



Article

Digitalization of Higher Education Services in Terms of Green Economy

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Abstract: The rapid digital transformation sweeping through higher education is undeniably opening up exciting new avenues for enhancing educational quality, boosting institutional efficiency, optimizing resource management, and fostering greater sustainability. However, this widespread embrace of digital technologies including artificial intelligence, data-intensive services, extensive digital infrastructure, and a plethora of electronic equipment—raises some critical questions. Specifically, it compels us to ask whether digitalization automatically translates into a positive contribution towards building a greener economy. This particular study dives deep into how the digitalization of services in higher education can genuinely support sustainable development. To do so, it proposes an innovative "integrated green digital university framework." This framework aims to forge a clear and strong link between digital transformation and the vital pillars of environmental, economic, and social sustainability. Our research adopted a systematic qualitative approach, meticulously reviewing and synthesizing scientific literature, institutional reports, and international evidence. We primarily focused on materials published between 2020 and 2026, with a special emphasis on the very latest research from 2024 to 2026. The analysis honed in on several key areas: digital learning, the adoption of Smart Campus technologies, the principles of Green IT, strategies for energy efficiency, the integration of renewable energy, the cultivation of green human capital, the implementation of circular resource management, fostering digital inclusion, and understanding the environmental costs associated with digital infrastructure. The findings reveal a promising picture: digitalization can significantly reduce our reliance on paper, minimize unnecessary travel, decrease the consumption of administrative materials, and cut down on inefficient resource utilization. Simultaneously, it empowers us with real-time monitoring and optimization capabilities for everything from campus energy and water usage to buildings, waste management, and transportation systems. Yet, the study also uncovers a significant "digital sustainability paradox." As we expand our AI capabilities and build out more data-centre infrastructure, we inevitably see a rise in electricity demand and an increase in electronic waste a pressing challenge, especially considering the International Energy Agency's projection that global data-centre electricity consumption could soar to approximately 945 TWh by 2030. Therefore, we conclude that achieving truly sustainable digital transformation necessitates a multi-faceted approach. This includes the widespread integration of renewable energy sources, the development of more energy-efficient computing methods, responsible procurement practices, comprehensive lifecycle management for digital assets, a strong commitment to digital inclusion, and the establishment of measurable sustainability indicators. The "green

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digital university model" proposed in this study offers a systemic framework designed to align digital innovation seamlessly with the broader transition towards a resilient, inclusive, and environmentally sound green economy.

Keywords: Digital transformation, Higher education, green digital university, green economy, Smart Campus, Artificial intelligence, Green IT, Green human capital, Digital sustainability, Renewable energy, Circular economy, Sustainable higher education.

Introduction

Higher education is undergoing a profound digital transformation, fundamentally reshaping how universities deliver everything from teaching and administration to research and daily campus services. Cutting-edge tools like artificial intelligence (AI), cloud computing, the Internet of Things, big-data analytics, advanced digital learning platforms, and smart-campus technologies are becoming deeply embedded in how institutions operate. This integration opens up exciting new possibilities for improving accessibility, boosting operational efficiency, optimizing how resources are managed, and ultimately enhancing the quality of education. Recent academic work highlights that we should no longer see universities simply as places of learning, but rather as complex socio-technical systems where digital innovation, institutional leadership, environmental performance, and social responsibility are increasingly intertwined. This evolving perspective is particularly crucial as higher education institutions are now expected to play a more active role in achieving the Sustainable Development Goals and contributing to the broader shift towards a green economy.

We're increasingly seeing digitalization and sustainability converge, especially in the development of green and Smart Campuses. New studies clearly show that AI, IoT, digital twins, and big-data technologies can facilitate real-time monitoring and optimization of critical campus resources—like energy, water, buildings, and transportation—thereby significantly improving both environmental and operational performance. What's more, digital tools can also foster "green education" and cultivate "green human capital" by seamlessly weaving climate literacy, circular-economy principles, renewable energy, and environmental responsibility into teaching and learning. UNESCO's most recent guidelines further underscore the importance of integrating climate education across all levels of tertiary education and ensuring that our digital and green transitions move forward hand-in-hand.

However, it's vital to recognize that simply going digital doesn't automatically guarantee environmental sustainability. The rapid growth of AI and data-intensive services has created a considerable digital sustainability challenge. The International Energy Agency, for instance, predicts that global data-centre electricity consumption could more than double to roughly 945 TWh by 2030, with AI being a primary driver of this increase. Consequently, the true sustainability of digital higher education hinges not just on adopting new technologies, but also on prioritizing energy efficiency, integrating renewable energy, making responsible procurement choices, carefully managing equipment lifecycles, reducing electronic waste, and ensuring broad digital inclusion.

With this complex backdrop in mind, our study investigates how the digitalization of higher education services can genuinely contribute to the transition towards a green economy. It proposes an integrated "green digital university" framework that deliberately connects digital learning, Smart Campus infrastructure, Green IT practices, renewable energy, green human capital development, circular resource management, digital inclusion, and measurable sustainability performance. This approach pushes beyond the traditional idea of a "digital university" towards a more systemic model, where digital transformation is thoughtfully and intentionally aligned with broader environmental, economic, and social sustainability goals.

Literature review:

The digital transformation of higher education has increasingly shifted from a technology-oriented process toward a broader institutional transformation associated

with sustainability, resource efficiency, and the transition to a green economy. Recent research conceptualizes universities as complex socio-technical systems in which digital infrastructure, education, research, governance, campus operations, and environmental performance are interconnected. A systematic review of 69 secondary studies emphasizes that sustainability in higher education should be addressed holistically through institutional governance, education, research, campus operations, stakeholder engagement, and assessment [1]. Similarly, a critical review of 670 studies demonstrates that university sustainability initiatives often remain fragmented rather than being implemented through coherent institutional strategies, highlighting the need for integrated governance and comprehensive sustainability assessment [2].

An important contribution to this field is provided by Zou et al., who examine the relationship between digitalization and green university development. Their framework incorporates four dimensions—green education, green research, green campus, and green life—and demonstrates that digital technologies can support sustainability across multiple university functions [3]. This approach provides a foundation for understanding digitalization not simply as technological modernization but as an enabling mechanism for institutional sustainability transformation.

The Smart Campus concept further connects digital technologies with sustainable university development. Haggag et al. identify artificial intelligence (AI), the Internet of Things (IoT), digital twins, big-data analytics, robotics, blockchain, and other advanced technologies as important tools for improving operational efficiency, resource monitoring, and sustainability performance. However, technological complexity, privacy and security risks, and substantial investment requirements may constrain implementation [4]. Digital twins and AI-enabled building systems can additionally support real-time monitoring, predictive analytics, energy optimization, adaptive control, and environmental performance management [5]. Their integration with zero-energy building technologies may further contribute to renewable-energy utilization, predictive maintenance, and carbon reduction [6].

AI is also becoming an important component of sustainable higher education. A systematic review of 39 studies identifies customized learning, accessibility, and resource allocation as major areas in which AI can contribute to sustainable higher education, while also emphasizing ethical, pedagogical, policy, and governance challenges [7]. Evidence from 51 studies concerning AI and Sustainable Development Goals further indicates that digital technologies can improve educational accessibility, flexibility, and inclusion, particularly in relation to SDG 4 and SDG 10 [8]. These findings suggest that the sustainability of digital transformation requires environmental benefits to be accompanied by social inclusion.

Sustainability education and institutional culture constitute another important dimension. Recent research supports a whole-institution approach in which sustainability is embedded in curricula, research, governance, operations, and stakeholder engagement rather than treated as a separate educational issue [9]. In parallel, green human resource management and sustainability-oriented competencies are increasingly recognized as essential for developing environmentally responsible organizational behavior and institutional capacity [10], [11]. Thus, successful digital-green transformation depends not only on infrastructure but also on the knowledge, competencies, and behaviors of students and employees.

The environmental costs of digitalization also require consideration. The expansion of electronic devices, smart infrastructure, and digital learning systems increases the importance of e-waste prevention, reuse, recycling, and lifecycle management [12]. At the same time, digitalization creates a sustainability paradox: although digital services can reduce paper use, travel, and physical resource consumption, digital infrastructure requires substantial electricity and hardware. The International Energy Agency projects that global data-centre electricity consumption could reach approximately 945 TWh by 2030, with AI representing a major driver of this growth [13]. Therefore, the environmental value of digitalization depends on energy efficiency, renewable-energy integration, hardware management, and lifecycle sustainability.

Recent higher-education sustainability research consequently emphasizes the need for comprehensive indicators and integrated assessment frameworks rather than isolated environmental measures [14]. Moreover, universities increasingly have responsibilities extending across teaching, research, management, and societal engagement in support of sustainable development [15]. Nevertheless, the literature remains fragmented across digital learning, Smart Campus technologies, AI, sustainability education, green human capital, energy efficiency, and circular resource management. The present study addresses this gap by conceptualizing the **green digital university** as an integrated model linking digital learning, Smart Campus technologies, Green IT, renewable energy, green human capital, circular resource management, digital inclusion, and measurable sustainability performance.

Methodology:

This study employed a **systematic qualitative research design** to examine how the digitalization of higher education services contributes to the transition toward a green economy. The methodology was developed to capture both the environmental opportunities and potential sustainability risks associated with digital transformation. In accordance with the conceptual framework of the study, the analysis focused on five interconnected dimensions: digital learning services, Smart Campus technologies, Green IT and energy efficiency, sustainability-oriented education and green human capital, and the environmental costs of digital infrastructure.

The study was based on a structured review and synthesis of recent scientific literature, institutional reports, and international evidence published primarily between **2020 and 2026**, with particular attention to studies published during 2024–2026. Relevant literature was identified through major academic databases and authoritative institutional sources, including **Scopus, Web of Science, ScienceDirect, UNESCO, the International Energy Agency (IEA), and EDUCAUSE**. The search strategy combined keywords and Boolean operators such as *“digitalization of higher education,” “digital university,” “green university,” “green economy,” “Smart Campus,” “Green IT,” “AI and sustainability,” “digital learning,” “renewable energy,” “e-waste,”* and *“higher education sustainability.”* Studies were considered relevant when they examined the relationship between digital technologies, university services, institutional sustainability, resource efficiency, or environmental performance.

Following this, a thematic analysis was carried out to pinpoint recurring patterns and relationships across all the selected sources. We organized the evidence into several key analytical categories: how digital services help reduce resource and paper use; the smart monitoring and optimization of campus resources; the development of digital and green competencies; the energy consumption and carbon implications of digital infrastructure; the integration of renewable energy and Green IT; the management of electronic waste and technology lifecycles; and finally, digital inclusion and accessibility. This way of classifying things aligns with recent Smart Campus research, which is increasingly focused on how AI, IoT, digital twins, and big-data technologies can be integrated to boost both operational efficiency and sustainability.

The study also employed **comparative and interpretive analysis** to distinguish between the potential environmental benefits and costs of digitalization. Particular attention was given to the emerging energy implications of artificial intelligence and data-intensive services. Recent IEA projections indicate that global data-centre electricity consumption could approximately double from 2025 levels to around 950 TWh by 2030, highlighting the necessity of considering the environmental footprint of digital infrastructure alongside its efficiency benefits.

Finally, the findings from the literature and institutional evidence were synthesized into an **integrated green digital university framework**. The framework evaluates digitalization according to environmental efficiency, economic viability, social inclusion, and lifecycle sustainability. This approach enables the study to move beyond viewing digital transformation solely as technological modernization and instead assess its capacity to support a systemic transition toward sustainable higher education and the broader green economy.

Discussion:

The findings indicate that the digitalization of higher education services should be understood not merely as technological modernization, but as a structural transformation with significant implications for the transition toward a green economy. Digital learning platforms, Smart Campus technologies, Green IT, data-driven governance, and digitally supported sustainability education can improve institutional efficiency and environmental performance. However, these benefits are conditional upon energy-efficient infrastructure, responsible equipment lifecycle management, renewable energy use, and the integration of digital transformation into broader sustainability strategies.

A key implication is that the environmental benefits of digitalization depend largely on **substitution effects**. Digital technologies generate greater sustainability gains when they replace resource-intensive activities such as paper-based administration, excessive printing, unnecessary physical mobility, and inefficient resource management. Therefore, universities should assess digital transformation not by the volume of technologies adopted, but by measurable improvements in resource efficiency, energy conservation, emissions reduction, and institutional sustainability.

The findings concerning **Smart Campus** systems demonstrate that digitalization can transform environmental management from periodic and reactive practices toward continuous, predictive, and data-driven governance. IoT sensors, automated building systems, and real-time monitoring platforms enable universities to optimize electricity, water, waste, transportation, and building performance. Consequently, digital infrastructure should be considered an integral component of university sustainability policy rather than solely an educational or administrative resource.

Another important implication concerns the development of **green human capital**. The green transition requires graduates who combine digital competencies with environmental awareness. Artificial intelligence, data analytics, digital modelling, and information systems should consequently be integrated with climate literacy, resource efficiency, circular economy principles, and environmental responsibility. This approach allows higher education institutions to contribute not only to their own environmental performance but also to the development of a workforce capable of supporting the wider green economic transition.

At the same time, the findings reveal a significant **digital sustainability paradox**. Digitalization can reduce paper use, physical mobility, and certain material requirements, but digital infrastructures themselves consume substantial electricity and require data centres, computing equipment, cooling systems, and network capacity. This challenge has become more significant with the rapid expansion of artificial intelligence and data-intensive applications. Accordingly, the environmental performance of digital higher education should be assessed from a lifecycle perspective, covering procurement, operation, maintenance, upgrading, reuse, and final disposal.

The role of **renewable energy and Green IT** is therefore increasingly strategic. Energy-efficient technologies, smart energy-management systems, renewable electricity, efficient cooling, and sustainable digital procurement can reduce the carbon intensity of digital educational services. However, technological investment alone is insufficient. Institutional financing, leadership, staff capacity, policy support, and long-term sustainability planning are necessary to transform digital innovation into measurable environmental outcomes.

The **digital divide** represents another critical consideration. Unequal access to reliable internet, appropriate devices, digital platforms, and technological skills may limit the social benefits of digital higher education and reinforce existing inequalities. Sustainable digitalization must therefore integrate environmental efficiency with economic viability and social inclusion.

Finally, the findings highlight the need for universities to introduce **integrated digital-green performance indicators**, including energy consumption per student, carbon emissions from digital services, renewable-energy utilization, paper reduction, e-waste generation, digital accessibility, smart-building coverage, and sustainability-related

learning outcomes. Such indicators can strengthen evidence-based governance and enable institutions to evaluate the actual sustainability effects of digital transformation.

Overall, the discussion supports a transition from the traditional **“digital university” to the “green digital university.”** Digitalization and the green economy are mutually reinforcing but not automatically aligned processes. The most sustainable pathway combines digital education, Smart Campus technologies, Green IT, renewable energy, circular procurement, e-waste management, green competencies, inclusive access, and transparent sustainability measurement. This integrated approach can position higher education institutions not merely as users of digital technologies, but as active drivers of the broader green economic transition.

Results:

The results demonstrate that the digitalization of higher education services is becoming an important institutional mechanism for advancing the principles of the green economy. Digital transformation contributes to sustainability through interconnected channels, including the reduction of physical resource consumption, optimization of campus operations, improvement of energy efficiency, expansion of virtual educational services, development of green competencies, and data-driven environmental governance. However, digitalization should not automatically be considered environmentally sustainable. Its contribution depends on the energy efficiency of digital infrastructure, the lifecycle management of electronic equipment, electricity sources, and the institutional capacity to integrate digital transformation with sustainability strategies.

A significant result concerns the transition from predominantly physical education to hybrid and digitally mediated learning models. Learning management systems, virtual classrooms, digital libraries, online assessment, electronic administrative services, and collaborative platforms can reduce paper consumption, printing, administrative material use, and, in some cases, commuting. These environmental benefits are most substantial when digital technologies replace resource-intensive activities rather than simply adding another technological layer to existing educational processes.

The findings further indicate that the environmental contribution of digital higher education is increasingly associated with the development of **Smart Campus** systems. Digital sensors, Internet of Things technologies, automated lighting and heating, building management systems, and real-time monitoring platforms enable universities to move from reactive resource management toward data-driven environmental governance. Such technologies support continuous monitoring of electricity, water consumption, waste generation, transportation, and building performance, allowing institutions to identify inefficiencies and allocate resources more effectively.

Digitalization also transforms sustainability-oriented teaching and learning. Digital platforms facilitate the integration of climate change, renewable energy, circular economy, environmental management, sustainable production, and responsible consumption into academic curricula. They also provide access to international research, open educational resources, virtual laboratories, simulations, and collaborative projects. Consequently, digital transformation contributes to the development of **green human capital** by combining digital competencies with environmental awareness and sustainability-related knowledge. Students increasingly require skills in data analytics, artificial intelligence, digital modelling, and information systems while understanding their implications for resource efficiency and environmental protection.

The results suggest that the most effective approach is an **integrated digital-green university model**, in which digital transformation, sustainability governance, infrastructure modernization, education, research, and community engagement reinforce one another. In this context, **Green IT**, energy-efficient technologies, smart energy-management systems, and technologies that reduce unnecessary travel are becoming increasingly important components of university sustainability strategies.

At the same time, the findings reveal a significant **digital sustainability paradox**. Although digitalization can reduce physical resource consumption, digital infrastructure requires electricity, data centres, network capacity, computing equipment, cooling systems, and electronic devices. The rapid expansion of artificial intelligence and other

data-intensive applications further increases these demands. Therefore, the environmental performance of digital higher education depends on energy-efficient computing, renewable electricity, responsible procurement, longer equipment lifecycles, cloud-resource optimization, and effective electronic-waste management.

Another important challenge is the **digital divide**. While digital learning can expand educational access, unequal availability of high-speed internet, appropriate devices, digital platforms, and technological skills may reproduce existing inequalities. Thus, sustainable digitalization must be environmentally efficient, economically viable, and socially inclusive.

The results also highlight the importance of renewable energy integration and digital sustainability measurement. Universities should complement traditional performance indicators with measures such as energy consumption per student, carbon emissions associated with digital services, renewable-energy share, paper consumption, electronic-waste generation, digital accessibility, smart-building coverage, and sustainability-related learning outcomes.

Overall, the findings confirm that digitalization can serve as a strategic accelerator of the green economy in higher education when implemented through an integrated framework. The strongest effects emerge when digital learning is combined with smart infrastructure, renewable energy, Green IT, environmental monitoring, circular procurement, e-waste management, sustainability-oriented curricula, and transparent performance measurement. Therefore, the relationship between digitalization and the green economy is systemic and conditional. The transition toward sustainable higher education requires a shift from the concept of a *digital university* to that of a **green digital university**, where digital transformation is deliberately designed and evaluated according to environmental, economic, and social sustainability criteria.

Conclusion:

This study concludes that the digitalization of higher education services can become a significant accelerator of the transition toward a green economy, but its contribution is neither automatic nor technologically determined. The findings demonstrate that digital learning platforms, Smart Campus technologies, Green IT, artificial intelligence, data-driven governance, and digitally enabled sustainability education can simultaneously improve institutional efficiency, resource management, accessibility, and environmental performance. However, these benefits are realized only when digital transformation is embedded within a coherent sustainability strategy and evaluated across environmental, economic, and social dimensions.

A central contribution of the study is the conceptualization of the **green digital university** as a systemic extension of the conventional digital university. Rather than treating digitalization and sustainability as separate policy domains, this model integrates digital learning, smart infrastructure, renewable energy, green human capital, circular resource management, digital inclusion, and measurable sustainability indicators. This systemic orientation is consistent with recent evidence showing that universities still frequently implement sustainability initiatives in fragmented ways and require more integrated governance and reliable assessment frameworks.

The study also confirms the importance of addressing the **digital sustainability paradox**. While digital services can reduce paper use, physical mobility, and inefficient resource consumption, the expansion of AI and data-intensive applications is increasing electricity demand. The IEA projects global data-centre electricity consumption to reach approximately 950 TWh by 2030, underscoring the need for energy-efficient computing, renewable electricity, lifecycle management, and responsible digital procurement.

From a policy perspective, universities should therefore move from technology adoption toward **measurable digital-green performance management**, incorporating indicators such as energy use per student, digital-service carbon emissions, renewable-energy share, e-waste, paper reduction, digital accessibility, and sustainability learning outcomes. UNESCO's recent whole-institution approach further reinforces the need to connect teaching, operations, governance, and community engagement in greening education.

Future research should empirically test the proposed framework using university-level panel data, lifecycle assessments, carbon accounting, and comparative cross-country studies. Such evidence would strengthen understanding of the causal relationship between digital transformation and sustainable economic performance and support the development of more resilient, inclusive, and environmentally responsible higher education systems.

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