and energy conservation protocols, after participating in their sustainability training. These labs try to simulate actual clinical

environments and prepare students to implement sustainability into practice as actions.

Interdisciplinary Learning

To enhance sustainability education's breadth and depth, nursing programs will increasingly connect with various disciplines like environmental science, public health, and engineering. With collaboration skills learned in nursing school, students can work on projects that tackle difficult questions - including climate change, management of health-care waste, and resource conservation (Lu et al., 20223). Collaborative activities with environmental science programs resulted in student-led initiatives aimed at reducing medical waste and evaluating the carbon footprint of healthcare facilities. Interdisciplinary partnerships provide students with broader perspectives and give students the opportunity to apply principles of sustainability to different clinical settings. A qualitative study by Lising et al. (2025) reported that students who were involved in interdisciplinary sustainability initiatives were 30% more likely to present novel green solutions in their clinical placements, indicating that interdisciplinary learning experiences can promote creative problem-solving.

Challenges

The incorporation of green initiatives into nursing education has many significant barriers. Limited resources present a significant challenge, especially in low- and middle-income countries, where many Nursing programs are underfunded and lack the planning funds to develop sustainability-based curriculum or eco-friendly training materials (Zoromba & EL-Gazar, 2025). For instance, the cost of reusable simulation equipment may be too high for an underfunded institution. Faculty awareness and training also pose a barrier, and many faculty have not received training in environmental sustainability, which has the potential to limit the depth of these ideas if they are attempted to be taught (Chung et al., 2024). If faculty do not understand sustainability concepts, they may inadvertently teach superficial sustainability outcomes, or worse yet, inconsistent ideas about the underlying principles of sustainability. Competing priorities in nursing curricula make integration complex. Programs typically prioritize clinical competencies over environmental education (Álvarez-Nieto et al., 2022), with clinical competencies such as patient assessment and technical competencies often exacerbating the marginalization of sustainability in nursing education and limiting the potential for sustainability to be incorporated into formal nursing training.

Facilitators

There are many factors that can facilitate the successful integration of green initiatives in nursing education. Leadership support - both from faculty and in an institutional capacity that lends itself to curriculum reform- is very important to the advancement of sustainability as part of a core nursing component in nursing education. Institutions with leaders who champion sustainability see about a 20% higher rate of adopting green curricula (Lising et al., 2025). A collaborative network, like the International Council of Nurses (ICN), can provide Institutions with resources to develop a core sustainability area of nursing education, including frameworks, guidelines, and course materials (Rickerd, 2023). This helps achieve some standardization and scalability of green initiatives in nursing education. Similarly, student advocacy is important, and if students develop initiatives such as green nursing clubs, the demand for education incorporating practices associated with sustainability can increase. Lee et al. (2023) noted that

in 15% of programs, the sustainability module was developed by students and not faculty, which illustrates how grassroots efforts can drive organizational change.

Impact on Practice

Integrating green initiatives into nursing education affects clinical practice greatly because sustainability-trained nurses can better bring forward eco-friendly practices in the healthcare environment. According to research by Zoromba and EL-Gazar (2025), nurses trained in sustainability reported 40% higher engagement in waste segregation, energy conservation, and sustainable equipment reuse compared to nurses who were not sustainability trained. In a qualitative study of sustainability-trained nurses by Yeboah et al. (2024), staff recommended switching from disposable surgical instruments to reusable surgical instruments at their facilities and realized a 15% reduction in waste. Sustainability-trained nurses also exhibited greater awareness of environmentally responsible healthcare practices and engaged in proactive reduction of resource use, such as turning off unused equipment and streamlining supply chain processes. By implementing sustainability as part of nursing education, institutions are developing a workforce capable of moving forward to influence systemic change toward greener practices in healthcare (Figure 2).

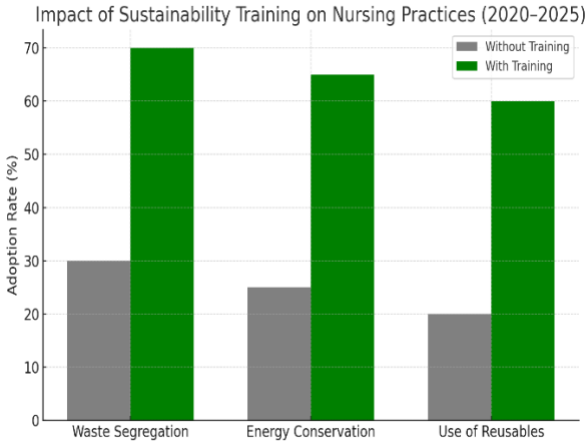

Figure 2: The Impact of Sustainability Training on Nursing Practices in Healthcare (2020–2025).

Value-Based General Medicine

Value-based general medicine is a transformative approach to healthcare delivery, centered on sustaining quality patient outcomes while optimizing resources and reducing costs. Unlike traditional models of care, which are paid based on the volume of care, value-based care aligns seamlessly with the values of sustainability by improving health care in the dimension of efficiency and patient-centeredness (Barratt & McGain, 2021). In a value-based care model, practitioners can now integrate sustainability goals with their revised value-based care model that improves the quality of health care while decreasing the climate impact of the health care sector (HCS). The global healthcare industry accounts for 5.7% of the annual global greenhouse gas emissions (GHG) (Eckelman et al., 2018), which is compounded by energy use and waste in hospitals. Sustainability specified in a value-based care model would minimise the HCS's carbon footprint, promoting efficiency through patient-centered practices such as preventative care, reducing unnecessary procedures, and smart use of appropriate digital technology. This value-based care option could be guided by the United Nations Sustainable Development Goals (SDGs), and

specifically the goals of good health and well-being (SDG 3) and responsible consumption and production (SDG 12), which promotes the delivery of healthcare interventions while being cognizant of the planet's fight against climate change to protect the lives of patients (Watts et al., 2021). This section discusses key opportunities, challenges, facilitators, and real-life examples of sustainability integrated into a value-based generalist medicine practice in contrast to existing models that measure quality based only on patient care.

Key Strategies

Value-based care reduces the number of unnecessary lab tests, procedures, and hospital admissions, thereby achieving improved patient outcomes and reducing the environmental burden of care more meaningfully. Overdiagnosis and overtreatment create unnecessary consumption of resources, such as energy, water, and a variety of materials involved in the diagnostic pathway (Olaiya et al., 2025). With these policies in place, we may see a reduction of up to 20% in resource consumption like this, and that is without considering differences in disposables used, as many imaging and laboratory tests once performed are some of the most resource-intensive, depending upon how they are conducted (Olaiya et al., 2025). Patel et al. (2025) demonstrated through their research that if policies were employed to optimize diagnostic pathways, that is, refining laboratory pathways to remove unnecessary protocol measures, primary care could optimize laboratory capacity and reduce waste of consumables by over 15%. They were able to do this by implementing evidence-informed guidelines that specified high-value tests and measured the environmental credentials of procedures to reduce wasteful duplication in laboratories, without compromising any environmental objectives. Resource optimization, as a means of structuring clinical decisions by sustainability targets, has now become one of the mainstays of sustainable or environmentally friendly value-based care, which goes beyond simply worrying about patient experience to align through our intervention, the patients and the environment's well-being.

The rise of telehealth has the potential to transform the mode of delivery of care and is certainly a sustainable way to engage patients without the environmental footprint as opposed to a traditional face-to-face consultation. Telehealth reduces patients ' travelling to their appointments and requires less physical infrastructure, which collectively takes engagement or energy out of the equity in greenhouse gas emissions being carried out in the healthcare sector. Lokmic-Tomkins et al. (2022) observed that the adoption of telehealth during COVID-19 allowed telehealth to provide substantial projected reductions in greenhouse gas emissions by 7–8% in health care delivery emissions as a consequence of minimizing patient travel and a reduction in energy consumption associated with healthcare facilities. In addition, virtual consultations also lessen the demand for energy-dependent hospital functions, including heating and cooling, or lighting functions. Consequently, outpatient settings reduce energy consumption by 10% (Karliner et al., 2020). Telehealth solutions offer remote monitoring of chronic illnesses, reducing visits to the hospital and ensuing resource consumption. Integrating telehealth into value-based care frameworks can emphasize access, increase patient satisfaction, and leverage environmental factors, making it a vital part of sustainable health care delivery.

Notably, green prescribing has the potential to decrease healthcare's environmental footprint by promoting non-pharmacological interventions like lifestyle alterations, physical activity, and dietary changes. The healthcare sector echoes its dependency on pharmaceuticals with the supply chain of production, packaging, and disposal of medications, all of which comprise a disproportionately large environmental footprint, including greenhouse gas contributions and chemical waste (Tantray et al., 2024). In the United Kingdom, efforts to incorporate initiatives like green prescribing showed promising findings where they decreased pharmaceutical waste by 12% while also enhancing patient outcomes, including patients diagnosed with diabetes and mental health issues (Tantray et al., 2024). "Prescribing" exercise programs or mindfulness-based therapies instead of medications not only impacted patients but also supplied a reduced environmental footprint from the production and disposal of pharmaceuticals. Through the inclusion of green prescribing into value-based care, healthcare professionals can marry clinical practice to sustainability objectives, achieving holistic patient care with minimal environmental damage.

Challenges

There are systemic challenges to the implementation of sustainability in value-based general medicine that are impeding adoption. As an example, some of the largest systemic barriers have been the proliferation of fee-for-service care models that put more emphasis on the number of services provided versus their value, leading to numerous procedures that are often unnecessary, resulting in increased environmental burdens (Eckelman et al., 2018). Moving to value-based care is a system-level change, and these types of changes tend to be slow and a resource burden. Another challenge to implementing sustainability in general practice is patient expectations. Many patients expect immediate actions, such as medication or diagnostic tests, rather than a sustainable approach, which typically entails a lifestyle change that takes time to produce results (Sharma et al., 2025). Having patients who may resist green prescribing, or other environmentally friendly strategies can create challenges to implementing sustainability in general practice. The absence of data is another challenge, as the lack of research on the environmental impact of value-based care models has been a barrier to using evidence-based practice (Malik et al., 2018). There is little data to support the environmental benefit of sustainable practices to inform health care professionals on the investment in sustainability. Without the information to show the environmental benefit, healthcare professionals are struggling to justify the investment in sustainability.

Facilitators

There are several factors that help integrate sustainability into value-based general medicine. Firstly, support from policy has a vital role. There are positive indicators from the Centers for Medicare & Medicaid Services (CMS) promoting "value"-based care models, to allow incorporation of potential sustainability indicators (Fadda, 2019). Policies that encourage and reward efficiency in resource utilization, which improve waste reduction, provide providers with leverage to utilize sustainability actions in practice. Secondly, digital transformation via EHRs and data analytics provides an efficiency tool and becomes another method for successful resource utilization. For example, they identify situations when care delivery takes place, resource utilization occurs through a wasteful procedure, and preventable procedures that lead to poor outcomes (Karliner et al., 2020). Not only do these technologies allow EHR utilization and tracking of environmental metrics with clinical outcomes, for example, energy reduction and

waste (carbon footprint), evolving growth in achieving a targeted outcome. Lastly, stakeholder collaboration between healthcare providers, policymakers, and environmental organizations can motivate systemic change through a collaborative approach towards a united goal (Patel et al., 2025). Working with organizations such as Health Care Without Harm promotes extensive frameworks, approaches, and tools that enhance our procedures, which support the sustained scalability of value-based care strategies.

Case Studies

An exemplar of sustainability accountability through their health care system is Kaiser Permanente in the United States. Kaiser Permanente reduced its greenhouse gas emissions by 10% over five years by embracing energy continuity via retrofitting facilities with LED lights, improving thermal efficiency by replacing or optimizing heating systems, and increasing the capacity of telehealth services (Provancha, 2019) of telehealth services. These types of activity exemplify the way value-based care can achieve environmental goals while still being mindful of patient needs. Likewise, the United Kingdom's green prescribing pilot program established pathways for people to take pharmacological alternatives to health care to reduce pharmaceutical waste by 12% but did lead to improvements in new products for chronic diseases (Tantray et al., 2024) through social prescribing and exercise programs. While there was collaboration between general practitioners, community organizations, and environmental advocates to promote affordable alternatives with the potential to green public health, these three examples show that sustainability and value-based general medicine are possible, and there are examples to explore ways for change.

Implications for Practice

This review highlights practices in laboratories, nursing curricula, and general medicine to integrate sustainability. Laboratories can enact a green certification program and develop sustainable procurement guidelines. Energy-efficient equipment should become a priority, as well as eco-friendly consumables. Although these could lead to a more efficient supply chain, individual and group purchases should happen sustainably so that global sustainability targets can also be achieved. An inclusion of sustainability issues in nursing curricula should educate nurses about the importance of their practice not only for the direct care of patients who use the healthcare system, but also for those who receive green or sustainable health services. Promoting interdisciplinary collaborations with environmental science will help nurse clinicians confront sustainability issues. Nurses who have been trained in sustainability and have foundations for sustainable practices have 40% higher odds of implementing green initiatives in their workplace. Public health can redefine care delivery models to reflect sustainability metrics in their value-based care models. There are models available that can minimize the consumption of resources and waste by at least 15%, and their anticipated impacts on clinical outcomes can be unparalleled, such as increasing diagnostic accuracy and improving patient engagement and satisfaction. Innovative strategies and interventions along the lines of reducing unnecessary diagnostic tests, expanding telehealth to more patients and locales, and operationalizing green prescribing would all fall under the umbrella of sustainability and align with the established principles of value-based care. Sustainable healthcare partnerships must be forged, facilitated by providers, policymakers, and environmental organizations, to scale the operationalization and

impact of environmentally sustainable practices in healthcare organizations and across multiple conditions and communities.

Future Directions

Critical gaps and opportunities for research of sustainable healthcare practices for global application and scale must be met. First, identifying affordable sustainable technologies for laboratories located in low- and middle-income countries (LMICs) is essential to lessen financial constraints and achieve green workplaces and democratize participation in sustainable practices. Research should navigate the scalable solutions that reduce costs yet meet performance criteria. Second, identify global opportunities to advance sustainability education in nursing programs to prepare a workforce to improve eco-consciousness.

Future work should consider standardized frameworks for incorporating sustainability into nursing education and pilot studies to assess the effects of sustainability education in nursing practice. To help inform evidence-based policy decisions, researchers will need to quantify the environmental costs associated with systems of value-based care. Much of the existing research on environmental sustainability in health has not utilized standardized measures of emissions, resource use, or waste reduction within a system of care or value-based care. Finally, research should examine the cross-cultural aspects of sustainable healthcare so we can ascertain applicability across different global contexts. Comparative studies of sustainable healthcare practices in high-, middle-, and low-income countries will help us see where there are commonalities and differences, which will help us establish opportunities for more universal approaches to sustainable healthcare and better understand local contexts to ensure that sustainable healthcare practices are equitably relevant and effective everywhere.

Conclusion

These areas of sustainable healthcare practice can help to address the environmental considerations of the healthcare sector while ensuring continuity of quality care. With eco-friendly laboratory administration, nursing education rooted in sustainable practices, and value-based general medicine, these areas can work synergistically. By identifying barriers and leveraging facilitators (e.g., institutional support and technology), health systems can postulate changes to advance sustainability. The transition to a more sustainable future will necessitate collaboration among providers, educators, policy makers, and researchers to operationalize these practices at the global level.

References

1. Abdu Asiri, B. A., Almutairi, R. M., Alfadhel, R. M., hawsawi, N. N. A., Faqeehi, S. M., & Alshammari, E. M. (2025). Technology-Driven Nursing Interventions to Support Telehealth in Cardiac Primary Care. *Saudi Journal of Medicine and Public Health*, *2*(2), 137–146. https://doi.org/10.64483/jmph-67
2. Al Atiyyah, A. H., Al Mutairi, D. M., Al Johani, K. I., Al Mutairi, M. B., Al Abdaly, H. S., Albreak, I. A., … Alrasheedi, W. A. (2024). Laboratory-Nursing Partnerships in Managing Multi-Drug-Resistant Organisms (MDROs): A Comprehensive Review. *Saudi Journal of Medicine and Public Health*, *1*(1), 154–164. https://doi.org/10.64483/jmph-73
3. Aljehani, M. R., & Alhayek , A. A. (2024). Renal Function Assessment: Core Responsibilities of Clinical Pathologists and Laboratory Technicians in Diagnostic Evaluation. *Saudi Journal of Medicine and Public Health*, *1*(1), 65–74. https://doi.org/10.64483/jmph-39
4. Alsharari, I. S. A., ALSHARARI, A. M. D. A., & ALSHARARI, F. S. H. A. (2024). Quality Control

of Laboratory Medicine: Preventing Errors for Diagnostic Reliability. *Saudi Journal of Medicine and Public Health*, *1*(1), 114–123. https://doi.org/10.64483/jmph-52

5. Álvarez-Nieto, C., Richardson, J., Navarro-Perán, M. Á., Tutticci, N., Huss, N., Elf, M., ... & López-Medina, I. M. (2022). Nursing students' attitudes towards climate change and sustainability: A cross-sectional multisite study. *Nurse education today*, *108*, 105185.
6. Barratt, A., & McGain, F. (2021). Overdiagnosis is increasing the carbon footprint of healthcare. *bmj*, *375*.
7. Chung, S. J., Lee, H., & Jang, S. J. (2024). Factors affecting environmental sustainability attitudes among nurses–Focusing on climate change cognition and behaviours: A cross-sectional study. *Journal of advanced nursing*.
8. Eckelman, M. J., & Sherman, J. (2016). Environmental impacts of the US health care system and effects on public health. *PloS one*, *11*(6), e0157014.
9. Eckelman, M. J., Sherman, J. D., & MacNeill, A. J. (2018). Life cycle environmental emissions and health damages from the Canadian healthcare system: an economic-environmental-epidemiological analysis. *PLoS medicine*, *15*(7), e1002623.
10. Fadda, J. (2019, December). Green healthcare system: Main features in supporting sustainability of healthcare system—A review. In *Green Buildings and Renewable Energy: Med Green Forum 2019-Part of World Renewable Energy Congress and Network* (pp. 113-128). Cham: Springer International Publishing.
11. Freese, T., Kat, R., Lanooij, S. D., Böllersen, T. C., Roo, C. M. D., Elzinga, N., ... & Feringa, B. L. (2024). The relevance of sustainable laboratory practices and Green Labs. *Integrating sustainable chemistry into research and industry for a circular economy*, 317.
12. Karliner, J., Slotterback, S., Boyd, R., Ashby, B., Steele, K., & Wang, J. (2020). Health care's climate footprint: the health sector contribution and opportunities for action. *European journal of public health*, *30*(Supplement_5), ckaa165-843.
13. Ketcherside, D. T., Miller, D. D., Kenerson, D. R., Scott, P. S., Andrew, J. P., Bakker, M. A., ... & Johnston, N. A. (2024). Effects of Wildfire Smoke on Volatile Organic Compound (VOC) and PM2. 5 Composition in a United States Intermountain Western Valley and Estimation of Human Health Risk. *Atmosphere*, *15*(10), 1172.
14. Lee, B., Liu, K., Warnock, T. S., Kim, M. O., & Skett, S. (2023). Students leading students: a qualitative study exploring a student-led model for engagement with the sustainable development goals. *International Journal of Sustainability in Higher Education*, *24*(3), 535-552.
15. Lee, J., Kim, H., & Kron, F. (2024). Virtual education strategies in the context of sustainable health care and medical education: A topic modelling analysis of four decades of research. *Medical Education*, *58*(1), 47-62.
16. Lising, D., Copley, J., Hill, A., Martyniuk, J., Patterson, F., Quinlan, T., & Parker, K. (2025). Exploring the "led" in health professional student-led experiences: A scoping review. *Advances in Health Sciences Education*, *30*(3), 1007-1036.
17. Lokmic-Tomkins, Z., Davies, S., Block, L. J., Cochrane, L., Dorin, A., Von Gerich, H., ... & Peltonen, L. M. (2022). Assessing the carbon footprint of digital health interventions: a scoping review. *Journal of the American Medical Informatics Association*, *29*(12), 2128-2139.
18. Malik, A., Lenzen, M., McAlister, S., & McGain, F. (2018). The carbon footprint of Australian health care. *The Lancet Planetary Health*, *2*(1), e27-e35.
19. Martín-García, J., Dies Álvarez, M. E., & Afonso, A. S. (2024). Understanding Science teachers' integration of active methodologies in Club settings: An exploratory study. *Education Sciences*, *14*(1), 106.
20. Musa, K., Okoliegbe, I., Abdalaziz, T., Aboushady, A. T., Stelling, J., & Gould, I. M.

(2023). Laboratory surveillance, quality management, and its role in addressing antimicrobial resistance in Africa: a narrative review. *Antibiotics*, *12*(8), 1313.

21. Olaiya, B. C., Aliyu, S., Obeagu, E. I., & Lawan, M. M. (2025). Sustainable building practices for modern clinical laboratories. *Discover Civil Engineering*, *2*(1), 74.
22. Patel, K. M., Thomas, T., Heron, D. E., Mantz, C. A., & Mantz, C. (2025). A threat to quality cancer care, accessibility, and sustainability: medicare payment policies and changing utilization patterns in radiation oncology. *Cureus*, *17*(3).
23. Provancha, C. A. (2019). *Kaiser Permanente: A Case Study on the Influence of Decentralized Organizational Structure on Supply Chain Transformation* (Doctoral dissertation, Northcentral University).
24. Rickerd, K. P. (2023). Green nursing. *Linfield Magazine*, *17*(2), 7.
25. Rodgers, B. (2000). Concept analysis: An evolutionary view. IN Rodgers, B. & Knafl, K.(Eds.) Concept Development in Nursing.
26. Seifert, C., Koep, L., Wolf, P., & Guenther, E. (2021). Life cycle assessment as decision support tool for environmental management in hospitals: a literature review. *Health care management review*, *46*(1), 12-24.
27. Sharifi, A. Mohammed. (2025). A Review of the Impacts of Climate Change on Emergency Medicine: Increased Natural Disasters and Their Related Health Impacts. *Saudi Journal of Medicine and Public Health*, *2*(1), 21–29. https://doi.org/10.64483/jmph-25
28. Sharma, V., Jamwal, A., Agrawal, R., & Pratap, S. (2025). A review on digital transformation in healthcare waste management: Applications, research trends and implications. *Waste Management & Research*, *43*(6), 828-849.
29. Tantray, J., Patel, A., Wani, S. N., Kosey, S., & Prajapati, B. G. (2024). Prescription precision: a comprehensive review of intelligent prescription systems. *Current pharmaceutical design*, *30*(34), 2671-2684.
30. Van Staalduinen, D. J., van den Bekerom, P., Groeneveld, S., Kidanemariam, M., Stiggelbout, A. M., & van den Akker-van Marle, M. E. (2022). The implementation of value-based healthcare: a scoping review. *BMC Health Services Research*, *22*(1), 270.
31. Wang, J., Shen, J., Ye, D., Yan, X., Zhang, Y., Yang, W., ... & Pan, L. (2020). Disinfection technology of hospital wastes and wastewater: Suggestions for disinfection strategy during coronavirus Disease 2019 (COVID-19) pandemic in China. *Environmental pollution*, *262*, 114665.
32. Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Beagley, J., Belesova, K., ... & Costello, A. (2021). The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *The lancet*, *397*(10269), 129-170.
33. Weathers, M. R., Mosher, M. M., & Maibach, E. (2020). Communicating the public health implications of climate change. In *Research handbook on communicating climate change* (pp. 259-271). Edward Elgar Publishing.
34. Wong, M., Tryliskyy, Y., Rashid, R., Barman, M. S., Shuymeko, M. V., Sharma, M. A., & Hossain, M. M. (2024). Diagnostic Test Accuracy of Detecting Donor-derived Cell-free DNA in Renal Transplant Rejection: A Systematic Review and Meta-analysis. *Transplantation*, *108*(9 S).
35. Yeboah, E. A., Adegboye, A. R. A., & Kneafsey, R. (2024). Nurses' perceptions, attitudes, and perspectives in relation to climate change and sustainable healthcare practices: A systematic review. *The Journal of Climate Change and Health*, *16*, 100290.
36. Zoromba, M. A., & El-Gazar, H. E. (2025). Nurses' attitudes, practices, and barriers toward sustainability behaviors: a qualitative study. *BMC nursing*, *24*(1), 437.