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Aligning Digital Futures with Ecological Citizenship for Sustainability

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Abstract

As digital technology continues to embed and influence everyday life, its social and environmental impacts need to be addressed seriously. This article introduces and clarifies the concept of *Ecological Citizenship* (*EC*), defining it as a form of citizenship that extends rights and duties beyond the human social sphere into ecological systems, requiring individuals, communities, and institutions to take responsibility for the environmental consequences of their digital practices. Unlike traditional forms of citizenship tied to legal or territorial boundaries, *EC* is grounded in shared ecological accountability and civic responsibility. We argue that *EC* offers a distinctive lens for shaping the evolution of a Sustainable Digital Society (*SDS*), where digital innovation and sustainability are co-aligned. Through theoretical analysis and case studies, this article examines how *EC* can support community-based, policy-led, and design-focused approaches towards digital sustainability. We look to highlight ways in which *EC* can be embedded in digital behaviour, infrastructure, and product design while acknowledging barriers such as the digital divide, unequal resource allocation, and adverse policy settings. This research aims to offer policymakers, technologists, and educators' pragmatic advice for realising sustainable design, environmental literacy, and universal digital access. The study looks to argue for a more systemic reconsideration of digital development, a consideration which places environmental values at the forefront of technological progress, to ensure that digital transformation is both socially equitable and beneficial to planetary well-being.

Keywords: Sustainable Digital Society; Ecological Citizenship; green computing; circular economy; digital policy; emerging technologies; environmental sustainability

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1. Introduction

The spread and growing acceleration of digital technologies are transforming nearly all areas of contemporary life [1,2]. Enterprise, communication, education, as well as governance, are all increasingly deeply rooted in digital technologies throughout the social, economic, and political dynamics of the 21st century [3,4]. While the persistent expansion of the digital world is regarded on all sides as being increasingly at an environmental cost. Increased energy demands of data centres [5,6], environmental impacts of manufacturing and e-waste disposal [7,8], increasing levels of e-waste [9,10], and the ecological and psychological impacts of hyper-connectivity [11] all raise critical and pressing questions about the long-term sustainable development of the digital. These pressures underscore the necessity for a more sustainable digital innovation approach, aligning technological progress and environmental responsibility.

In light of these pressures, the concept of a Sustainable Digital Society (*SDS*) has increasingly come to the forefront [12]. *SDS* seeks to not only reduce the environmental footprint of digital technologies but also use them for the benefit of society in support of broad environmental goals [13,14]. However, technological fixes alone are insufficient; achieving such a society requires cultural and behavioural change in how individuals, institutions, and communities engage with technology. Here, we propose *Ecological Citizenship (EC)* as a guiding philosophy and practice. *EC* is defined in this paper as an ethos-driven approach to digital life, rooted in ecological responsibility, civic participation, and inclusivity for both human and more-than-human worlds [15]. This definition clarifies that *EC* is not merely a metaphor, but a normative and practical framework for aligning digital transitions with sustainability. Political science and citizenship education have significantly expanded the concept of citizenship [16,17]. It is no longer seen as merely a legal status matter or political rights. Instead, it is portrayed as an engaged practice encompassing civic activity, moral duty, and participation in solving issues of society, including those pertaining to both the environmental and digital context [18]. Building on this expansion, *EC* adapts citizenship to the ecological era, emphasizing that digital practices, from data consumption to device use, are inseparable from environmental impacts [19]. This framing allows us to situate *EC* as both a theoretical contribution to sustainability scholarship and a practical response to the call for ways to integrate values-driven approaches into sustainable digital transitions.

This paper discusses how the inclusion of *EC* values in the development of digital technology can contribute to creating a more sustainable and equitable digital future. It investigates key sustainability topics such as energy consumption, device lifecycles, and electronic waste, as well as the effects of improvements in sustainable computing, low-power algorithms, and circular economy models. It connects *EC* principles with concrete actions in digital innovation through case study assessments and stipulates future research possibilities in ensuring that technology development is environmentally conscious. By explicitly linking *EC* to both theoretical debates and policy agendas, this paper positions *EC* as a critical conceptual and practical tool for imagining and realizing an ecologically resilient digital society.

2. Why EC and SDS?

Given the changing landscape of sustainable digital development, there is an increasing need to redefine how individuals and societies are embedded within both technological systems and the natural environment, ecologically and as civic actors [12]. As digital technologies shape communication, consumption, learning, and governance, their ecological implications demand attention [20]. In this paper, we define *EC* as a civic and ethical orientation in which responsibility for environmental sustainability is shared across individuals, communities, corporations, and governments. Unlike conventional models of citizenship, which are often tethered to rights and responsibilities conferred by the state, *EC* extends accountability beyond territorial and legal structures into ecological systems. This means recognising that digital actions, such as device upgrading, energy-intensive data use, or reliance on non-recyclable hardware, have ecological consequences that reverberate globally. *EC* therefore reframes digital participation as not only a matter of access or rights but also a matter of ecological justice and planetary stewardship.

This evolution calls for ecological responsibility to extend into technological domains, where behaviours in online and physical spaces have real-world environmental consequences. Digital *EC* in this sense breaks from state-centred models grounded solely in institutional participation and legal rights, and instead embraces a more expansive, participatory vision of civic responsibility.

Building on political theory and civic education, this approach highlights the importance of everyday actions, for instance, such as reducing data usage, prolonging device lifespans, supporting sustainable tech design, and resisting environmentally damaging digital practices, combined with broader civic engagement like campaigning for sustainable tech policy and civic digital green activism.

The distinction between *EC* and related concepts such as "digital citizenship" lies in EC's explicit ecological orientation. Digital citizenship traditionally emphasises responsible online behaviour, literacy, and inclusion. *EC* incorporates these but goes further, making environmental responsibility a non-negotiable foundation of participation. This reframing introduces a necessary environmental dimension into frameworks of digital ethics, green computing, and digital governance, aligning them with sustainability science. At its core is collective responsibility, where stewardship of the digital realm involves users, developers, corporations, governments, and civil society.

A focus on environmental justice is central: digital ecological harms, such as e-waste, data centre emissions, and resource extraction, often disproportionately impact marginalised groups. By emphasizing distributive justice, *EC* connects the environmental costs of digitalisation to questions of equity and fairness, ensuring that the burdens and benefits of digital transformation are not unevenly shared [21,22]. This framework is grounded in the recognition that digital behaviours, like frequent device upgrades or data-intensive usage, are fundamentally intertwined with ecological outcomes. Increasing awareness can subsequently catalyse collective action and foster a transition from passive digital consumption to empowered EC.

Ultimately, digitally focused *EC* is more than an ideal. It is an urgent imperative for nurturing sustainable digital cultures, where ecological literacy and civic responsibility are embedded into digital systems and infrastructures. By positioning *EC* as a framework for an *SDS*, we argue that sustainability in digitalisation cannot be achieved solely through efficiency improvements or technological innovation but must also involve cultural change and institutional redesign.

3. Research Objectives

The following research objectives were designed to assess the integration of *EC* into digital technologies, identify good practices and best practices, and develop policy and practice recommendations for fostering a more sustainable and equitable digital society.

1. Assess the integration of *EC* into digital technologies: Examine how EC principles can be applied most effectively to design, develop, and use digital technologies for environmental sustainability.
2. Identify good practices and best practices: Identify and study cases and best practices wherein *EC* principles have been successfully implemented in digital practices and assess their effectiveness in achieving sustainability goals.
3. Develop policy and practice recommendations: Make detailed recommendations and proposals for integrating *EC* into digital policy and practice that can work towards a more sustainable and equitable digital society.

4. Approach

This study adopts a qualitative, comparative case study methodology to investigate how principles of *EC* are being integrated into digital systems that aim to support an *SDS*. The research follows an interpretivist and exploratory design, privileging practice-based illustrations over purely theoretical models. The goal is to identify how *EC* values manifest in real-world digital projects through policy mechanisms, governance frameworks, and citizen engagement. The decision to employ a comparative case study method is deliberate.

While alternative approaches such as large-scale quantitative modelling or survey-based research can provide a breadth of data on digital sustainability practices, they often overlook the contextual and situated dimensions of how ecological values become embedded in digital infrastructures. A case study approach, by contrast, allows for close examination of institutional, infrastructural, and socio-technical processes. This is important for *EC* because it is not only a normative framework but also an applied practice that varies across scales, actors, and geographies. The choice of case studies began with a broad search of global digital sustainability projects. This involved identifying a broad and diverse set of projects spanning ecological and digital interests. They were drawn from global sustainability databases, urban innovation repositories such as UN-Habitat and Eurocities, research literature, and grey reports related to ICT4D (Information and Communication Technology for Development). The scope was intentionally broad to span a range of settings, including diversity in geography, scale (grass roots, national, and municipal), application of technology (infrastructure, fabrication, and digital services), and governance models (public, private, civic, or hybrids).

From this initial pool, three case studies were selected for in-depth analysis. The selection was based on four specific criteria. First, each case had to demonstrate clear and explicit alignment with *EC* principles such as participation, stewardship, environmental justice, and democratic accountability. Second, the cases needed to offer evidence of policy relevance and potential scalability to other regions or systems. Third, they required a level of documentation that would support rigorous analysis, including quantitative or qualitative outcomes. Finally, the selected cases had to represent different pathways toward digital sustainability, one grounded in urban governance, one focused on rural infrastructure and digital inclusion, and one that rethinks urban production models.

The methodological positioning of this research is located at the intersection of interpretivist political ecology and sustainability transitions studies. Interpretivist methods emphasise meaning-making, allowing us to analyse how concepts of ecological responsibility are framed by institutions and communities. At the same time, transitions studies highlight systemic changes in technology, governance, and society. By integrating these traditions, the case analysis is able to show both the normative content of *EC* (how actors define EC) and its operationalisation (how this is enacted in practice). This hybrid framework was chosen over, for example, grounded theory, because the study begins with an explicit theoretical anchor in *EC* that is being tested against empirical instances rather than built inductively from scratch.

The three cases that met the inclusion criteria and were selected for detailed study are the Green Digital Charter (GDC), the SolarKiosk initiative in rural Kenya, and the Fab City Global Initiative. Each case provides a unique example of how *EC* principles can be applied within different sectors and contexts, offering valuable insights into the intersection of digital development and ecological ethics. Together, these cases present a comparative lens through which *EC* can be mobilised through varying policy, technological, and social instruments. Table 1 summarises the key aspects of these case studies, highlighting their alignment with *EC* principles, policy relevance, scalability, and the thoroughness of their documentation.

Table 1. Case study alignment with inclusion criteria.

Criteria	GDC	SolarKiosk	Fab City Global Initiative
Alignment with *EC* principles	Demonstrates participation, stewardship, environmental justice, and democratic accountability in urban governance.	Focuses on participation, stewardship, and environmental justice in rural digital inclusion.	Promotes democratic accountability, sustainability, and environmental justice in urban production models.

Table 1. *Cont.*

Criteria	GDC	SolarKiosk	Fab City Global Initiative
Policy relevance and scalability	Offers policy frameworks that can be scaled to other urban areas globally.	Can be adapted to other rural regions with similar infrastructure challenges.	Scalable to cities worldwide, offering innovative approaches to sustainable urban production.
Documentation and rigorous analysis	Supported by extensive documentation, including policy reports and outcomes.	Detailed records on rural impact, including qualitative and quantitative data.	Comprehensive data on urban sustainability efforts, with documentation available for comparative study.
Diverse pathways toward digital sustainability	Urban governance model that integrates digital tools for sustainability.	Focus on rural infrastructure, digital inclusion, and solar technology.	Rethinks urban production models, integrating digital tools for sustainable urban living.

5. Data Collection and Analysis

Data collection relied exclusively on secondary sources due to the transnational nature of the case studies. Sources included official project reports [23–26], policy documents, white papers, peer-reviewed publications, and performance dashboards published by implementing bodies or city governments. Additional sources included repositories related to civic technology initiatives, Fab Lab networks, and international sustainability platforms. Where possible, data were triangulated across different types of sources (e.g., pairing municipal energy use reports with Eurocities documentation) to improve validity and reduce reliance on promotional narratives.

The analytical process followed a deductive thematic coding strategy, informed by established conceptual dimensions of *EC* as outlined by Dobson [21] as well as by sustainability transitions literature. Thematic codes included citizen participation and empowerment, environmental accountability, circular resource use, institutional and governance design, and the presence of measurable sustainability metrics such as carbon reductions or material reuse. Each case was manually coded, with emerging themes clustered to identify both case-specific insights and cross-case patterns. The results were then organised using a structured analytical framework to compare the role of *EC* principles across contexts. This comparative framework provided a systematic lens for assessing how digital sustainability initiatives translate *EC* principles into operational strategies, environmental outcomes, and community engagement practices. It also helped identify whether each initiative was primarily policy-driven, infrastructure-led, or production-oriented, and how this positioning influenced outcomes.

6. Methodological Limitations

While the methodology offers strong interpretive depth, several limitations must be acknowledged. First, there is a selection bias toward successful, often-publicised case studies. While these cases are valuable for understanding best practices, they may underrepresent projects that failed, were controversial, or encountered resistance. Future research should intentionally include negative or control cases to enhance external validity and to better understand conditions of failure or unintended consequence. Second, this study is dependent on secondary data. Although a variety of source types were used to triangulate information, many of the performance metrics relied on project self-reporting. As such, there may be some degree of positive bias or inconsistency in how outcomes were measured and presented. Finally, there is a quantitative limitation. Of the three cases, only two, SolarKiosk and the GDC, offer clear quantitative environmental indicators such as

CO_2 offsets or energy savings. The Fab City initiative, while promising in its scope and ambition, has not yet produced fully scaled lifecycle assessments or carbon accounting that would allow for direct comparative evaluation. These methodological limitations also shape the theoretical reach of this study. Because the analysis is grounded in secondary and largely successful cases, the conclusions drawn are illustrative rather than predictive. This means that while the research can identify pathways and models of *EC* integration, it cannot guarantee replicability under different political or cultural conditions. The interpretivist approach is well suited to unpacking meaning and practice, but it constrains our ability to generalise in the way that econometric modelling or cross-national surveys might allow. However, this is not a flaw but a trade-off: by focusing on depth and contextual detail, the study contributes to theory-building around EC, while recognising that further empirical work is needed to test these models at scale.

7. Findings

This section provides detailed analysis of three case studies: GDC, SolarKiosk, and the Fab City Global Initiative, selected for their distinctive but complementary articulations of *EC* in digital contexts. These cases were chosen specifically to illustrate institutional, infrastructural, and socio-technical trajectories towards sustainability by means of environmental justice, democratic accountability, stewardship, and civic engagement. All three projects provide measurable outcomes and theoretical interest, helping to connect abstract *EC* concepts to functioning digital infrastructures.

The GDC is an institutionalised way of incorporating *EC* into city digital policy. Launched in 2009 by Eurocities in collaboration with the European Commission, the Charter has been signed by up to over 40 European cities, including Amsterdam, Dublin, Zagreb, Helsinki, and Vienna. Its central commitments are to reduce the carbon footprint of ICT operations, embracing green public procurement, exchanging sustainability innovation, and monitoring progress through peer-to-peer benchmarking [26]. Above all, the GDC shifts the burden of ecological stewardship from the person to civic systems as a whole. Following Dobson's [21] model, the institutional model incorporates environmental responsibility into the system of urban governance. To achieve this, the Charter has been promoting ecological democracy not just by tackling emissions but through the kind of policy-sharing architecture that sets up cities to co-create sustainability targets and learn from each other in open, cyclical systems.

In contrast to the urban-oriented policy approach of the GDC, SolarKiosk offers an infrastructure-oriented *EC* model rooted in rural energy poverty and digital exclusion problems. It is a socially embedded project initiated by the German social business SOLARKIOSK AG that has established modular, solar-powered kiosks in off-grid Kenyan villages and parts of Ethiopia. SolarKiosk kiosks incorporate photovoltaic panels, lithium-ion battery backup, and Wi-Fi routers and provide electricity and internet access to off-grid communities using a reliable power source [25]. SolarKiosk's environmental and social impacts are two-fold. First, each kiosk displaces approximately 1.2 metric tons of CO_2 emissions annually by providing an alternative to diesel generators typically used for charging mobile phones and powering small businesses [25]. Second, the kiosks are digital access centres offering the facilities for mobile banking, e-learning, digital health knowledge, and petty entrepreneurship. They also build civic capacity through equipping local operators with training in kiosk maintenance, solar power technology, and ICT skills, as is EC's emphasis on participatory stewardship and technological empowerment. Rather than treating environmental responsibility as a matter of individual morality or state-directed management, SolarKiosk translates access to clean power and digital services into a communal undertaking. The individuals are not passive consumers but custodians of the

system, facilitated by technical intelligence, local ownership, and direct participation in low-carbon digital futures. This model does *EC* in carbon reduction and distributive justice and broadens citizenship into energy and information systems previously missing.

The Fab City Global Initiative advances a Sustainable Digital Society with its alignment to the ethos of EC. Through innovation led by citizens, local production, and circular economies, it empowers people and communities to be effective agents of environmental design, ecological justice, and sustainability. Fab Labs with digital fabrication capabilities enable citizens to design, prototype, and manufacture locally. This collaborative approach not only engages people as active citizens but also enables reuse and upcycling of materials. Pilot evidence indicates that 40% or more of materials utilised in projects at Fab Labs are recycled or sourced locally, greatly diminishing dependence on global supply chains [23]. By reducing reliance on global supply chains, Fab City gives further credence to EC's environmental justice ideals. By using circular economies, it minimises waste and carbon footprints, a vision for cities to produce everything they use by 2054. Well over 50 cities worldwide have already embraced this vision, giving rise to green, local manufacturing processes [24]. The Fab City Dashboard is also an indication of the initiative's dedication to environmental sustainability as cities can monitor progress towards autonomy and measure their environmental impact. The dashboard facilitates transparency and adheres to EC's focus on democratic participation and institutional accountability [27]. Digital fabrication and open-source design are also prioritised in Fab City in order to construct sustainable infrastructures. This model reduces the environmental impact of technology, offering an alternative to wasteful, traditional systems of production. With collaborative innovation and open-source innovation, Fab City looks to enable a more sustainable digital world, showing that local production, circular economies, and sustainability can be combined in city planning [23]. In general, the Fab City model shows how *EC* can be used to construct a sustainable, resilient, and responsible digital society. Where SolarKiosk prioritises access and GDC prioritises governance, Fab City transforms digital sustainability into a problem of material culture and civic imagination. It provides us with an interactive platform upon which environmental stewardship is exercised not as abstention, but as collective creativity. In doing so, it builds new forms of *EC* that are founded on transparency, agency, and responsibility that is proximity-based.

Together, these three case studies demonstrate that *EC* is realisable in a variety of socio-technical systems by policy, infrastructure, and production. Each case deploys a distinct operational model of EC. The GDC demonstrates how municipal government and public policy can facilitate ecological responsibility and civic accountability. SolarKiosk transforms energy and digital access into collective environmental infrastructure managed at the community level. Fab City invites citizens to co-create their material world with digital values and open-source principles. Here, *EC* is no longer a purely normative dream; instead, it becomes a set of institutional designs, participatory practices, and measurable environmental impacts brought together into the architecture of digital society.

The case study strategies presented above and in Table 2 highlight the variety of approaches employed by different case projects, along with their diverse geographic focuses, operational methods, and key *EC* principles. This range illustrates the broad potential of *EC* to contribute to an *SDS*. The diversity of these projects underscores the opportunity for a more integrated and comprehensive vision of *EC*. Each project represents a distinct aspect of *EC* in action, and collectively, they offer a roadmap for building a more cohesive *EC* ecosystem. Figure 1 aims to show how these projects, when connected, can support each other and help create a digitally sustainable and ecologically resilient society. This vision brings together activities across governance, infrastructure, and production

systems into a unified framework, fostering collective impact through interconnected and complementary actions.

Table 2. Key case study details.

Case Study	Primary Mode	Scalability Evidence	Key Environmental Impacts	Stakeholder Involvement	Challenges Faced	Future Potential
GDC	Policy and governance	Adopted by 40+ European cities with shared reporting frameworks; facilitates peer-to-peer benchmarking and policy sharing	Reduction in ICT carbon footprints; promotion of green public procurement	Local governments, policymakers, urban planners, and sustainability experts	Achieving consistent adoption across diverse governance structures	Expanding to cities outside Europe; evolving policy frameworks to address new digital challenges
SolarKiosk	Community infrastructure	Replicated in multiple rural regions; potential for wider deployment in other off-grid communities	Displacement of CO_2 emissions by reducing reliance on diesel generators; provision of clean energy	Local community members, social enterprises, energy providers, NGOs	Overcoming initial investment costs; ensuring long-term sustainability in remote areas	Expansion to other African nations and globally, with further technological advancements
Fab City Global Initiative	Local production systems	Network of 50+ cities implementing local production and circular economy models, tracking progress through a Fab City Dashboard	Reduced waste and carbon emissions through material reuse; reduction in supply chain dependence	Citizens, local governments, Fab Labs, sustainability organisations	Limited local access to necessary resources or technology in some areas	Broader global adoption, advancing circular economies and sustainable manufacturing in more cities

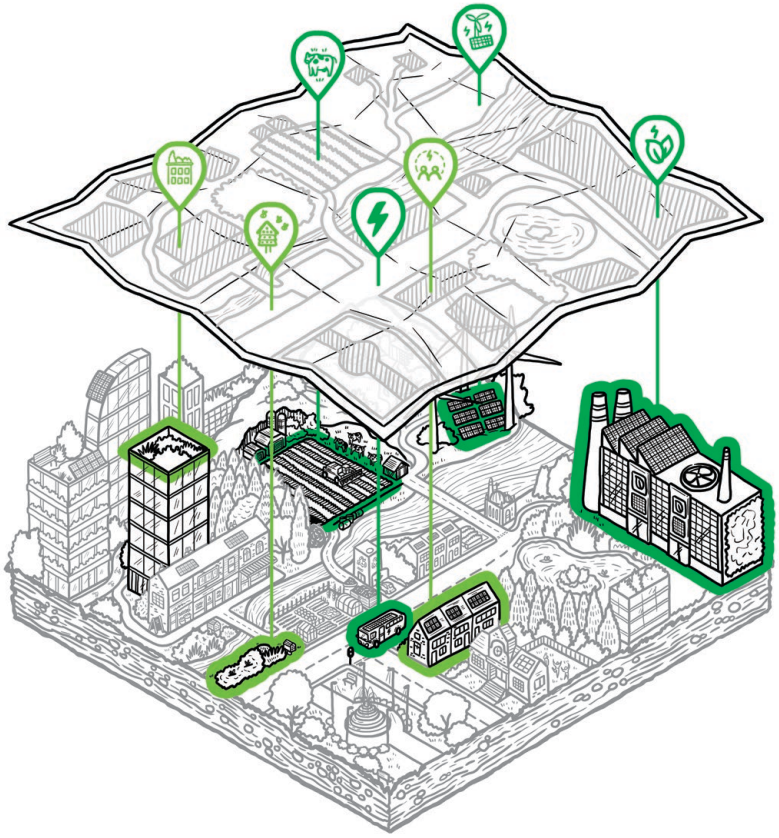

Figure 1. Illustration highlighting the potential to link different elements of communities via *SDS*. (Illustration Credit: Amber Anderson).

8. Discussion

Picking up from previous studies by Dobson [21], Connelly [15], and more recent ones from [22], *EC* has been redefined to refer to an ethic of shared environmental accountability that transgresses the level of consumer practice, and instead addresses civic action, democratic responsibility, and transformation at the level of systems. In contrast to traditional models of citizenship as legally enforceable entitlements and state-defined duties, *EC* resides in a sphere where private actions connect with public obligations, environmentalism with social justice, and local imagination with global systems thinking. All three case studies analysed, GDC, SolarKiosk, and the Fab City Global Initiative, exemplify a unique path along which *EC*'s idealist abstractions can be made concrete. These paths closely map onto the three primary modes found in the *EC* literature: governance-led reform, infrastructure-based inclusion, and production-based participation.

The GDC is a prime example of how *EC* principles are institutionalised within governance mechanisms. By requiring signatory cities to adopt energy-efficient ICT standards, report on progress in an open manner, and cooperate in sustainability innovation, the Charter enshrines environmental responsibility as a civic duty of municipal government. This is consistent with Dobson's [21] vision of *EC* as a form of post-cosmopolitan responsibility that summons institutional and individual actors alike to work together in collaborative environmental stewardship. The GDC's benchmarking system and peer learning networks also attest to Rakova and Dobbe's [22] argument that systemic accountability is the way forward in guaranteeing ecological justice in the digital age. The Charter is also reminiscent of Lange's [20] argument that digital governance must have sustainability as an unwavering design principle, particularly since cities are becoming increasingly data-driven ecosystems. By reframing digital governance as an environmental space of responsibility, the GDC offers a transposable model for the development of *EC* principles in the policy context of urban digital change.

SolarKiosk positions infrastructure and access to energy at the forefront of *EC*, as compared to other models. Grounded in rural Kenya and Ethiopia, the initiative addresses both the technological gap and ecological injustice of energy poverty. By delivering clean, solar-powered digital access points and training local operators in solar and ICT maintenance, SolarKiosk activates *EC* principles of distributive justice, participatory stewardship, and technological empowerment. This echoes Lattas's [28] argument that *EC* must include distributive and procedural dimensions of justice. It also resonates with Isin and Ruppert's definition of digital citizenship as enacted in acts, not status, as one sees in the DIY care of members within their own infrastructures. In SolarKiosk, citizenship is a practiced technique connected with everyday ecological practice: solar-charging equipment, optimising a kiosk's energy usage, and distributing digital service access. In doing so, it decentralises environmental responsibility and democratises the availability of low-carbon futures.

The third, and potentially more radical, articulation of *EC* is one offered by the Fab City Global Initiative, derived from the reorganisation of material and production systems at the urban scale. Through its global network of Fab Labs and emphasis on local self-reliance by the year 2054, Fab City embraces the *EC* literature that emphasises future-oriented planning, ethics of circular economy, and redesigning digital technology for the purposes of local empowerment. Citizens in Fab Labs are no longer mere consumers or users but are reimagined as co-producers of sustainable goods. Fab City's emphasis on open-source design, local expertise, and shared experimentation illustrates how civic action can be used to achieve ecological objectives. Its decentralised model of governance, between public institutions, university labs, and community-level makerspaces, also illustrates how hybrid ecologies of innovation can realise *EC* in non-policy or corporate spaces.

Together, these cases highlight that *EC* is not fixed or static but instead a flexible framework that adapts to governance regimes, social imperatives, and technological forces. This adaptability is crucial for its relevance to *SDS*, as it suggests *EC* can be operationalised differently depending on societal needs and institutional capacities. However, it also raises important theoretical and practical challenges. The problem of scale remains unresolved; while GDC has achieved adoption across more than 40 cities, SolarKiosk and Fab City are still relatively early-stage models of diffusion. This underscores the difficulty of translating *EC* from normative concept into universal practice, particularly across regions with starkly different regulatory, cultural, or infrastructural contexts.

Second, gaps in impact measurement limit the conclusiveness of the analysis. The lack of comprehensive lifecycle assessment in Fab City, for example, makes it harder to quantify ecological gains, even though participation and creativity are visibly enhanced. This points to a broader theoretical limitation: interpretivist case study analysis allows for depth and nuance but cannot deliver generalisable models in the same way that econometric or lifecycle analysis might. Instead, the value lies in theory-building, identifying patterns and articulating hypotheses about how *EC* principles might embed themselves in socio-technical systems, which future quantitative work can test.

From a societal perspective, the research suggests that digital sustainability requires reconceptualizing citizens not as passive consumers but as active ecological actors [29]. The cases demonstrate that *EC* can provide citizens with both responsibility and the means to shape digital futures, whether through policy co-design (GDC), local stewardship of energy and information infrastructures (SolarKiosk), or collective innovation and production (Fab City). This has implications for civic education, where digital literacy should be expanded to include ecological responsibility, building awareness that online behaviour and technology choices are inseparable from environmental outcomes. For managers and organisational leaders, the findings point to a need for embedding *EC* values into strategy and operations. As Salimath and Carter [30] note, sustainable technological entrepreneurship requires balancing innovation with ecological accountability. The case studies suggest that this balance is achievable when managers cultivate participatory governance structures, enable long-term stewardship of infrastructures, and adopt circular economy practices in design and supply chains. This means organisations should look beyond efficiency metrics and actively foster digital practices that distribute responsibility across employees, consumers, and communities. For policymakers and institutions, the research illustrates that organisational ecosystems, not just individual firms or governments, must align around *EC* principles to achieve meaningful digital sustainability. As Salimath and Chandna [31] argue, sustainable consumption and growth require complementary perspectives and systemic approaches. The three case studies validate this: governance reforms (GDC), community infrastructures (SolarKiosk), and production innovations (Fab City) are interdependent levers. Taken together, they imply that managerial and policy strategies should not only mitigate digital harms but proactively design systems where *EC* is embedded into organisational culture, resource allocation, and innovation trajectories.

9. Recommendations

The analysis of the three case studies demonstrates that the principles of *EC* are not only relevant to the digital age but also operationalisable in policy, infrastructural, and organisational settings. To move from isolated projects toward systemic transformation, there must be deliberate action at multiple levels of society. Below, we set out recommendations for policymakers, industry and organisational leaders, and educators, drawing on both the findings of this study and broader scholarship on sustainable technological entrepreneurship [30] and sustainable consumption [31].

Governments at municipal, national, and international levels must integrate *EC* principles into digital governance frameworks. The GDC provides evidence that policies mandating energy-efficient ICT standards, transparent reporting, and collaborative peer learning can institutionalise ecological responsibility as a public duty. However, such initiatives remain largely Eurocentric. Future governance strategies should ensure that *EC* is embedded in diverse regulatory and cultural contexts, particularly in nations outside of Europe, for instance, where digital expansion is rapid but ecological harms are also concentrated. To achieve this, we recommend three steps. First, introduce policy incentives (e.g., tax credits, grants, or procurement preferences) for organisations and communities that adopt sustainable digital practices. Second, mandate reporting mechanisms that go beyond energy efficiency to include lifecycle assessments of digital infrastructures and devices. Third, create enabling environments for citizen participation in digital governance, open consultations, digital assemblies, or participatory budgeting for green technology investments. These mechanisms ensure that *EC* principles of responsibility and justice are not rhetorical but practically embedded in governance design.

The ICT sector, which spans hardware, software, and service providers, has a central role in aligning business models with *EC* values. The Fab City model demonstrates how circular economy practices, open-source design, and distributed innovation can reduce dependency on global supply chains and empower localised, low-carbon production. Yet such practices require managerial commitment to long-term stewardship rather than short-term efficiency. Industry leaders should prioritise three forms of managerial action. First, adopt circular economy strategies in digital design and supply chains, extending product lifespans, enabling modular repairs, and supporting recycling and upcycling at scale. Second, embed *EC* values into corporate governance structures by creating cross-departmental sustainability roles that integrate environmental responsibility into strategy, operations, and consumer engagement. Third, cultivate partnerships with civic and educational institutions, recognizing that sustainability is not achieved by firms alone but through ecosystems of cooperation. In this way, *EC* shifts from being an external ethical demand to an internalised organisational culture that guides innovation and entrepreneurship.

Education represents the most durable route to embedding *EC* values into the long-term culture of an *SDS*. While digital literacy is often focused on technical skills, this study demonstrates that ecological literacy must be equally foregrounded. In SolarKiosk, for example, stewardship of digital kiosks was sustained through training programs that integrated ICT and solar maintenance skills. Similarly, Fab City Labs function as learning environments where participants co-create sustainable futures through experimentation.

We recommend that universities, schools, and community educators integrate ecological responsibility into digital literacy programs at all levels. Curricula should include modules on the ecological footprint of digital practices, responsible data use, and the systemic links between online behaviours and environmental outcomes. Beyond formal education, civic institutions, such as libraries, makerspaces, and cultural centres, should function as hubs for ecological digital practice, fostering inclusive access and collective responsibility.

Perhaps most importantly, the case studies show that the effectiveness of *EC* depends on cross-sectoral integration. Governance-led initiatives like the GDC require alignment with community-based projects like SolarKiosk and production innovations like Fab City to generate systemic change. We therefore recommend the establishment of hybrid platforms, forums where policymakers, managers, educators, and citizens collaborate to align digital development with ecological values. Such platforms can serve as incubators for new policy frameworks, public–private partnerships, and shared accountability mechanisms.

10. Conclusions

The establishment of an SDS requires policy, industry, and education sector collaboration. Successful implementation of *EC* principles, as illustrated by the GDC, SolarKiosk, and Fab City Global Initiative, depends on a systematised approach that integrates sustainability into governance systems, business practice, and education curriculums. Policymakers must create inclusive and open regulatory environments that promote green technology and digital access. The industry players must adopt the values of circular economy, innovate energy-saving technologies, and guide consumers towards sustainable digital consumption. The educational sector must provide the knowledge and skills to foster environmental responsibility in future technologists and citizens.

By working together across these areas, we can build a digital future that is not only technologically advanced but socially equitable and ecologically sustainable. The concepts of *EC* offer a way forward in addressing the environmental consequences of digitalisation and in making sure that digital innovation benefits society and the planet. Only through collaboration between policymakers, business leaders, and educators can we realise a truly sustainable and equitable digital world.

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