

Sustainable Digital Healthcare Technologies: Exploring Further Possibilities

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ABSTRACT

The Intergovernmental Panel on Climate Change, recognized as the foremost authority on climate science, highlights in its latest report the escalating effects on both human and planetary health, which disproportionately affect marginalized and disadvantaged communities worldwide, thereby exacerbating issues of climate justice. To assess whether Digital Healthcare Technologies (DHT) can contribute meaningfully to reducing carbon emissions in healthcare; to identify transparent, standardized, and accessible life-cycle-based evaluation approaches for environmental impacts; and to consider the economic, social, and environmental implications of adopting DHT. A further aim is to surface prerequisites for sustainability, interoperability, sound data governance, and digital equity. Narrative synthesis of recent peer-reviewed literature and policy/standards documents on DHT and sustainability, with targeted review of frameworks for environmental life-cycle assessment and decision support for healthcare leaders. DHT show potential to lower emissions by reducing travel, paper and material use, and inefficient workflows; however, their climate benefits are hard to verify without standardized life-cycle evaluation.

Evident gaps include limited, non-uniform frameworks and tools suitable for busy decision-makers. Key enablers for sustainable DHT deployment are: interoperability (systems that “communicate”), avoidance of data fragmentation through robust governance, and active measures to reduce inequalities in digital access. Scholars emphasize governance, common standards, and equal opportunities as conditions for genuine sustainability. E-health should not be seen as a mere technological upgrade but as a core element of a broader transformation in how care is organized and delivered. Only a holistic approach, combining standardized environmental assessment, strong governance, interoperability, and equity-by-design, can enable health systems to meet the demands of the digital era in a fair, inclusive, and environmentally responsible way.

Keywords: eHealth; Sustainable Healthcare; Digital Health; Interoperability; Data Governance; Empowerment of Patients; Digital Equality; Resilience of Health Systems

Abbreviations: AI: Artificial Intelligence; CHR: Citizen's Health Record; CPD: Continuing Professional Development; DHT: Digital Health Technologies; DL: Deep Learning; EHR: Electronic Health Record; EMR: Electronic Medical Record; EPA: Environmental Protection Agency; EU: European Union; FIWARE: Future Internet Ware (Open-Source Platform); GHG: Greenhouse Gas; ICT: Information and Communication Technologies; IoT: Internet of Things; ML: Machine Learning; NHS: National Health Service; OECD: Organisation for Economic Co-Operation and Development; OR: Operating Room; TBL: Triple Bottom Line; UN: United Nations; WHO: World Health Organization; EBHC: Evidence-Based Health Care; epSOS: Smart Open Services for European Patients

Introduction

Sustainability presents a challenge across various sectors and developmental contexts. In the field of healthcare, sustainability is closely linked to e-health, which, however, faces significant difficulties in its implementation. Several factors hinder the successful adoption of e-health solutions; among them are the complex nature of healthcare, the continuously growing demand for services, and, consequently, the intensive use of resources. Furthermore, there is a lack of a clear and commonly accepted definition of sustainability within the healthcare sector. Finally, as long as strict regulations and intricate processes persist, the effective implementation of e-health will remain a considerable challenge. The Intergovernmental Panel on Climate Change (IPCC) underscores that climate impacts on human and planetary health are accelerating and disproportionately borne by marginalized groups, raising issues of climate justice. Within this context, the healthcare sector, identified among the largest contributors to global pollution, must confront its climate responsibility. Digital health technologies (DHT), including telehealth, AI, IoT and EMR/EHR, are increasingly viewed as pathways to reduce healthcare's carbon footprint. Yet, to judge whether DHT can genuinely cut emissions, transparent, standardized and accessible life-cycle assessments are needed before implementation.

Available frameworks and tools remain fragmented and not easily actionable by busy decision-makers. Beyond technical capability, adoption has economic, social and environmental implications: systems must interoperate, avoid data fragmentation and narrow digital inequities through sound governance and equity-by-design [1-3]. Numerous studies have suggested sustainability models; however, these models often overlook crucial elements, including economic and funding assessments, the impact of changes on current employees, and the acceptance of these changes by patients and staff. Additionally, various studies have indicated that the lack of a well-defined concept of sustainability in existing literature leads to a deficiency in rigorous evaluation methods for sustainability, thereby obstructing the ability to assess e-health sustainability effectively. Moreover, the lack of a holistic perspective on the sustainability of e-health solutions continues to be the primary obstacle in developing sustainability frameworks and assessment methodologies [4,5]. In the digital age, modern healthcare systems are facing increasing pressures. Some of them are the aging of the population, with the natural consequence of an increase in chronic diseases and thus an increase in health costs. Hospitals in turn, with the increase in demand for their services, increase waste generation by burdening the planet.

All these consequences, of our time, have as an imperative the implementation of a digital transformation for the development of innovative health care models that will be friendly to both people and the planet that hosts them gasping [1,6]. In this context, e-health is a one-way street for healthcare systems. Digital health records, telemedicine, and health apps are transforming healthcare delivery

into something other than what we know. It is imperative to integrate, in all our actions, the sustainability of the planet, minimizing any redundancy, as well as in health. It is becoming evident that eHealth goes beyond mere modernization. It is about aligning healthcare systems with broader social and environmental objectives [7,8]. Currently, there is no universally accepted definition that expresses "sustainable healthcare". There are definitions that emphasize financial stability, while others prioritize reducing ecological impact. There is also no shortage of definitions that focus on ensuring social equality and universal access. This article will try to demonstrate that these aspects are deeply intertwined and that eHealth can act as a conduit between them. Building on recent research on e-governance and digital health sustainability, the article will highlight the need to embrace digital transformation with the ultimate goal of long-term resilience of healthcare systems [9-11].

Materials and Methods

Purpose of the Study

This review examines how Digital Health Technologies (DHT), including telehealth, AI, IoT, and EMR/EHR, can contribute to the sustainability of healthcare systems, with a particular focus on their potential to reduce carbon emissions. In parallel, it seeks to identify transparent, standardized, and accessible life-cycle-based approaches for assessing environmental impacts, and to surface the preconditions that enable sustainable digital transformation: interoperability, sound data governance, and digital equity. Beyond the technical dimension, the study considers economic and social implications so that sustainability is approached holistically, not just environmentally [12].

Material and Analysis

We conducted a narrative review of recent peer-reviewed studies and high-credibility policy/standards documents relevant to digital health and sustainability. Searches were performed in major bibliographic databases (Scopus, PubMed, Web of Science, MEDLINE, CINAHL, Elsevier Direct, EBSCO) and in HEAL-Link for Greek academic resources. We complemented these with targeted searches of authoritative organizations (e.g., IPCC, WHO, European Commission) for frameworks and guidance on environmental assessment and digital health governance.

Results

Exploring Existing Models of Sustainability in Healthcare

Most existing research examines sustainability in healthcare primarily from a managerial perspective. Doyle, et al. [13] introduced a sustainability model aimed at facilitating changes within healthcare. This model is presented as a self-assessment tool comprising 10 prioritized factors out of over 100 identified elements. These factors are organized into three principal domains, assigned weights as follows: process (31%), staff (52%), and organization (17%).

Each of the ten factors is divided into four levels, allowing users to select one level that best represents the current state. Nonetheless, several critical elements are absent from these factors, including economic and funding assessments, the likelihood of staff layoffs and their repercussions on the organization, as well as the socio-cultural dimensions affecting both the organization and its personnel [14]. Molfenter, et al. [15] created a model aimed at predicting the sustainability of modifications in healthcare, introducing nine factors, each encompassing various levels. Nevertheless, this model fails to consider patient-related elements, including their satisfaction with the changes that have been made. An important factor in maintaining changes within healthcare, which is rarely addressed in existing literature, is the willingness of healthcare stakeholders (such as patients, healthcare providers, families, and managers) to adjust to these modifications [16].

Penzenstadler and Femmer presented a sustainability model that encompasses three levels for software products [17]. In their study, the researchers outlined the dimensions of sustainability as individual, social, economic, environmental, and technical. These dimensions are positioned at the highest level of the model, whereas the middle level consists of values, indicators, and regulations [18]. Activities related to the model, such as waste reduction, are found at the lower tier. This model prioritizes environmental sustainability; however, it lacks a reliable assessment method that can evaluate the influence of each factor in forecasting the sustainability of the solution. A comprehensive integrative review on healthcare sustainability revealed that out of 92 studies, only 6 utilized specifically designed tools for measuring sustainability. Braithwaite et al. pointed out the lack of a unified and rigorous definition of sustainability, along with the discrepancies in its conceptual framework [19]. Another investigation determined that the lack of a thorough definition of sustainability posed a significant obstacle to the advancement of the field. Additional research addresses sustainability in healthcare by concentrating on the development of tools and frameworks aimed at maintaining healthcare organizations, rather than examining the internal changes within these entities [20].

Moreover, another study explored the contribution of digital solutions to the sustainability of healthcare overall, by illustrating various types of interactions that can occur through digital platforms [4]. Finally, a study by A. Bartosiewicz et al. underscored the significance of IT competence among nurses in relation to the effective utilization of new technologies in their work. This suggests that multiple factors must be taken into account when assessing the quality of an e-health solution [21].

Definition of Sustainable Health

Sustainable healthcare transcends being merely an operational objective. It represents a transformative approach to providing medical services that harmonizes environmental, social, and economic aspects. Consequently, health systems are capable of

producing beneficial outcomes for society while preserving resources for future generations. A multifaceted framework of interconnected strategies aimed at the restoration, management, and enhancement of human health, grounded in ecological principles, which is sustainable in environmental, economic, and social dimensions indefinitely. This system operates in harmony with both the human body and the non-human environment, ensuring that it does not produce unjust or disproportionate effects on any significant component of the healthcare system [22-24]. The rationale behind sustainable healthcare rests largely on ecological and social responsibility. The Brundtland Report had already warned that, if current practices continue, future generations will be deprived of the ability to meet their own needs. In line with this, three studies adopted the UN's definition of sustainability: "meeting the needs of the present without compromising the ability of future generations to meet their own needs" [25,26].

Wade, et al. (2016) and Garde, et al. (2020) [17] defined the sustainability of e-health solutions as the ability of an application to continue performing a specific function and remain operational over time. Ouhbi, et al. (2017) [18] and Fanta, et al. (2019) viewed it as continuous use, considering not only the three dimensions of sustainability but also other critical factors of the system under study. Lenz (2012) [19], on the other hand, linked the sustainability of healthcare information systems to replacement costs, emphasizing that "sustainable healthcare information systems should prevent the need for costly system replacements every five to ten years" [27]. At the same time, healthcare systems face practical challenges, as hospitals and clinics consume large amounts of energy and water, generate hazardous and non-hazardous waste, and contribute significantly to greenhouse gas emissions. This highlights the need to complement theoretical definitions with concrete practices, such as improving energy efficiency, reducing waste, and adopting integrated management systems that align quality care with environmental responsibility. In this sense, sustainable healthcare is not only about protecting the future but also about rethinking how care is delivered today [1,20].

Sustainability in Healthcare Operations

The healthcare industry significantly contributes to environmental degradation, representing approximately 5.2% of global greenhouse gas (GHG) emissions. Major contributors include energy-demanding activities such as heating, cooling, lighting, and the use of medical equipment, in addition to the manufacturing and disposal of pharmaceuticals, medical devices, and single-use products. In the healthcare delivery systems of OECD nations, hospitals emerge as the primary sources of climate change emissions, responsible for 28.6% of the total emissions, in contrast to ambulatory care services, which account for 18% [28]. In hospital-centric healthcare frameworks, particularly in the United States, the proportion of GHG emissions linked to hospitals is even more pronounced, reaching as high as 36%

[29]. The transition to renewable energy sources, the adoption of energy-efficient systems, and the optimization of plant design are key. Similarly, hospitals need large amounts of water for hygiene, patient care, and sterilization of equipment. Efficient water management systems, such as leak detection and wastewater recycling, are essential for conserving water resources. Waste management is also an important issue, given the variety of waste generated, including hazardous and biomedical waste. Recycling, safe disposal, and reducing single-use materials can significantly limit damage to the environment [30,31].

Sustainable practices aim not only to improve health but also to enhance societal well-being, emphasizing prevention, equitable access, and health awareness, elements that contribute to reducing overall morbidity. Hospitals can also collaborate with other agencies to address broader public health challenges. The active participation of healthcare professionals and patients in sustainability initiatives is crucial, as it reinforces our collective duty towards a sustainable future [32]. The healthcare industry has a significant but also an expensive impact on the environment. Hospitals, specifically, rank as some of the most energy-consuming establishments in the United States, playing a considerable role in the national emissions of greenhouse gases and carbon dioxide. Mitigating this pollution and the emissions of greenhouse gases would lead to a decrease in the prevalence of human illnesses, ultimately resulting in cost savings for both the healthcare system and society at large. Moreover, healthcare industry has a costly environmental impact, as hospitals are among the most energy-consuming facilities in the United States, utilizing approximately 836 trillion British thermal units (Btu) of energy and incurring over \$10 billion in energy costs each year, which typically constitutes between 1% and 3% of a hospital's overall operating budget.

A study conducted in 2007 estimated that the health care sector accounted for 8 percent of all greenhouse gas emissions in the U.S. and 7% of total carbon dioxide emissions. Commonly observed wasteful practices within health care include the unnecessary heating or cooling of unoccupied areas, inadequate maintenance of equipment, and neglecting to inspect for air and water leaks [33-36]. Health facilities generated around 6,600 tons of waste per day, much of which ends up in landfills. According to the U.S. Environmental Protection Agency, nearly 85% of hospital waste is non-hazardous, yet it is often mistakenly placed in medical waste containers ("red bags"). This not only increases disposal costs but also requires unnecessary treatment, which can itself raise pollution levels through incineration or other harmful methods. One report estimates that processing red bag waste can cost up to 20 times more than handling standard solid waste. Other inefficient practices include failing to recycle or reuse common items such as paper, plastic, and cardboard [37]. Operating rooms (ORs) have one of the highest environmental impacts within hospitals. They account for nearly one third of total hospital supply costs and generate significant expenses from both energy use and waste management.

Many of the practices in ORs are inefficient: disposable products are often chosen over reusable ones, sterile blue wraps are discarded after a single use instead of being recycled or replaced with hard cases, and unused items from pre-packaged surgical kits are frequently thrown away. New technologies, however, offer opportunities to make hospital operations more sustainable. Digital health tools and automation can streamline workflows and reduce the use of physical resources. Telemedicine, for example, lowers the need for in-person visits, cutting down both travel and the associated carbon emissions [38-40]. Bringing sustainability into daily hospital practice is not without its challenges. High upfront investments, complex regulations, and resistance to organizational change often slow down progress. Yet, with clear planning, supportive government policies, and strong public-private partnerships, these barriers can be overcome [30]. Ultimately, hospitals that commit to sustainability are not just reducing their environmental footprint. They are also driving innovation, strengthening their role as socially responsible institutions, and ensuring that healthcare contributes to healthier communities today while protecting the environment for future generations [34].

The Role of Stakeholders in Healthcare Sustainability

Stakeholder theory holds that the primary goal of a healthcare organization should be to fairly balance the interests of all stakeholders while adhering to ethical and legal standards. This assumes a shift in mindset: from a one-dimensional emphasis on profit, towards an approach that recognizes the complexity of relationships and the diverse perspectives that shape health institutions. The integration of non-traditional stakeholders, such as ecosystems and future generations, highlights the need for regulatory perspectives that prioritize the collective good over immediate economic benefit. An important element of stakeholder engagement is their depth of involvement. As described in Friedman's "engagement ladder," the range ranges from simple, non-participatory forms of communication to collaborative synergies. At the highest levels, stakeholders actively participate in decision-making, leveraging standards such as the Triple Bottom Line (TBL) and ISO 26000, which support collective decisions and synergies that link organizational goals to social and environmental goals [30,40,41].

Health organizations are facing increasing pressure from stakeholders to adopt sustainable practices. Governments and NGOs promote compliance with social and environmental regulations, emphasizing pollution prevention and reducing resource consumption. Public scrutiny prompts institutions to set transparent and realistic goals, while healthcare providers encourage suppliers to adhere to environmentally and socially responsible standards [42]. The active participation of stakeholders is essential for the transformation of health organizations. Indicatively, the creation of "green teams" allows healthcare professionals to actively contribute to the achievement of environmental goals, fostering sustainability in organizational culture. At the same time, such initiatives strengthen

internal engagement and cultivate patient trust. As healthcare systems embody sustainability as a fundamental value, stakeholder input becomes critical in shaping policies and practices that align with broader societal goals. This requires transparency, accountability, and continuous improvement, respecting all voices [31,34]. Consequently, stakeholders play a crucial role in promoting sustainability in the healthcare space. Their involvement ensures that the healthcare sector fulfills its ethical and legal obligations while contributing to the enduring well-being of society and the environment [30].

The Role of eHealth as a Driver of Sustainable Healthcare

The integration of information and communication technologies (ICT) in healthcare delivery, often called eHealth, is directly linked to healthcare sustainability. eHealth includes electronic health records (EHR), telemedicine, mobile health (mHealth), and digital platforms that engage patients. All of these instruments have the potential to revolutionize healthcare systems by enhancing efficiency, and efficiency, widening equitable access [7,43,44]. As such, eHealth directly helps sustainability, because it has positive effects for the environment, society and the economy. Digital files and electronic communication reduce the use of paper, while teleconsultations reduce unnecessary travel, thus reducing pollution. Socially, eHealth promotes equity and inclusion by facilitating access to specialized services for remote or disadvantaged populations. Cost-effectively, digital tools reduce repetitive tests, simplify administrative procedures, and enhance prevention, thereby improving the efficiency of the health system [8,45,46]. However, the implementation of eHealth has not been uniform, as many initiatives have not achieved the expected impact. Research shows that up to three-quarters of projects stop at the pilot stage or initial implementation. The failures are mainly related to inadequate integration into daily processes, limited user involvement in planning, and inadequate training of healthcare professionals. When technologies do not align with clinical practice, they are seen more as a burden than a support, which limits their viability [47-49].

The environmental dimension of eHealth is often neglected, but it is becoming increasingly important. Health systems contribute to carbon emissions, energy consumption, and waste generation. Digitalization, remote monitoring, and logistics optimization can reduce these impacts. For example, telemedicine limits emissions from patient movements, while e-prescribing reduces pharmaceutical waste [1,8]. From an economic perspective, eHealth can reduce pressures through better organization and preventive care. Platforms for chronic disease management, for example, help reduce hospital admissions and improve quality of life. However, high upfront costs, along with maintenance and training needs, pose a barrier, particularly in countries with lower resources. Long-term sustainability requires stable funding mechanisms and appropriate return models [7,46,50]. The social sustainability of eHealth is linked to education and skills development. The integration of digital knowledge into medical

and nursing curricula, as well as continuous training, are essential to prepare healthcare personnel for a digital environment. Equally important is informing citizens so that they can safely and effectively use eHealth tools [8,43].

Interoperability and Data Governance in Sustainable eHealth

One of the most critical issues for the sustainable implementation of eHealth is interoperability and data governance. Digital technologies have the potential to transform healthcare systems, improving efficiency, accessibility, and equity. However, the realization of these capabilities depends heavily on the secure and seamless exchange of data between different systems, providers and national structures. Interoperability is the foundation for sustainable e-health because it facilitates the transfer of health information across institutional and national borders, reduces service overlaps, prevents medical errors and promotes patient-centered models of care. In practice, however, it remains difficult to achieve. Many health systems continue to rely on legacy and disconnected infrastructure, while proprietary platforms limit communication and data sharing. At the same time, the financial incentives of providers and suppliers are often misaligned, while cultural and organizational barriers lead to hesitation by professionals to change established workflows or share data with other institutions. All of this shows that interoperability is not just a technical issue; it is also a matter of governance, trust and institutional cooperation [7,49,51,52].

The European Union has taken the lead in addressing these challenges by developing policies that enhance interoperability and sustainable digital health ecosystems. The eHealth Action Plan (2004) [27] stressed the importance of international cooperation, standardization and citizen-centered service delivery. The European Union has played a leading role in promoting interoperability, with initiatives such as the eHealth Action Plan (2004), which emphasized international cooperation, standardization and citizen-centered services. At the national level, some countries have made notable progress: for example, the NHS app in the UK and national health portals in Denmark and Sweden allow citizens to access their health records and interact with professionals online. These cases show how strong governance and continuous investment can build trust and integrated systems. By contrast, the United States still faces major challenges with fragmentation and reliance on private vendors, despite significant investments [45,46,53]. From a sustainability perspective, interoperability and data governance also support the triple bottom line. Economically, they reduce duplication and inefficiency; socially, they enhance equity and citizen empowerment; and environmentally, they lower paper use and unnecessary travel through digital records and telemedicine [1,8].

Looking to the future, the sustainable development of eHealth requires a balance between innovation and regulation. The use of open standards, open-source platforms, and cloud solutions like

FIWARE promises greater flexibility and reduces the risk of reliance on individual vendors. At the same time, regulation and oversight are essential to ensure that technologies remain secure and responsible. The training of health professionals is crucial for their adaptation to the new systems, while strengthening the digital literacy of citizens contributes to the correct and safe use of tools. Only by combining technological innovation, institutional governance and social preparedness can eHealth act as a driver of sustainable healthcare. Interoperability and data governance are therefore not secondary elements, but fundamental pillars for the development of systems that respond to the economic, social and environmental needs of the 21st century [8,43,54,55].

Digital Equity and Patient Empowerment in eHealth

A key dimension of sustainable e-health is the extent to which digital technologies enhance equity and give patients a greater role in their own care. eHealth promises to better connect citizens to services, reduce geographical and social barriers, and tools for self-management. However, in practice the picture is uneven. "Digital equality" refers to whether all citizens, regardless of socio-economic status, age, disability or place of residence, have the necessary access, skills and confidence to use eHealth tools. Without this equality, there is a risk that technology will enhance rather than reduce inequalities [8]. The European Commission has repeatedly stressed that citizen-centered design is a key condition for sustainability. The development of the Citizen's Health Record (CHR) is a prime example, as it transfers ownership of data to the patients themselves and enhances transparency between health providers. Patient empowerment is not limited to access information but involves participation in treatment decisions, active interaction with digital platforms, and the ability to control the use of personal data. Research shows that patients who enjoy this level of empowerment show greater commitment to treatments, higher satisfaction and better health outcomes [7,30,35,36].

Digital technologies can also reduce geographical disparities. Telemedicine restricts movement, offering access to specialized care in rural or remote areas. Scandinavian countries, such as Denmark and Sweden, have established national health portals that allow citizens to view their medical records, make appointments, and communicate with doctors remotely, promoting overall accessibility. At European level, the epSOS initiative has shown that the exchange of health information across national borders can ensure continuity of care for patients travelling or living abroad, while promoting inclusion [7,56,57]. Despite the benefits, achieving digital equality is not a given. Factors such as age, income, and educational attainment influence the degree of digital literacy. Older patients often find it difficult to use new technologies, while lower-income individuals may lack access to devices or fast internet. This creates the "digital divide", which threatens to lead to a two-speed health system: the most affluent and savvy benefit, while the weakest are left behind. To

avoid this, targeted policies are needed, such as subsidies for access to digital media, educational programs to enhance digital literacy, and design practices that consider different needs [43,46,58]. Privacy and trust are also crucial.

The ability to manage personal data enhances autonomy but raises concerns about potential misuse, surveillance, or breaches. The GDPR has set a strong legal framework to protect rights, but incidents of non-compliance and cyberattacks show that without resilient governance, trust can easily be lost. For citizens to participate sustainably, it is essential to feel secure about the handling of their data [49,59]. Empowerment is also linked to economic and environmental sustainability. Patients using digital monitoring tools or participating in prevention programs can reduce unnecessary hospitalizations, helping to reduce costs for the healthcare system. At the same time, travel and resource consumption are limited, reducing the environmental footprint. Thus, empowerment is not only a matter of rights, but also a lever for efficiency and resilience of the system [1]. Overall, the trajectory of eHealth will be determined by how equity and empowerment issues are addressed. If solutions are truly accessible, affordable, and designed with user diversity in mind, then eHealth can be a driver of inclusivity and sustainability. On the contrary, without protection of privacy, without trust and without support for citizens' skills, it risks widening existing inequalities. For this reason, integrating equity into any digital health strategy is necessary for health systems to move towards a future that combines efficiency, inclusion and responsible environmental management [60].

Case Studies of Sustainable eHealth in Practice

The research conducted by Palm, et al. [40,61] provides a comparative analysis of how nine health systems within the OECD articulate and implement their national eHealth strategies. These systems include Australia, Denmark, Estonia, Finland, Norway, Sweden, the UK (NHS England), Catalonia (Spain), and the U.S. Veterans Affairs system. Instead of concentrating on technical specifics or individual initiatives, the authors take a broader perspective to investigate three fundamental dimensions:

1. The vision and objectives established by each system,
2. The methods proposed to achieve those objectives (resources, policies, roles, coordination), and
3. The frameworks for follow-up, evaluation, and accountability [61].

Why is this overarching perspective so essential? Because a strategy transcends a mere wish list; it serves as a roadmap. In the absence of clear alignment between ambitious goals and tangible plans, and without systems to monitor progress, even the most visionary aspirations can fail to make an impact. Palm et al. observe that while the majority of systems articulate a clear vision, there is

significant variation in how they detail the 'how' and the 'afterwards'. Australia and Estonia stand out as models, with comprehensively detailed strategies, defined roles, timelines, and integrated monitoring. Conversely, others such as Sweden or Catalonia demonstrate stronger rhetorical commitment but lack robust structural follow-up and specificity [3].

Another recurring theme is the engagement of stakeholders, specifically how governments involve medical professionals, technology companies, patient organizations, and regional entities in the formulation and implementation of eHealth initiatives. The authors observe that numerous countries reference stakeholder collaboration in their documentation, yet they often fail to provide a detailed explanation of how this collaboration is practically achieved. In many instances, the development process is described only in a cursory manner, leaving the reader uncertain about the depth or inclusiveness of the collaboration. Nevertheless, despite the variations, there are shared elements. Many strategies position eHealth as a catalyst for integration, data sharing, improved access, and enhanced system efficiency. They frequently link digital health objectives to broader national strategies concerning health, digital transformation, cybersecurity, or data governance. When such alignment is clearly defined and well-articulated, the strategy tends to exhibit greater coherence and resilience [62-64]. In contrast, in systems where planning is more fragmented, or where digital health is less integrated into comprehensive national plans, the likelihood of fragmentation or redundancy escalates.

Challenges and Opportunities

Health organizations face significant obstacles in their efforts to adopt sustainable practices, but these can be a starting point for long-term improvements. The difficulties stem mainly from the high consumption of resources that characterize the health sector: high energy use, large quantities of waste and dependence on materials that burden the environment. Hospitals, for example, consume a significant part of national energy, which leads to high greenhouse gas emissions and exacerbates climate change. Rising energy costs and aging infrastructure exacerbate the problem, making the need for energy efficiency and the utilization of renewable sources imperative [65]. Integrating sustainability into healthcare operations is complex. Most management systems focus on individual goals, such as reducing costs or improving clinical indicators, without adopting a holistic approach. In this way, opportunities for systemic change are lost. In waste management, for example, most initiatives are limited to regulatory compliance, without leveraging innovations such as circular material use models or life cycle assessments. Similarly, available standards, such as ISO 14001, provide a general framework but need adjustments to meet the specific needs of healthcare, such as hazardous waste management or the environmental impact of medicines.

The fragmented structure of health systems, with different actors, infrastructure levels, and regulations, adds complexity and makes coordination difficult. Despite the difficulties, there is great potential for innovation. New technologies and design solutions can significantly reduce environmental impact. The use of natural light, energy-efficient systems and sustainable materials in hospitals, in addition to saving energy, also contributes to the recovery of patients and the improvement of the working environment. At the same time, digital applications, such as telemedicine, reduce the need for physical facilities and commuting, reducing the carbon footprint [66,67]. Sustainability is also linked to financial incentives. Investing in energy-efficient infrastructure or renewable energy leads to significant long-term savings while reducing reliance on volatile markets. The shift to value-based care models, rather than the volume of services, aligns with sustainability goals, as it encourages community-based prevention and interventions, reducing overall resource consumption. Active stakeholder involvement is crucial. When patients, employees, and the local community participate in sustainability initiatives, a culture of environmental responsibility is fostered. Information campaigns or "green action" groups within hospitals can enhance engagement and create positive examples.

Additionally, partnerships with suppliers to adopt more sustainable practices in the supply chain multiply the impact and enhance the resilience of the health system as a whole [68,69]. To sum up, the barriers to sustainability in healthcare are severe, but they come with great opportunities. Through systemic reforms, technological innovation, and collaboration between all stakeholders, health systems can turn challenges into drivers of change. Thus, they not only enhance their operational resilience, but also meet their moral obligation to protect the health of people and the environment.

Education and Capacity Building for Sustainable eHealth

Worldwide, healthcare practitioners are charged with delivering high-quality care that is centered on patients and communities to achieve better health outcomes. In today's rapidly evolving healthcare environment, it is crucial to remain informed about the latest medical innovations and best practices to effectively address patients' needs. Consequently, the ongoing development of healthcare professionals has become increasingly important in response to the global healthcare demands. The aim of this continuous growth in healthcare is to foster a learning environment that enhances the knowledge and skills of healthcare professionals. This enhancement will improve their ability to provide patients with high-quality, evidence-based care. Therefore, eLearning has emerged as a promising strategy for capacity building and ongoing development for healthcare professionals. eLearning utilizes digital technologies to disseminate educational content and training programs, providing flexibility and accessibility to healthcare providers with various specialties across different settings [70-72].

Key indicators encompass knowledge acquisition, evaluating the depth and relevance of eLearning content, skill enhancement, and assessing practical competencies within the roles of participants; clinical performance, measuring the real-world application of knowledge and skills; and overall professional competence, which includes a comprehensive effectiveness across various dimensions of healthcare practice. In addition, eLearning empowers learners to personalize their educational experiences, accommodating individual preferences and learning styles. Furthermore, through self-paced modules and interactive sessions, eLearning facilitates opportunities for tailored skill enhancement and ongoing professional development. Additionally, eLearning offers the convenience of accessing educational content at times that suit the learners. This adaptability allows learners to effectively manage their professional responsibilities alongside their educational endeavors [72-74].

Despite the advantages associated with eLearning programs, there are challenges that must be examined, understood, and addressed to ensure the successful implementation of eLearning initiatives for the ongoing professional development (CPD) of healthcare practitioners. Therefore, after decades of research into the deployment of eLearning for healthcare professionals, it is crucial to evaluate the effectiveness and challenges that eLearning programs encounter in the capacity building of healthcare professionals [70]. Over the last ten years, the impact of eLearning on improving the capacity of healthcare professionals has garnered significant interest from policymakers, international organizations, researchers, and educators. The effectiveness of eLearning programs pertains to the degree to which electronic learning interventions, implemented through digital technologies and online platforms fulfill their intended objectives in enhancing the knowledge, skills, clinical performance, and overall professional competence of healthcare professionals [70-75].

Discussion

Sustainable healthcare is not a fixed goal that is conquered for good, but a continuous process of adaptation and improvement. Initially, the debate around sustainability focused on reducing the environmental footprint of hospitals and improving resource efficiency. Gradually, however, the vision expanded, with digital transformation now playing a decisive role. As such, eHealth has ceased to be an alternative and has become a key component in providing fair, effective and environmentally responsible care. Available evidence shows that eHealth contributes to all three pillars of sustainability. From an environmental perspective, digital tools reduce waste and duplication. On a societal level, they facilitate inclusive access and empower patients. Cost-effectively, they improve efficiency and reduce costs. However, examples of projects that did not succeed show that technology alone is not enough. Without proper integration into the workflow, adequate training, and lack of user acceptance, even the most sophisticated systems risk failing and turning into costly investments with no meaningful impact. Central to success are people: patients, healthcare professionals

and policymakers. Sustainable eHealth goes beyond the technical dimension of interoperability; It requires building trust, clarity about data ownership, and a culture in which digital tools are perceived as supportive rather than a hindrance.

Patient empowerment emerges as a fundamental factor. When citizens have the right tools and the confidence to actively participate in their care, not only do clinical outcomes improve, but the resilience of the system is also strengthened, with less waste and better resource management. International experiences confirm this. Countries that consistently invested in digital infrastructure, implemented transparent governance mechanisms, and engaged citizens from the early stages, such as Denmark and Sweden, have made more progress than those that relied on isolated and disconnected initiatives. At the European level, epSOS and EU governance strategies show how cooperation and interoperability can act as common objectives with a real impact. However, challenges remain. Digital divides persist, creating concerns about equality and universal access. Data protection and cybersecurity require constant vigilance, especially as systems become more interconnected. New technologies, such as artificial intelligence and predictive analytics, open up great possibilities but also new ethical challenges.

The future of sustainable healthcare will be judged by the ability of systems to seize these opportunities and at the same time manage risks, in a way that fosters trust and promotes inclusion. Ultimately, the path to sustainable care is intertwined with the digital journey. eHealth doesn't just offer faster or cheaper services; It offers the possibility for fairer and more responsible care, with respect for the environment and the needs of future generations. Realizing this vision requires perseverance, collaboration, and commitment. Sustainability is not just a goal, but an ongoing responsibility that health systems are called upon to serve.

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Competing Interests

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