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The Environment for a Digitally Enabled Circular Plastics Economy in Africa: Lessons from Cross-Sectional Stakeholder Engagements

Abstract

Purpose

This paper aims to provide insights into the environment needed for advancing a digitally enabled circular plastic economy in Africa. It explores important technical and social paradigms for the transition.

Design/methodology/approach

This study adopted an interpretivist paradigm, drawing on thematic analysis on qualitative data from an inter-sectoral engagement with 69 circular economy stakeholders across the continent.

Findings

The results shows that, while substantial progress has been made with regard to the development and deployment of niche innovations in Africa, the overall progress of circular plastic economy is slowed due to relatively minimal changes at the regime levels as well as pressures from the exogenous landscape. The study highlights that regime changes are crucial for disrupting the entrenched linear plastic economy in developing countries, which is supported by significant sunk investment and corporate state capture.

Originality/value

The study makes an important theoretical contribution by using empirical evidence from various African regions to articulate the critical importance of the regime dimension in accelerating the circular economy transition in general, and the circular plastic economy in particular, in Africa.

Research limitations/implications

The main limitation of this study is with the sample as it uses data collected from five (5) countries. Therefore, while it offers a panoramic view of multi-level synergy of actors and sectors across African countries, it is limited in its scope and ability to illuminate country-specific nuances and peculiarities.

Practical implications

The study underlines the importance of policy innovations and regulatory changes in order for technologies to have a meaningful contribution to the transition to a circular plastic economy.

Keywords: Circular economy; Plastics; Africa; Digital innovations; Emerging Technologies; Circular Plastics Economy; Sustainable Development

1 Introduction

The circular economy represents a transformative approach to sustainability, crucial for addressing escalating plastic waste challenges in Africa. This paper engages with the discourse on the role of digital technologies as a key driver of circular economy practices in developing contexts. Scholars have increasingly recognized that transitioning from a linear to a circular economy is not merely a technological shift but a complex socio-economic change, especially significant in the context of Africa's unique environmental and cultural landscape(Geissdoerfer et al., 2017; Schroeder et al., 2019). Existing research extensively documents the roles of policy, technology, and infrastructure in circular economies. However, these studies predominantly focus on developed economies and often overlook the unique challenges and opportunities presented by African contexts, where digitalization intersects distinctly with socio-economic factors (Ajwani-Ramchandani et al., 2021; Chauhan et al., 2022). Extant research has also sometimes tended to focus on specific aspects and factors that account for technological change. This approach often leaves gaps in understanding systems-level dynamics and nuanced insights on how digital innovations could specifically drive circular economy transitions in a way that is congruent with Africa's development trajectory and environmental strategies.

However, while there is a consensus on the potential of digital technologies to support the circular economy, there is insufficient exploration into how these technologies interact with the socio-economic realities in African countries. This gap is critical as it hinders the formulation of effective, context-specific strategies that could facilitate a more robust adoption of circular economy practices across the continent. This paper therefore applies the multi-level perspective (MLP) framework to analyze the transition from a linear to a digitally enabled circular plastics system specifically within the African context. By doing so, it fills a significant gap in the existing literature, which has predominantly focused on circular economy transitions in developed countries without adequate consideration of the unique challenges and opportunities in developing regions like Africa. This contribution is important for several reasons; firstly, It enhances our understanding of how socio-technical transitions occur in contexts characterized by different economic, environmental, and institutional dynamics. This is crucial for developing tailored strategies that are more likely to be effective in the specific socio-economic and political contexts of African countries. Secondly, the study highlights the importance of regime changes—changes in the deeper structural and institutional conditions—in driving the adoption and effectiveness of circular economy practices. This focus is particularly relevant because many African economies are locked into linear production and consumption patterns due to

entrenched interests and infrastructures. Understanding the role of regimes can help in designing interventions that target these deeper layers of socio-economic structures. Thirdly, by examining the role of digital technologies in this transition, the paper contributes to the emerging field of digital circular economy, which is still underexplored, especially in the African context. This is significant as digital technologies could play a transformative role in overcoming logistical and informational barriers that are prevalent in less developed regions (Schirmeister and Mülhaupt, 2022; Stahel, 2019). The theoretical insights provided by the study are directly linked to practical implications, making it highly relevant for policymakers, industry stakeholders, and development agencies. The identification of specific technologies and policy innovations needed to support the transition provides actionable knowledge that can be used to foster real-world changes.

The purpose of this paper is to explore how digital technologies can be effectively integrated into the circular plastic economy in Africa to facilitate a transition from traditional linear models to more sustainable circular practices. This study seeks to answer the pressing question of how socio-technical factors and digital innovations can collectively overcome the structural barriers that currently hinder the adoption of circular economy principles in African contexts. By addressing this question, the paper aims to resolve the identified theoretical gaps concerning the integration of technology within circular economy frameworks in developing regions, offering new pathways for sustainable development. Through its novel theoretical contributions and empirical findings, this paper articulates the critical importance of the regime dimension in accelerating the transition to a circular plastic economy in Africa. It sets the stage for further research and practical applications aimed at enhancing the continent's environmental resilience and economic sustainability.

~~Plastic pollution remains a critical challenge in the 21st century, originating from established design and production systems and consumption habits (UNEP, 2021). Plastic production has continued to increase from 270 million tonnes to 367 million tonnes between 2010 and 2020 (Statista, 2022). Furthermore, it was estimated that only 32.5% of the 61.8 million tonnes of plastic produced in Europe, as of 2018, was recycled (Plastics Europe, 2018) while less than 10% was recycled in Africa (UNEP, 2018b). Despite Sub-Saharan Africa currently contributing the smallest proportion of plastic waste globally (Ayeleru et al., 2020), the region faces exacerbated challenges due to significant leakage throughout the plastic value chain. Leakage primarily occurs in households, open markets, formal institutions, public and commercial areas, and manufacturing companies, as a result of inadequate infrastructure, inefficient waste management systems, and lack of coordination among stakeholders (Oyinlola et al., 2022b).~~

~~The consensus among scholars is that transitioning from a linear economy to a circular economy offers a viable pathway to address the plastic pollution challenge and foster a sustainable future (Geissdoerfer et al., 2017). The circular economy presents opportunities to redirect society towards new production systems and consumption habits, characterized by strategies like the 3Rs (Reduce, Reuse, and Recycle)~~

framework (Manickam and Duraisamy, 2019) and and the more comprehensive 9Rs framework (Potting et al., 2017), encompassing R_0-Refuse, R_1-Rethink, R_2-Reduce, R_3-Reuse, R_4-Repair, R_5-Refurbish, R_6-Remanufacture, R_7-Repurpose, R_8-Recycle, and R_9-Recover. Notably, the Ellen MacArthur Foundation (EMF) has played a significant role in promoting and advancing the circular economy, providing resources, publications, and tools to facilitate effective policies, product design, and business practices (Ellen MacArthur Foundation, 2014; Ellen MacArthur Foundation et al., 2019). Furthermore, circular economy practices align with multiple targets of the Sustainable Development Goals (SDGs) (Schroeder et al., 2019).

The circular plastic economy (CPE), a system which employs the principles of the circular economy across the entire plastic value chain, offers a viable solution in ensuring that plastic is managed sustainably. The CPE concept is also applicable to Africa and is expected not only to reduce leakage of plastic waste into the natural environment, but also create better employment and increase household incomes (WWF, 2022). The African continent is a promising context for scholarly investigations of circular economy practices and innovations. There has been significant practitioner interests and third sector campaigns within the past decade, but there have been relatively fewer reports and investigations of these by way of scholarly inquiries. This paper bridges this important gap in knowledge by providing new empirical insights on the processes, practices and opportunities for a circular plastic economy on the African continent .

Various scholars have argued that digitalization can accelerate the transition to a circular economy (Ajwani-Ramchandani et al., 2021; Chauhan et al., 2022) as digital technologies can facilitate and optimise processes for the transition (Schirmeister and Mülhaupt, 2022; Stahel, 2019). However, technologies are only effective when they work in dynamic synergies with people and the socio-cultural contexts that shape their uptake and impact. An adequate understanding of the interaction between society and technology is important for stakeholders to drive systemic changes, however, scientific studies illuminating the social – technical interactions are scarce. This understanding can help in tackling the myriad of fundamental challenges that exists for implementing and embedding digital technologies for achieving a circular plastic economy in Africa. These challenges span technical dimensions such as, energy, transport, recycling technology, financing and successful scaling of effective interventions and practices. They also include social dimensions such as education, health, occupation, security, and diversity. Furthermore, given the heterogenous, culturally, and politically diverse profile of African countries, it is pertinent to have research which adequately describe this interaction across the continent. Within the past decade, African countries have experienced economic growth which have invariably been associated with increasing volume of plastic wastes (Kolade, Oyinlola & Rawn, 2023). This is therefore an urgent need to focus more attention on sustainable growth and the socio-technical transitions that should drive such growth. While awareness has risen about the need for a circular economy, the African continent has not seen commensurate progress in terms of concrete actions and measurable outcomes (Barrie et al., 2022). This is partly due to the challenges posed by the institutional environments in which national governments are often not up to date on

~~global discourses (Kolade et al., 2022), and public engagement is typically not matched by policy commitment and political will (Adetoyinbo et al., 2022). Also, many of the stakeholders in the private sector continue to operate in silos, thereby limiting the gains and impact of current circular economy campaigns (Oyinlola et al., 2022b). Therefore, this paper aims to provide insights on important technical and social paradigms, explicating the multi-stakeholder dynamics that underpin the technology-people interactions in the advancement of the circular plastic economy in Africa. This understanding is crucial for implementing robust interventions that will accelerate Africa's transition to a circular plastic economy.~~

~~The rest of the paper is structured as follows. Section 2 presents theoretical background on the multilevel perspective framework. Section 3 presents an in-depth description of the methodology and sample employed in this study. The key findings of this qualitative study with respect to the research questions are discussed in Section 4. Finally, Sections 5 outlines the main conclusions, limitations of the study and suggests areas for further research.~~

2 Theoretical Background

2.1 Circular Plastics Economy

The problem of plastic pollution emanates from entrenched design and production systems and associated consumption habits that characterise the linear economy. There has been an increase of production of plastics at a global level from 270 million tonnes to 367 million tonnes between 2010 and 2020 (Statista, 2023). Annually, more than 12 million tonnes of plastics leak in the world's oceans, posing severe risks for marine life (Jambeck et al., 2015). According to recent estimates, about 381 million tonnes of plastic waste is generated, of which 50% is single-use (Grodzińska-Jurczak et al., 2022; Phillips, 2022). With the increasing global concern on plastic pollution, the circular plastic economy (CPE), a system which employs the principles of the circular economy across the entire plastic value chain, offers a viable solution in ensuring that plastic is managed sustainably. The CPE approach promotes innovative design, encourages recycling, and incentivises the reuse of materials, thereby minimising issues arising from the use and disposal of plastic products (Völker et al., 2020). In other words, the CPE fosters a shift to more sustainable ways of managing the plastic pollution challenge through innovation (Dedehayir et al., 2018). The CPE offers a more competitive, adaptive, regenerative and resource-efficient plastics value chain (Blomsma et al., 2019; Mrowiec, 2018; Murray et al., 2017). Furthermore, the CPE provides a good model for resolving the different environmental and ecological concerns caused by inefficient plastic waste management. It also offers viable solutions for recovering significant value that has been lost in the traditional linear plastics value chain. A CPE will require significant changes in technological approaches, economic resources and investment and changes to societal behaviour and attitudes, including preventing waste dumping, uptake of reuse schemes, and better participation in recycling schemes (Bucknall, 2020). The CPE concept is also applicable to Africa and is expected not only to reduce leakage of plastic waste into the natural environment, but also create better employment and increase household incomes (WWF, 2022). The African context is a promising context for scholarly investigations of circular economy practices and innovations. There has been

significant practitioner interests and third sector campaigns within the past decade, but there have been relatively fewer reports and investigations of these by way of scholarly inquiries. This paper bridges this important gap in knowledge by providing new empirical insights on the processes, practices and opportunities for a circular plastic economy on the African continent.

2.2 Digital Technology

Technology enables changes and developments across all sectors (Kagermann, 2015). The increasing use of digital technologies across the globe over the last three decades has brought about great transformation and sped up developments and innovations in almost all spheres of life. Digital technologies have shown promises in various sectors in Africa. These include the applications of mobile applications, geographical information systems (GIS) and artificial intelligence (AI) across sectors such as Finance (Kingiri and Fu, 2019), Energy (Annunziata et al., 2015), Education (Oke and Fernandes, 2020) and Agriculture (Syngenta, 2019). Thus, the application of digital technologies needs to be promoted, especially in terms of bridging the circularity divide between high and low-income countries (Adejumo et al., 2020; Barrie et al., 2022; Hong Nham and Ha, 2022). Digital innovations can positively disrupt the landscape by channelling and driving a multi-stakeholder approach that brings digital innovators, researchers, policymakers and ordinary citizens together in the collective drive towards new, circular production and consumption habits on the African continent (Kolade et al., 2022). The World Economic Forum (WEF) has called for an acceleration to a circular economy to meet climate goals set for 2050. WEF contend that this can be met by responsible digitalisation which takes into account public good (World Economic Forum, 2021). According to Khajuria *et al.*, (2022), the circular economy approach combined with technological innovation have proven to be a highly efficient way to reduce final waste and decrease the use of natural resources. Antikainen et al. (2018) discuss how digitalisation in the circular economy can enable companies to be more efficient and reduce on transaction costs. Kagermann (2015) on the other hand posit that digitalisation can allow for transparency which can help companies advance their circular economy agendas. Dantas et al., (2021) have argued that the circular economy and industry nexus can help achieve some of the UN SDGs7, 8, 9, 11, 12, 13 as the concept 'connects innovative technologies with novel circular production and business models'. Khan et al. (2022) have shown that there is a connection between technological innovation and positive impact on the circular economy which in turn leads to value generation.

Emerging technologies such as artificial intelligence and blockchain have been used in efforts to recreate new opportunities and improve on already existing initiatives in the African Circular Plastic Economy. Several scholars have highlighted how various technologies could contribute to the circular economy. For example, Chidepatil et al. (2020) asserted that artificial intelligence drawing on multiple sensors and backed by the traceability of blockchain could remove barriers to a circular plastic economy. They argue that the use of AI can segregate plastic waste, therefore ensuring efficient and intelligent segregation, which can be a complex and inefficient process.

Blockchain technology can facilitate a trusted exchange between recycled feedstock buyers (usually manufacturers), recyclers and segregators of plastic waste.

Therefore, the information can be easily exchanged and validated along the value chain, providing different partners with relevant information on plastic waste and how best to reduce or recycle it. Singh (2019) discussed how municipal waste management can make use of GIS (Geographic Information Systems) and the layers available from remote sensing. These sort of innovations having a positive impact on the environment are sometimes referred to as Eco-Innovations (EI). De Jesus and Mendonça (2018) define eco-innovation as a "transformative process to move away from the status quo. Thus, it creates a socio-economic system based on the concept of the circular economy, therefore increasing efficiency and competitiveness while also having positive impacts on the environment and society" (De Jesus and Mendonça, 2018). Several enterprises have been formed based on Eco-Innovations in Africa. In Kenya, for instance, Alternative Energy Solutions (AES) uses innovative technology to convert various kinds of plastic to produce oil (Horvath et al., 2018).

Specific characteristics of the African continent present promising prospects for the utilisation of digital innovations. For example, the continent has a young demographic profile, with almost 60% of the population under 25 (Statista, 2021). Furthermore, Africa has the fastest-growing internet penetration (Granguillhome Ochoa et al., 2022; GSMA, 2020). As a result, the continent has attracted significant investment in digital platforms, such as the Google AI hub in Ghana and Facebook hub in Kenya. In addition, several technology innovation hubs have sprung up across the continent (Atiase et al., 2020), giving young people the opportunity to immerse themselves in technologies that result in innovations supporting development. This can also be accelerated when people and technology come together in a dynamic synergy.

Despite these developments and initiatives, Africa is still behind the curve in innovation investment due to the weak national innovation ecosystem (Adepoju, 2022; Valentina et al., 2021) and fragmented information on how these opportunities can be operationalised for the advancement of the CPE. Therefore, this paper contributes to the circular economy literature by providing a deeper understanding of the socio-technical interaction required to enhance and support CPE innovations across the continent.

2.3 Multilevel Perspective framework

This paper adopts a multi-level perspective (MLP), situated within the theory of social-technical transitions. The approach helps bridge the gap between technical study and social context. MLP has been applied in various fields such as renewable energy (Finn et al., 2020), transport (Edge et al., 2020), textiles (Muylaert and Maréchal, 2022), agriculture (Darnhofer, 2015), water and sanitation (van Welie et al., 2018). Because societies and technology co-evolve, user practices and societal factors give important insight into realistic technological innovation when considering transition pathways. Therefore, this analytical framework has proven to be versatile and influential (Murphy, 2015). The MLP framework can be used to interrogate how a broader transition process may or may not be dominated by the technological innovation component (Edsand, 2019; Kundu et al., 2016).

The MLP framework highlights three analytical levels in a transition process: socio-technical regimes, niches, and an exogenous socio-technical landscape (Geels,

2011). The framework acknowledges an independent socio-technical landscape that exerts pressure on a transition process, but also hosts “regimes” of stabilizing institutions, governance structures, and associations that uphold practice and rules. Geels (2002) identified seven regime dimensions: industry structure; technology; infrastructures; policy; culture (symbolic meanings of technology); science (knowledge) and markets (user practices and application domains). The existence of niches within regimes where new technologies incubate and even develop interconnections is identified an enabler of radical innovation. All three levels interact in a long-term transformation during a transition (Osunmuyiwa et al., 2018). ~~The application of the MLP is~~

The regime level in the Multi-Level Perspective (MLP) framework refers to the current established system or "ways of doing" things within a specific societal system (Deviney et al., 2023). It represents the dominant practices, rules, and technologies that shape the functioning of the system, which together comprise regimes. The regime level is crucial in understanding transitions towards sustainability as it is where resistance to change often resides, and where pressure from the landscape level can trigger shifts towards more sustainable behaviours (Lenfle, 2017). The stability of old systems and technologies, engendered by regimes, can be challenged by "niches", described as the incubation rooms for radical novelties. These niches are protected from normal market selection which are otherwise biased towards established technologies and products (Geels, 2002). In the context of developing countries, the regime and niche levels play a crucial role in shaping political power dynamics, policy implementation, and governance structures (Kervalishvili, 2022; Smith and Sullivan, 2003). Regimes in developing countries define the relationship between social interests, the state, and economic actors, influencing how agendas are set, policies are formulated, and decisions are made (Worsham, 2014). The strength of a regime in developing countries is determined by its ability to navigate tensions between old and new systems, adapt to varying political landscapes, and address complex social and economic challenges (Lenfle, 2017).

The MLP is therefore a viable analytical framework with which to interrogate the impact of the dynamic interactions between socio-technical regimes and niche innovations on the technological trajectories that underpin the transition from linear to circular plastic economy. It helps unpack the process through which digital innovations is driving new routines among key stakeholders which in turn aggregate to new socio-technical regimes that challenge linear habits of production and consumption.

The application of the MLP is, however, not without challenges (Smith et al., 2010), including the geography of sustainability transitions and the MLP original focus on the European context. More recent studies have applied the MLP framework to understand African sustainability transitions, including Kaweesa et al. (2021), who analysed the dynamics of the conservation agriculture niche in Uganda. Newell and Phillips (2016), who explored energy transitions in Kenya; van den Bold (2021), who looked at energy in Senegal; and Power et al. (2016) who focused on energy transitions in Mozambique and South Africa. ~~To the best of our knowledge, our study is the first to interrogate the role of the regime level as the primary driver of transition to a circular plastic economy.~~

A growing area of focus for accelerating the circularity transition is the use of technology (Geissdoerfer *et al.*, 2017), which makes the multi-level perspective a suitable framework for analysing the paradigm shift from a linear plastics system to a digitally enabled circular plastics system in Africa. While many studies have applied this framework in the African context, these have been predominantly in the Energy sector. Scholars who have used the MLP to examine the circular plastic economy include Oyake-Ombis et al. (2015), who identified plastic waste innovations in East Africa and examined them as niche developments in the MLP sense, and ~~Hsu et al. (2022)~~Hsu et al. (2022) who focused on closing material cycles in Europe concerning plastic, and highlighted knowledge, information and data as key. However, none of these studies have adequately grappled with the potentially decisive role of the regime level in developing countries context of transitioning to a circular plastic economy. To the best of our knowledge, our study is the first to interrogate the role of the regime level as the primary driver of transition to a circular plastic economy. We argue that, because the circular plastic economy seeks to upend an economic model that is beholden to big corporate interests and associated with sunk-investment and other lock-in mechanisms, the regime level of the multi-level framework is a fruitful direction of inquiry in contexts of weak and unstable institutions. Niche digital innovations are necessary, but not sufficient on their own, to effect circular transition. Regime changes, via policy innovations and regulatory interventions, are likely to be required to effectively harness the power of niche innovations to transform the exogenous landscape in a complete loop of socio-technical transition to a circular plastic economy in Africa.

~~Therefore, this study uses the MLP framework to analyse the transition from a linear plastics system to a digitally enabled circular plastics system in the African context. The research questions we propose to investigate in this article are:~~

~~I. Which digital technologies are relevant to the circular plastic economy transition, and how could they be used as a suitable intervention by various stakeholders (Niches)?~~
~~II. What is the current state of play with regard to the seven regime dimensions identified by Geels (2002)?~~
~~III. What are some of the external pressures that affect the socio-technical transition processes from the current linear to a circular plastics economy landscape?~~

~~These questions were designed to address the three analytical levels (Niches, Regime and Landscape) in a transition process as outlined in the Multi-Level Perspective framework. By answering these questions, this paper fills the knowledge gap of technology-society interaction for the circular plastic economy transition.~~

The analysis identifies landscape pressures (crucial challenges) associated with the circular plastic economy. It provides new insight into the seven regime dimensions, and further explores some of the pressing external pressures from the exogenous landscape. Furthermore, it illuminates the multi-stakeholder, multi-dimensional synergy of regimes, niche innovations and landscape required to successfully drive a circular plastic transition in Africa. It highlights how socio-technical niche innovations

(various digital technologies and applications by social entrepreneurs) can contribute to the transition to a circular plastic economy in Africa while highlighting the critical importance of the regime dimension.

3 Methodology

This study provides novel insights on the innovations on a niche level, the dynamics of existing regimes, and the landscape of the African circular plastic economy. Because the Circular Plastic Economy is still a new phenomenon in its early stages of growth (especially in Africa), there is limited literature on the subject (Desmond and Asamba, 2019). Therefore, a qualitative research methodology is appropriate for this understudied subject since it requires the interpretation and integration of "the experiences of those who have directly experienced the phenomenon, recognizing the value of participants' unique viewpoints that can only be fully understood within the context of their experience and worldview" (Castleberry and Nolen, 2018, p. 807). We thus used focus group discussions in order to gain collective opinion on a multi-layered issue as the circular plastic economy, in line with the recommendations of McLafferty (2004). This was followed by semi-structured interviews with some of the focus group participants. This study is part of a wider study (XXX) - which employed a mixed methods approach – see more details in (Author et al., 2022a).

3.1 Research Context

The research context for this study encompasses the unique socio-economic and environmental landscapes of Sub-Saharan Africa, a region that presents distinct challenges and opportunities for implementing circular economy (CE) principles (Oyinlola and Kolade, 2023). This context is crucial for understanding the potential and limitations of integrating digital technologies into the plastic value chain in developing countries. Sub-Saharan Africa, characterized by its diverse cultures, economic variability, and differing levels of technological advancement, serves as an ideal setting for examining how digital innovations can support sustainable waste management practices (Okoya et al., 2023). The region has been experiencing rapid urbanization and industrialization, leading to increased production and consumption patterns that heavily rely on linear economic models(Schröder and Oyinlola, 2023). These models are often associated with high levels of resource extraction and waste generation, which are unsustainable in the long term. The region's waste management infrastructure is generally underdeveloped. Many countries face significant challenges in terms of solid waste collection, segregation, recycling, and disposal. The existing systems are often inefficient and struggle to cope with the volume of waste generated, much of which consists of plastics. This inefficiency is exacerbated by a lack of strict regulatory frameworks and enforcement, inadequate financial and human resources, and limited public awareness and participation in waste management practices (Schröder et al., 2023). Furthermore, the digital landscape in Africa presents both challenges and opportunities. While there is a growing penetration of mobile technology and internet access, which facilitates the adoption of digital solutions, the full potential of advanced technologies like artificial intelligence, blockchain, and big data analytics is yet to be fully harnessed in the context of CE. These technologies have the potential to transform waste management by improving data collection and

analysis, enhancing transparency in the recycling chain, and enabling greater stakeholder coordination and collaboration (Tijani et al., 2023).

Given this backdrop, the research investigates how digital technologies can be integrated into the circular economy framework to address the specific challenges of the African context. It focuses on understanding the role of socio-technical systems in facilitating or hindering such integration and aims to provide actionable insights that can guide policy-making, industrial strategies, and entrepreneurial initiatives towards sustainable waste management and resource use in Africa.

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~~3.1~~3.2 Data collection

This study adopted a purposeful sampling method, which is a widely used technique in qualitative research for the identification and selection of information-rich cases (Palinkas et al., 2015). Qualitative data was collected in a sequential process, through focus groups, then in-depth interviews of selected focus group participants. Using the criteria outlined in Table 1, various stakeholders were identified, classed into stakeholder groups, and contacted by email, with some follow-ups done by telephone. The scope for the selection of participants was influenced by the location of collaborators on the XXX plastic project. We acknowledge this limitation and the selection bias due to the geographical context of the study. To match region with stakeholder groups, interested participants were given information about the most relevant focus group for them. Focus groups were designed to have a maximum of six participants, because the pilot studies showed that it would be difficult to adequately capture the views of all participants, in larger group sizes, within the allocated time of 90 -120 minutes. A first come, first served approach was adopted in terms of confirming a place for participants. However, no focus group was oversubscribed, and therefore, no interested stakeholder was denied a place. The downside of this approach was that last minute cancellations resulted in some focus groups having fewer participants.

~~Table 1~~ Appendix 1 gives details of the Seventeen (17) focus groups (engaging a total of 69 participants) which were conducted based on stakeholder type and region. For example, Focus group 1 brought together identified digital innovators in the southern African region, while Focus group 2 brought stakeholders in Academia from west Africa. The focus groups were held online using video conferencing, recorded, and transcribed. A briefing on the objectives of the XXX plastic project preceded the focus group meetings to obtain relevant consent. Participants were then allowed to introduce themselves and their roles within the sector. Opening questions were unique to the stakeholder groups, while general questions are presented in Appendix ~~1~~2. Following the analysis of the results from the focus groups, certain participants emerged as ideal candidates for further interviews as the insights they provided demonstrated their expertise and experience. It was anticipated they would be able to inform the subject more deeply. Semi-structured interviews (Creswell, 2014) were conducted with these selected participants to gain deeper insights on the research questions. Interviews were conducted online using video conferencing, and all interviews were transcribed

and recorded after receiving relevant consent from the participants. In total, ten key stakeholders were interviewed using the guide presented in Appendix 2.3.

Table 1: Details of the focus groups held

Stakeholder Group	Criteria for selection	Country/Region	Number of Participants	Date
Academia	Participants were selected based on publication records including relevant intersection or direct participation in pollution or circular economy topics, and by referrals from industrial participants.	Nigeria	4	Thurs, 15th Oct 2020
		Namibia	4	Wed, 7th Oct 2020
		Rwanda	3	Thurs, 15th Oct 2020
Civil Society	Participants were selected based on public track record of participation in meetings and conferences, evidence of funded projects, and their advocacy presence as documented online and via traditional media.	Nigeria	4	Tue, 29th Sep 2020
		Namibia	5	Thurs, 1st Oct 2020
		Rwanda	2	Fri, 16th Oct 2020
Digital Innovators and Start-ups	Participants were selected based on publicly available product information, business processes, and activities. This enabled us to confirm their current use of digital tools and technologies.	Namibia	8	Thurs, 1st Oct 2020
		East Africa	4	Fri, 16th Oct 2020
		Southern Africa	6	Thurs, 22nd Oct 2020
Governments, Policy makers, Parastatals and projects within government	Participants included national ministries, regional and local governments as well as parastatals (organisations owned by the national government) with traditional responsibility related to environmental management. This was to ensure current legal provisions were represented, and future decision makers could be informed with the hope of closing gaps in knowledge of the state of the art across the network.	Rwanda	3	Tue 13th Oct 2020
		Namibia	3	Wed, 14th Oct 2020
		Namibia	3	Wed, 14th Oct 2020
Investors/Funders	Participants were selected from a subset of entities who had previously participated in "green" or environmental funding programs.	Africa	3	Wed, 14th Oct 2020
		Namibia	4	Wed, 14th Oct 2020
Waste Management Organisations	Participants were selected based on being in the top 25% of waste handlers in their jurisdiction or exhibited specialty services.	Nigeria	4	Tue, 29th Sep 2020
		Rwanda	6	Tue 13th Oct 2020
		Namibia	3	Fri, 2nd Oct 2020

All interviews and focus groups were conducted in English and recorded using the video conferencing software. The recordings were then transcribed verbatim using Microsoft Word's transcribe functionality. A Research Assistant then reviewed and edited all of the transcripts against the audio recordings to ensure accuracy. Theoretical saturation was reached through this sequential process of data collection, where no new themes or relevant information emerged from the data. This saturation point was crucial for ensuring that the collected data sufficiently covered the research questions and that further data collection would not yield additional insights.

~~3.2~~3.3 Data Analysis

The responses from the focus groups and interviews were transcribed and then analysed using NVIVO 13 software to identify the themes emerging from the qualitative data set (Clarke and Braun, 2017). In doing this, we followed the six-stage process recommended by Braun and Clarke (2006). Firstly, the focus groups and interviews were transcribed, and the transcripts read and re-read by the team to note initial ideas. In the second stage, we generated initial codes across the entire datasets. This enabled the research team, in stage three, to identify recurring and potential cross-cutting themes across respondents and the two types of data- focus group and interviews. The first set of pattern codes was made using vignettes that highlights the key insights from the respondents. These vignettes were then summarised into second order words and phrases such as Technologies, Opportunities, Funding, Innovations, Challenges, Policy, Data etc. In the fourth stage, we reviewed the initial themes to ensure coherence and consistency of the themes in relation to the coded extracts and the entire dataset. In the fifth stage, the themes were defined and named. In this stage, the second order terms were utilised to make phrases, clauses, and sentence patterns for thematic naming and identification. The production of the report was undertaken in the sixth and final stage.

4 Results ~~and Discussion~~

The results of the study are presented ~~and discussed~~ in the sections below, with ~~the first three sections,~~ each ~~answering one of the research questions as well as~~section, focusing on one of the three analytical levels of the MLP framework.

4.1 Niches - Digital technologies relevant to the circular plastic economy transition

This section discusses the results regarding the ~~first research question, i.e. Which~~niches, exploring which digital technologies are relevant to the circular plastic economy transition, and how ~~could~~ they could be used as a suitable intervention by various stakeholders~~?~~. Furthermore, it gives insight into the Niches, the first analytical level of the MLP.

Through engagement with stakeholders during the focus group and the literature as detailed in ~~Kolade et al. (2022)~~Kolade et al. (2022), we identified ten digital technologies, that could make positive contributions in implementing circular economy frameworks such as the ~~9R framework, thereby accelerating the circular plastic transition.~~9Rs framework (encompassing R_0-Refuse, R_1-Rethink, R_2-Reduce, R_3-

Reuse, R_4-Repair, R_5-Refurbish, R_6-Remanufacture, R_7-Repurpose, R_8-Recycle, and R_9-Recover)(Potting et al., 2017), , thereby accelerating the circular plastic transition. These technologies include

I. Artificial Intelligence (AI), which could optimise circularity across the entire CPE ecosystem,
II. Geographic Information Systems (GIS), which could streamline operations in the CPE as well as efficiently connect CPE stakeholders.
III. Blockchain, which could foster transparency and facilitate data exchange across the CPE.
IV. Internet of Things (IoT); which could support embedding sensors for information exchange across the CPE
V. Robotics, which could support automation across the CPE
VI. 3D Printing, which could support decentralised recycling and reuse in the CPE
VII. Serverless computing, or Function as a Service (FaaS), which eliminates the cost of infrastructural setup and deployment.
VIII. Augmented Reality/Virtual Reality (AR/VR), which could aid building digital solutions for awareness, sensitisation and training on best practices,
IX. 5G, which could support Real-time communication using IoT sensors
X. Mobile apps which could serve as an essential interface for all CPE stakeholders to interact for circularity

Our findings overlap with previous published research in AI and blockchain Technology (Chidepatil et al., 2020), Remote sensing and GIS (Singh, 2019), and internet of Things (Mdukaza et al., 2018). These technologies are enablers for the strategies of the 9Rs framework. For example, mobile apps, GIS and IoT can be used to implement R_4-Repair and R_8-Recycle, by linking consumers, waste collectors, repairers, and recyclers. Similarly, AR/VR, IoT and mobile apps can be used to implement R_0-Refuse, R_1-Rethink, R_2-Reduce, R_3-Reuse, by educating consumers while AI, IoT and AR/VR can implement R_1-Rethink, R_2-Reduce, by helping producers redesign plastic products.

The engagement with stakeholders led to the identification of the leading organisation across the continent who have deployed digital technologies. Some of these include Mr Green Africa in Nairobi, Kenya, which leverages technology and enables waste collectors to be part of the value chain; WeCyclers in Lagos, Nigeria which are known for engaging residents of low income densely populated, urban areas by incentivising them to recycle their waste; and Yo - Waste in Uganda which is a technology focussed waste management company focusing on waste, recycling and smart city solutions. An extended list of similar organisations from across the continent can be found in Oyinlola et al. (2022b).

4.2 Regime Dimensions

As stated, data collected from the focus groups and interviews were used to generate insights into the seven regime dimensions identified by Geels (2002). This section, therefore, ~~addresses the second analytical level of the MLP - Regimes and answers the second research question - What is~~explores the current state of play regarding to

the seven regime dimensions identified by Geels (2002)~~?~~. These regime dimensions (industry structure; technology; infrastructures; policy; culture; science and markets) are discussed below.

4.2.1 Industry structure and stakeholder collaboration

Based on extensive engagement with various stakeholders, our results enabled us to map the key players, as presented in Figure 1. The findings highlight the need for collaboration between the key players. For example, one participant noted

> "I'm looking forward to enhanced collaboration because we are all doing the same thing in different ways with the same people: the policymakers, government agencies and so on. It would be a very good thing to strategize a little bit amongst the groups identified and see how the different programs can actually meet the purpose for which they are set up." (R3 Nigeria Civil Society FGD)

The observation for multi-sectoral collaboration was also highlighted by Modak (2021), who presented within the context of circular economy practices in India. Similarly, our findings align with the findings of other scholars that inadequate collaboration and coordination among different sets of stakeholders pose a significant challenge to the progress of the circular economy (Sarja et al., 2021). A multi-stakeholder synergy and collaboration can energise the entire ecosystem, support new ideas and innovations, and accelerate the diffusion of innovation across communities in urban and rural areas. These collaborative initiatives need to be intentional in their target of industry and government stakeholders, with specific needs and interests in mind. Some good practice examples were identified from the focus groups; for example, Nigerian civil society organisations have been finding ways to identify specific areas of interest alignments in choosing their industry and government partners; for example, a participant stated,

> "One of the major things we have also done is we've had a partnership with Lafarge. Lafarge is a cement company and as a cement company, they use a form of fuel for their cement processing…We have also had partnerships with different state governments. We have had a partnership with Lagos State. You know Lagos state is around the coastal areas and one of the challenges being faced is plastic waste… So we have been able to partner with them by providing what they need" (R5 Nigeria Civil Society FGD)

Furthermore, the results highlight the importance of better communication and networking strategies as key drivers of better synergies and collaborations within and across countries. Stakeholders stressed the importance of network events as a channel of sharing best practices across countries:

> "I think this issue of starting to network with what's happening in other countries is something that we've been trying to do, to put together a network so that we can share best practices in different countries at different levels… We need to communicate, to network, to coordinate and also to get the buy-in and commitment from all the stakeholders" (R2 Namibia Academic FGD).

These networking and collaboration opportunities enable an omnidirectional, heterarchical process of stakeholder engagement in the circular plastic economy (Obembe et al., 2021). This approach is, in turn, best suited to the co-creation of

innovations and a higher level of the ongoing commitment from stakeholders. Diaz et al., (2021) noted that synergies across the board would be facilitated by considering circularity as a socio-technical challenge, while Nikas et al. (2022) suggested utilising a multidisciplinary approach where communities create knowledge jointly with non-scientific stakeholders such as civil societies, industries and policy makers.

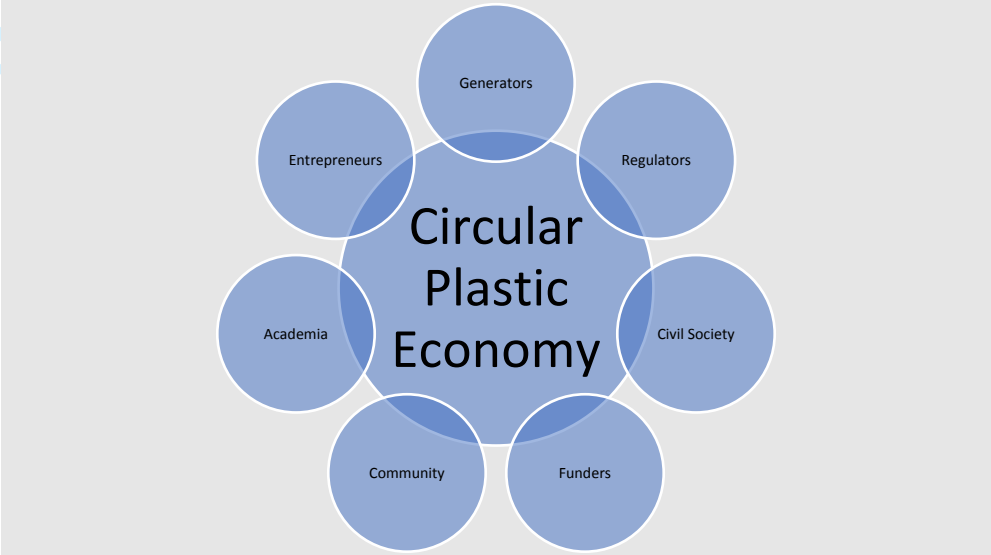

Figure 1: Key stakeholders for transitioning to a circular plastic economy

4.2.2 Technology attributes

Our findings showed that the inadequate waste management infrastructure prevalent in Africa has created new opportunities for using digital technology in waste management, especially in the informal sector. Digital technology was found to offer intelligent solutions for waste management such as optimising the collection, promoting transparency, tracking waste flows, remote sensing etc. For example, one participant responded:

> "For our waste pickers, we made what we call a route optimization algorithm that helps them navigate through a neighbourhood depending on the jobs and locations they have to visit on that day" (R2, Rwanda Start-ups FGD)

Our findings showed that Mobile and web applications are prominent among the digital technologies being deployed in Africa towards transitioning to a circular plastic economy. This can be explained by the proliferation of smartphones on the continent (GSMA, 2020) and their use as the primary devices for connecting to the internet. The deployment of mobile apps has enhanced communication and interaction among the different actors in the waste management space. Other technologies like GIS, AI, and IoT have been deployed to a lesser extent by a few digital innovators in Africa's plastic waste management space. These local-scale cleantech technology innovations are essential and Lukkarinen et al. (2018) suggested they should be analysed further. However, there is still a lot more to be done concerning issues relating to technology infrastructure, digital knowledge, accessibility, and use.

4.2.3 Infrastructure

Our findings showed that Africa's digital infrastructure has been rapidly evolving in recent times; for example, Africa now has the fastest-growing internet penetration in the world, and the continent has attracted significant investment in digital platforms. While national innovation systems may still be weak across the continent, several drivers are providing the opportunity for digital innovations to thrive, including a bourgeoning youth population deeply connected to knowledge and capital globally and are now building a significant foundation for innovation to thrive. This indicates that, with supporting policies and an enabling environment, the continent will soon have a robust digital infrastructure that will support the dissemination of these radical innovations for the circular plastic economy.

While the digital infrastructure is rapidly evolving, our results showed that the lack of other essential infrastructure, such as waste management systems, security, transport, and power, pose a challenge to the dissemination of these digital innovations. This is consistent with the literature; for example Mwanza and Mbohwa, (2019) place emphasis on the inadequate infrastructure and recycling technology as a significant barrier for plastic manufacturing industries in Africa to achieve reduction by means of reverse arrangements (material collection for reuse and recycle after their primary intended use). In addition, several stakeholders and scholars have highlighted the need for investment in technology for collection, sorting, recycling and alternative delivery mechanisms (avoiding plastics) across Africa (Rweyendela and Kombe, 2021). In our study, stakeholders across various countries underline the critical importance of infrastructure, including digital infrastructure, to promote and incentivise circular plastic economy activities:

> "There is a need for a digital inclination for all activities, in terms of data collection, in terms of listing of activities - such that when opportunities to scale come, it is easier to cascade what you are doing individually. Technological platforms will help to synchronize all the data." (R1 Nigeria Waste Management FGD)

4.2.4 Policy

The policy context is another critical dimension that will shape the transition to a circular plastic economy in Africa. Our engagement with stakeholders showed that an enabling political economy is vital for the socio-technical transition to a circular plastic economy on the continent. Stakeholders noted that, despite the overwhelming potential of digital technologies, the ability to scale and grow organically would be stifled without the enabling political economy. In essence, for the technologies to contribute, robust strategies, guidelines and legislations that work in combination and collaboration with and for all stakeholders must be explicitly defined and established. This aligns with the assertion of Oyake-Ombis et al. (2015).

Our findings showed that global commitments to tackle plastic waste have pushed governments and policymakers across Africa to act. This has resulted in several good policies enacted to promote the circular economy. However, there are significant challenges associated with coordination and enforcement. For example, highlighting the disconnect between excellent policy ideas and actual implementations, participants from various Civil Society focus groups noted below

> "The policy of no single-use plastics is very much welcome, but how do we implement it? We do have the laws, we have the regulations, we have the policies, but implementation now becomes a problem. There's nothing you're going to write about that has never been said before, but implementation is the key." (R2 Nigeria Civil Society FGD)

> "I feel like the lack of enforcement when it comes to breaking the laws regarding littering and other offences is a real issue. For example, if you see someone dump plastic on the streets, the police won't say anything. Though there should be an act that says this is the fine, but it's not implemented so everyone else doesn't really bother anymore." (R5 Namibia Civil Society FGD)

A notable percentage of the population in Africa lives below the poverty line, which makes survival an urgent priority for many households. In these circumstances, environmental issues take the back seat, often perceived as a concern of developed, western countries. As the pressing need for food and necessities trumps environmental concerns, incentives, rather than penalties, work better as policy instruments among low-income populations. However, a balance needs to be struck between incentives and penalties. For example, bans on plastic bag use are widely exercised policy measures to mitigate the challenge of single-use plastics. To date, 36 African countries have adopted and implemented such policies (Attafuah-Wadee and Tilkanen, 2020). However, Attafuah-Wadee and Tilkanen (2020) suggest that anecdotal evidence indicates the effect of plastic ban policies is modest in stemming the inflow of plastic products into the waste stream. Rwanda has been identified as a noteworthy exception to this trend, where, the plastic ban implemented since 2008, can be deemed successful (Clavel, 2014).

4.2.5 Culture

Our results suggests that, though there is a willingness to adopt new technologies for managing plastic waste, there will be a need for capacity development and public education, this aligns with the quantitative results presented in ~~Kolade et al. (2022)~~Kolade et al. (2022) . Our findings also showed challenges associated with societal perception and cultural attitudes to waste. For example, plastic waste collection is seen as a filthy trade for needy people, and social status plays a role in how people approach reuse and recycling ~~(Adefila et al., 2020; Oyinlola et al., 2018)~~(Adefila et al., 2020; Oyinlola et al., 2018). Therefore, stereotypes and stigma about waste management must be tackled, and regulators must constantly and consistently sensitise the public on the importance of cooperating with waste collectors. Similarly, digital firms need to speak the language of the institutions and waste collectors. There should be an attempt to upgrade waste collectors' and institutions' tools and digital literacy for a sustainable collaboration. Government subsidies should provide the opportunity for digital firms to create special incentives which will motivate the stakeholders. In addition, there is significant room for changing the culture by addressing issues such as level of literacy, digitalisation awareness and acceptance.

4.2.6 Science

Scientific evidence for the use of high and low-level digital technologies for achieving a circular plastic economy is a vital regime dimension of the socio-technical transition. Our findings indicate that most techno-scientific knowledge is on R_8-Recycle, and R_9-Recover while the more important strategies, such as R_0-Refuse, R_1-Rethink, R_2-Reduce, R_3-Reuse and R_4-Repair, are not as widespread yet.

The results showed that the invitation to invest in alternative packaging had not gained much traction despite several innovations around the continent. For example, biodegradable packaging has been produced locally using banana leaves and water hyacinth. However, this, and similar innovations, have not diffused across the continent. The scientific community needs to work with other stakeholders for systems to promote, celebrate, and diffuse these sorts of innovations across the continent. For example, the United Nations Industrial Development Organisations (UNIDO), in collaboration with the Federal Ministry of Environment, Nigeria and other stakeholders, launched a project on sustainable alternative materials to plastics. These collaborations will advance the technical knowledge and science necessary to evolve, publicise and implement these niche innovations to accelerate socio-technical transition. This is aligned with the suggestion of Nikas et al. (2022) that scientific communities are required to adopt an interdisciplinary approach by communicating and collaborating with one another.

4.2.7 Markets

In terms of user practices and application domain, our results showed that, while there has been a surge in the number of entrepreneurs embracing digital innovations for the circular plastic economy throughout the past decade; majority of these have operated with very slim profit margins, are not financially sustainable (mainly relying on grants), and have not been able to scale. For example, one interviewee said:

> "It can be quite frustrating doing this business here in Nigeria. Even the logistics of picking up waste was even more expensive than what I was collecting." (R3 Key stakeholder Interview, Nigeria)

Regulatory advantages generally determine technological and economic advantages (Losacker and Liefner, 2020); though these organisations have the technological advantage, they lack the regulatory and demand advantages. Global concerns on the impact of plastic waste are driving the regulatory advantage, which in turn will drive the demand advantage.

While these digital innovators may not be profit-making, their environmental and social impact makes them attractive to governments and donor organisations. Previous studies such as Oyinlola et al. (2022b) have argued that investors/funders must follow a more rigorous standard approach to assess the performance of organisations. This approach should recognise the environmental and social impact within the rubric of financial sustainability.

Our findings also showed that investor appetite is low in this sector. Furthermore, a participant observed:

> "A strong business case is needed to convince investors as the margins are extremely thin in our line of business. This is one reason why we intend to go higher in the value chain to begin to produce finished products as this will lead to higher margins. Another barrier to getting funding is that the waste management sector in Nigeria is fragmented and lacks structured regulation and so investors might be a bit hesitant." (R2 Nigeria Waste Management FGD)

4.3 Landscape Challenges

The data collected were thematically analysed to ~~answer the third research question i.e. What are some of~~explore the external pressures that affect the socio-technical transition processes from the current linear to a circular plastics economy landscape~~?~~. Five themes were identified from the analysis which includes (1) Regulation (2) Funding (3) Awareness/Education (4) Data (5) Capacity. These themes, which addresses the third analytical level of the MLP - Landscape, are discussed in detail below.

4.3.1 Regulation

The first theme identified in the data analysis was regulation. Our findings showed that the current regulatory landscape across the continent was a significant obstacle to circular transition. This includes implementing and enforcing relevant/robust policies that can enable niche innovations to scale and advance. It was observed that overall, there are several excellent waste management policies across the continent, although most of them would benefit from better coordination and enforcement. The Extended Producer Responsibility (EPR) scheme is one example, where producers of plastics have a responsibility in post-consumer recovery. For instance, in Kenya, an EPR Scheme for packaging has been implemented but can benefit from stricter enforcement. A further supportive legislation should be on recycled matter; for example, developing and enforcing a policy that requires plastic producers to include recycled materials can result in an exponential increase in demand for recyclable content. An interview participant highlighted the critical importance of policies and regulations as tools:

> "It will be nice to have support from government to incentivise new patterns of circular economy behaviour in society, but also point where retailers, for instance, would be required by law to take back returnable bottles. Or to have some sort of tax exemption for using recycled material in packaging. Consumers are not willing to pay more for recycled plastic, which is more costly than virgin plastic, so we need some legislative support in terms of incentives to use recycled products" (R7 Key stakeholder Interview, Nigeria) .

However, it is pertinent to note that there are policies in some countries that stifle innovation and/or impede digital innovations from operating profitably. This aligns with the findings of Rweyendela and Kombe (2021), who found that the current legislative environment in Tanzania sends mixed signals about the transition to a Circular Economy. They further noted that although possible stimulants are on offer, potentially counterproductive restrictions are also in place.

4.3.2 Funding

The second theme emerging from the analysis was related to funding. Our study showed that while considerable opportunities exist in the sector, organisations find it challenging to be financially sustainable; hence the majority of the key players driving the transition usually rely on grants. Although waste management initiatives are recognised as viable businesses in the medium to long term, start-ups in this sector are struggling to access start-up capital in the first few years to pilot their innovation, pending when they can make a viable investment case for scaling. Investors are typically reluctant because of small profit margins and weak regulatory environment in the sector. This is exacerbated by the challenge of limited information on investment and funding opportunities, as the following participants noted:

> "The other thing is lack of funding resources. Some people may have some ideas to come up with recycling projects, but there's no funding. And then there's a lack of networking opportunities that may even facilitate this" (R1 Key stakeholder Interview, Zambia)

4.3.3 Awareness/ Education

The third theme was related to awareness/education about plastic pollution. In contrast to developed countries, our results indicate that among the public across Africa, there is still a significant lack of education and awareness on sustainable waste management, as the following comments show:

> "We need first to start with awareness. We are not doing enough. we need to put in more effort in creating awareness on a national scale. People are still buying plastics because there's just no understanding of why people need to reduce plastic" R3 Namibia Civil Society FGD)

> "One of the points I believe is lack of awareness or lack of knowledge that waste is a valuable resource. Many people just see it as something to be disposed of. There's actually also lack of understanding of the sustainable development concept because they are not thinking about the future generation or the environmental impacts that the waste have. They see disposal sites as the final place for waste disposal and they are used to the traditional linear method" (R1 Nigeria Civil Society FGD)

Orji et al. (2022) attributed the hesitancy of transitioning to a circular economy by the Nigerian Manufacturing sector to the poor understanding of factors for a productive circular supply chain in the manufacturing sector.

One of the unfortunate outcomes of this is that currently, numerous collectors are not able to get enough feedstock for recycling. Therefore community awareness/education initiatives and programmes for behavioural change will need to be developed and rolled out, for example, Hsu and Chen, (2021) proposed encouraging environmentally friendly habits through gamification. These should go in tandem with appropriate policies.

4.3.4 Data

The fourth theme resulting from the analysis is the lack of data. Our findings highlighted that a significant setback for the transition was the lack of accurate data on waste. Some comments from the focus groups supporting this theme include

> "Here in the African context, there's just a huge lack of data. So, because the circular economy is such a new concept, people haven't collected data so much." (R3 Nigeria Waste Management FGD)

> "We don't have datasets like those that that exist in other parts of the world. It would be good to have because I believe that if there are no sources of data, then that's a general problem. In Africa there's some things we don't track. There's just a lack of data in general about what's going on." (R2 Rwanda Academia FGD)

> "Right now, we don't have any reference point. Nobody knows how much plastic is recycled, no one knows how much PET, how much HDPE is recycled, and all these other various characterizations of recyclables. So, we need a system that will be able to inform current players and could-be investors so that people can know how much recyclables are available and all." (R2 Zambia Start-ups FGD).

We observed that there is still a wide gap in the systems and/or technologies for capturing and tracking data on waste. This is especially important considering the complexities around the many material flows in the circular plastic economy. Stakeholders would operate more efficiently if information such as type, location, distribution, quantity collected, quantity recycled etc. ~~of plastic waste is available as Hsu et al. (2022)~~of plastic waste is available as Hsu et al. (2022) noted that stakeholders need to be able to access data, information and knowledge across the circular economy value chain to be able to operate optimally. Similarly, Ahmed et al., (2022) suggested having several data sharing platforms.

4.3.5 Capacity

The fifth theme identified relates to capacity and capability. Our findings revealed a clear need to develop skills relevant to the circular economy, including technologies and techniques for effecting behavioural change.

> "Many players in the industry are operating in a space where we lack systems that can harness our potential properly. If there could be a way of being assisted in terms of institutional capacity, that would be a very, very helpful system." (R3 Zambia Start-ups FGD)

These findings are aligned with the literature where several scholars such as Abdelmeguid et al. (2022) and Paletta et al. (2019) have suggested that countries and organisations need to put appropriate mechanisms in place to develop capacity and capability for the circular economy. To achieve this, there needs to be a comprehensive mapping of the skills gap required for the transition to a digitally enabled circular plastic economy in Africa and the policy framework for building the capacity and capability of local skills to develop and use digital technologies for developing niche innovations.

~~4.4 Transitioning to a digitally enabled circular plastic economy~~

5 Discussion

In addressing the complexity of transitioning to a circular plastic economy in Africa, our discussion synthesizes the findings into a structured analysis guided by the multi-level perspective (MLP) framework. This framework aids in systematically exploring the interaction between technology, policy, and socio-economic factors at different

levels: niches, regimes, and landscape. The first section of our discussion, focusing on niches, delves into various digital technologies identified as pivotal for advancing circular economy practices within the continent. Technologies such as Artificial Intelligence, Blockchain, and Mobile Apps are examined for their potential to enhance sustainability through the 9Rs framework. The second section addresses the regime dimensions, highlighting the critical areas of industry structure and stakeholder collaboration, where enhanced communication and cooperative strategies are deemed essential for effective socio-technical transitions. The third section, concerning landscape challenges, discusses broader external pressures such as regulatory frameworks, funding mechanisms, and public awareness that impact the adoption and efficacy of circular economy practices.

The multi-level perspective (MLP) framework employed in this study serves as a critical lens for assessing the role of digital technologies and socio-technical regimes in transitioning from a linear to a circular plastics economy. The results highlights the interaction between niche innovations, regime dynamics, and broader landscape pressures, offering a comprehensive understanding of the systemic changes required for this transition. By aligning our findings with this theoretical approach, we explore the significant potential of digital technologies such as 3D printing, blockchain, and mobile apps, and identify the structural challenges they address within the African context.

Figure 2 presents a summary of the results discussed above; It highlights the crucial considerations for the seven regime dimensions. It further illustrates that even though these niche innovations can accelerate the transition from a linear to circular plastics economy by implementing strategies of the 9Rs framework, the regime dimensions and landscape pressures remain challenging for the transition process.

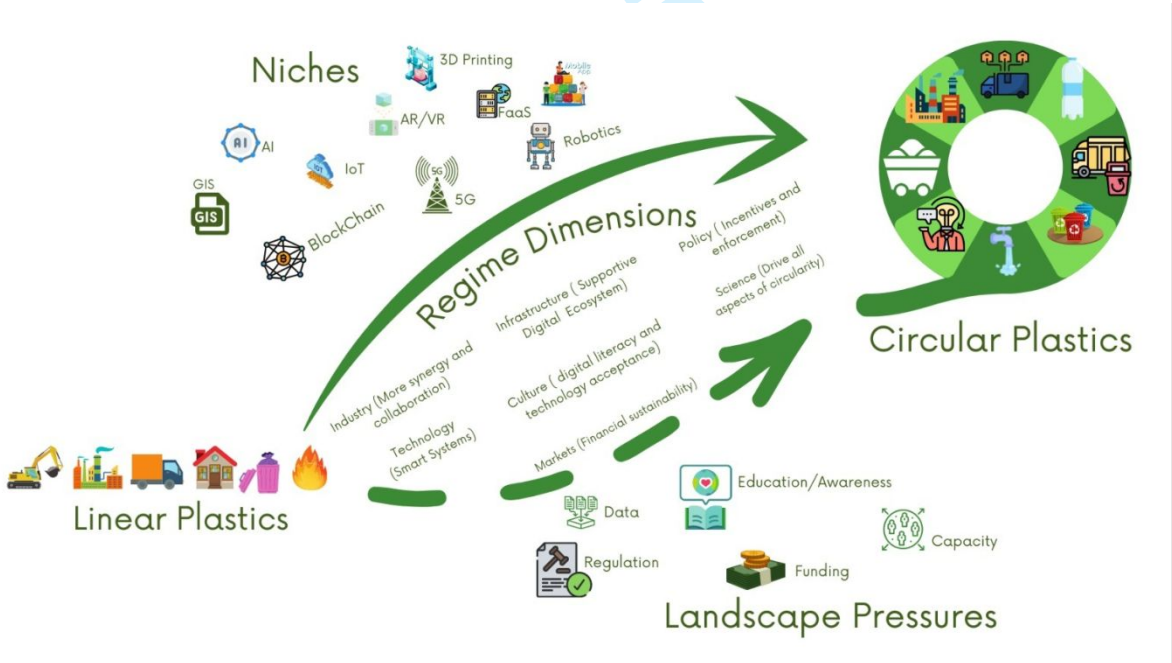

Figure 2: Socio-Technical Transition to a Circular Plastic Economy

Of these ten niche innovations, 3D printing, Blockchain and Mobile apps, were identified as top priorities due to their relevance for the African context as discussed below.

3D Printing: The results showed that 3D printing technology can help in implementing R_3-Reuse, R_4-Repair, R_5-Refurbish, R_6-Remanufacture, R_7-Repurpose and R_8-Recycle. Even though plastics suitable for 3D Printing might be a smaller percentage of the waste stream, they still constitute a significant volume, causing environmental issues, such as floods in African cities. 3D printing technology can reuse plastic materials in producing complex parts in remote areas while reducing the environmental footprint associated with traditional supply chain logistics ~~(Zhong and Pearce, 2018).~~(Zhong and Pearce, 2018). Examples of products that have been created from this technology include medical supplies and school shoes for children in Haiti (Ishengoma and Mtaho, 2014), prosthetic limbs (Gretsch et al., 2016) and microscopes for schools in Kenya (Owen, 2018). These opportunities imply that 3D printing provides the opportunity to add significant value to the waste stream, thus incentivising communities to engage in the circular plastic economy (Oyinlola et al., 2023). Furthermore, the UK Department for International Development, UNICEF and the United Nations have touted this technology as a leading frontier technology that should be utilised within international development (Ramalingam et al., 2016; UN, 2018). Therefore, the capacity of this technology to contribute to larger developmental concerns in Africa implies that it should be prioritised in the circular plastic economy.

Blockchain: The results identified Blockchain as a technology that could foster transparency and facilitate data exchange across the circular plastic economy. It can be used to develop a more transparent and accountable system whereby information from the "molecular barcode" of plastics can be publicly tagged and tracked, but not altered, through the product lifecycle. Therefore, this technology offers distinct possibilities in driving an important shift in the perception of end-of-life plastic from wastes to assets. Given the inadequate infrastructure for waste management, this technology offers the opportunity for decentralised tracking and tracing of the plastic value chain. Therefore, this technology simultaneously addresses the identified landscape challenges of data and awareness/education thereby implementing R_1-Rethink and R_2-Reduce.

Mobile apps: Mobile apps was identified as the most popular technology by stakeholders. They offer endless possibilities, such as serving as an essential interface for all stakeholders to interact for circularity and enhancing communication and interaction among the different actors in the waste management space. Across Africa, there has been a proliferation of smartphones over the past two decades (GSMA, 2020), these are usually the primary devices for connecting to the internet This indicates that they should be a high priority. Our results, showed that unlike other technologies that have not been deployed or deployed by few, there are several examples of start-ups/innovators whose innovations incorporate mobile apps across Africa (see Appendix ~~34~~). This is more pronounced when observing the thirty nine (39) organisations presented in Oyinlola et al. (2022). However, it should be noted that majority of this are used for implementing R_8-Recycle but there are opportunities for more relevant strategies like R_2-Reduce.

Despite remarkable advancements in the development and implementation of niche innovations for the African plastic value chain. Minimal reforms at the regime level have slowed transition progress. This is consistent with the perspectives of prominent researchers such as Geels (2010) who recognised the socio-technical regime as the fundamental level of interest. Of the seven regime dimensions, industry structure and stakeholder collaboration call for greater attention in the transition process. This is because participation and multi-stakeholder engagement are critical to realising sustainable socio-technical transitions (Chilvers et al., 2018) which are "challenged and complicated by lock-in mechanisms related with technology, sunk investment and entrenched societal habits of consumption" ~~(Kolade et al., 2022)~~(Kolade et al., 2022). Furthermore, low coordination, cooperation and cohesion were identified as a critical hindrance in the transition. Therefore, stakeholders across the public and private sectors need to work together to achieve transition objectives (Geels, 2010). Additionally, stakeholders must embrace an attitude of collaboration rather than competition. Some of the digital technologies highlighted might be utilised to create systems, platforms, and forums for stakeholder cooperation.

In addition, the need to foster and strengthen research and development for the circular economy is pertinent. The scientific community (including technology disruptors and innovators) needs to drive increased activity in other circular economy areas, such as reducing and reusing plastics and transforming plastic waste into value-added products. More research needs to be explored in areas such as the direct and indirect impact of plastic production and waste leakage in the African context both for short and long-term and value chain studies. A critical factor for the actualisation of the circular plastic economy will be building local capacity and capability to innovate with and use digital technologies for developing niche innovations for the circular plastic economy.

A critical dimension of the regime is the political economy, the state has a crucial responsibility in implementing transition interventions and regulations as well as the numerous forms and sites of power it deploys to mediate transition relations (Argyriou and Barry, 2021). ~~Regulations is essential for the transition and must go beyond enacting waste management policies and restrictions but focus on the entire value chain, for example, Schroeder et al. (2023)~~Regulations is essential for the transition and must go beyond enacting waste management policies and restrictions but focus on the entire value chain, for example, Schroeder et al. (2023) suggested a policy framework comprised of four important components: (i) implementation of mandatory Extended Producer Responsibility (EPR) schemes; (ii) a common continental approach to standards on materials, product design and recycling; (iii) support policies for digital innovations and business models for decentralized plastics collection and recycling; and (iv) social support policies for informal sector inclusion. The political economy needs to adequately cater for private sector stakeholders, who are often at the frontline accelerating transition by mobilising new networks of innovators and investors. On the other hand, drawing on scientific evidence, state actors need to mobilise the political will to tackle the reluctance and resistance of the population to transition policies. They also need to put innovative and effective institutional processes and monitoring and supervision arrangements to ensure consistency by

enforcers. Furthermore, governments must constantly assess existing regulations to find opportunities to update the policy landscape.

Given the tight market environment, governments' burden lies in facilitating programmes that could make funds available to entrepreneurs willing to venture into this space in order to boost the user practices and application domain dimensions of the regime. The current trend of diffusion of innovations across the continent indicates that a growth in the market is expected, which will in turn put organisations in a better position to generate income and attract investors (Oyinlola et al., 2022b). Digital technologies can play a role in driving markets, for example, a mobile app for a digital aggregator platform could be developed, for linking various stakeholder as well as serving as a virtual market place. With adequate regulation and high-level support, this sort of platforms could evolve into a vital support mechanism for the governance of the circular plastic economy as well as an enabler for stakeholder to access content, share ideas, and develop new mutually beneficial arrangements for reuse and recycling.

Even though there are many opportunities at the niche level, it might be the case that with the external pressures from the exogenous landscape, the contribution to the transition is limited. A summary of potential interventions by stakeholders to mitigate these external pressures is presented in appendix 45. These suggested interventions were co-created with stakeholders during the data collection activities. The table depicts the distinct roles of each stakeholder group in addressing the identified challenges. For example, Civil Society stakeholders could address the funding challenge by facilitating multi-layer collaboration for a systematic approach to funding and investment. In contrast, stakeholders from the governments/policymaker group could address the capacity challenge by encouraging local context innovative technologies and kickstarting initiatives for building national capacity for the circular plastic economy.

The findings underscore the unique challenges and opportunities that characterize the African context in the transition from a linear to a circular economy, distinguishing our research from other studies. While the global discourse on circular economy often centre's on technological and policy innovations, the African context reveals critical insights into the socio-economic and infrastructural realities that shape these innovations' implementation and effectiveness. Our findings highlight that, despite the potential of niche innovations like 3D printing, blockchain, and mobile apps to drive circularity, the transition in Africa is markedly influenced by systemic regulatory weaknesses and a lack of cohesive stakeholder engagement. This study contributes a nuanced understanding by demonstrating how these technologies can not only foster recycling and waste reduction but also how their integration into the local economies is contingent upon specific regime changes and landscape adaptations. Such context-specific insights provide a deeper comprehension of the barriers to and drivers for a circular economy in Africa, illustrating the necessity for tailored strategies that acknowledge and harness the unique attributes of the African economic, political, and social landscapes. This differentiation in focus and findings enriches the broader discourse on circular economy by offering a concrete example of how global concepts

must be adapted to local contexts to be successful, particularly in regions with distinct developmental challenges.

This paper significantly enriches the body of work on the circular economy, particularly within the context of developing regions such as Africa. Our study contributes to two main areas: the application of digital technologies in circular economy practices and the examination of socio-technical transitions within a uniquely African context. By integrating findings from our empirical research with established theories and recent studies, such as those by Geels (2010) on socio-technical regimes and the work by (Schröder et al., 2023) on policy frameworks for circular economies, we provide a nuanced analysis that bridges significant gaps in the existing literature. Notably, our research offers detailed insights into how specific digital technologies—3D printing, blockchain, and mobile apps—can be effectively harnessed to overcome infrastructural and regulatory challenges that are often overlooked in more generalized studies focused on developed economies. Furthermore, the inclusion of real-world applications and the identification of stakeholder roles in this transition process enhance the practical relevance of our findings. This approach not only extends the theoretical understanding of the circular economy but also contributes methodologically by employing triangulation to strengthen the validity of our conclusions and highlight areas where further research is necessary due to the current lack of literature on specific regional challenges and technological implementations in Africa.

~~5~~6 Conclusion

~~The multi-level perspective framework has been used to analyse~~In conclusion, this study has critically examined the transition ~~from~~towards a ~~linear plastics system to a digitally enabled circular plastics system. Drawing from cross-sectional stakeholder engagements, the study offers unique insights into the niches, regimes, and landscape in the~~ circular plastic economy ~~(CPE)~~ in Africa ~~as well as provides practical suggestions on how this can be operationalised.~~

~~Our study makes an important theoretical contribution by using empirical evidence to articulate the critical importance~~through the lens of the ~~regime dimension in accelerating the circular economy transition in general, and the circular plastic economy in particular, in Africa. This aligns with the views~~multi-level perspective (MLP) framework, revealing a complex interplay of ~~leading scholars who identified socio-technical regime as the primary level of interest, while the niche and landscape levels are derived from regime. Our study shows that, while substantial progress has been made with regard to the development and deployment of niche~~technological innovations ~~in Africa, the overall progress of circular plastic economy is slowed due to relatively minimal changes at the regime levels as well as~~ , regime dynamics, and landscape pressures ~~from the exogenous landscape. In order to upend lock-in to the linear paradigm of production and societal habit of consumption, there is a need for radical, and sustained progress in circular economy policies and regulatory changes that supports niche innovations that drive continuous changes in the exogenous landscape.~~

~~With a rapidly evolving digital ecosystem across sub-Saharan Africa, there are several opportunities for socio-technical niche innovations, various~~. Our findings illuminate the significant role digital technologies ~~and applications by social entrepreneurs, to accelerate Africa's circular plastic economy transition. The study highlighted ten of these niche~~ can play in fostering circular economy practices, with technologies ~~and identified mobile apps~~like Artificial Intelligence, Blockchain ~~and 3D printing as important~~, and Mobile Apps emerging as key enablers. However, the effectiveness of these technologies ~~for niche CPE innovations for Africa. For these technologies to have a meaningful contribution, policy innovations and regulatory changes are required to positively transform the exogenous landscape. Thus, a socio-technical transition to a circular plastic economy can be achieved by:~~ is contingent upon overcoming substantial systemic barriers, including inadequate infrastructure, regulatory gaps, and the need for enhanced stakeholder collaboration.

- ~~Strengthening, and changing where necessary, the regulatory landscape in terms of implementing/enforcing policies that support socio-technical niche innovations.~~
- ~~Providing innovative funding mechanisms to support socio-technical niche innovations to be financially viable in a slim profit margin environment.~~
- ~~Using incentives to drive a cultural and behavioural change as well as address issues such as level of literacy, environmental awareness, and digitalisation acceptance.~~
- ~~Identifying skills gaps in the socio-technical transition and developing local skills to fill these gaps.~~
- ~~Implementing robust systems and/or technologies for capturing data and tracking plastic materials for the circular economy.~~
- ~~Developing systems, platforms, and fora for collaboration between all stakeholders.~~

~~All of these areas offer opportunities for further research, especially on African country-level which is an under-researched area. Africa's socio-technical transition to a digitally enabled circular plastic economy is significant, as strong growth in plastic production and consumption is predicted and centralised waste management and recycling infrastructure are mostly inadequate across the continent. Therefore, these socio-technical niche innovations can fill the gap by offering smart solutions for waste management such as optimising the collection, promoting transparency and tracking waste flows, thus contributing to achieving a digitally enabled circular plastics economy for Africa.~~

We identified critical challenges at the regime level that impede progress, such as entrenched industry structures and insufficient multi-stakeholder engagement. The study underscores the necessity for robust policy frameworks that support innovation and integrate circular economy principles into national development agendas. Moreover, the landscape challenges highlighted, including funding limitations, regulatory inconsistencies, and the need for greater public awareness, emphasize the urgent call for a concerted effort from all sectors of society.

This research contributes to the broader literature by providing a nuanced understanding of how digital technologies can be integrated within the African context to promote a circular economy. It extends the discourse beyond the technological aspects, considering the socio-economic and political frameworks that are essential for sustainable development. Future research should focus on detailed case studies within specific African contexts to explore how localized solutions can be designed and implemented, and how these solutions interact with broader national and regional policies.

Ultimately, the transition to a circular plastic economy in Africa requires not just technological solutions but a transformative shift in how economies, societies, and environmental resources are managed. It calls for an integrated approach that aligns economic development with environmental sustainability, driven by innovation, supported by policy, and guided by the collaborative efforts of all stakeholders.

Although this paper makes considerable contributions to the academic literature in explicating the critical role of regime changes as a necessary dimension to upend the lock-in to a linear plastic economy that is otherwise stabilised by sunk investment and corporate state capture in developing country contexts, it has some limitations. One such limitation is that it uses data collected from five (5) countries, all of which were predominantly English speaking, i.e. there was no French speaking country. Another limitation is that while it offers a panoramic view of multi-level synergy of actors and sectors across African countries, it is limited in its scope and ability to illuminate country-specific nuances and peculiarities. This is especially important in terms of further unpacking the regime level, given the peculiar political and institutional contexts in various African countries. Future studies can therefore take more in-depth case study approach for specific countries, to explicate the specific challenges, opportunities, and successes of the regime dimension in driving the circular plastic transition. Such a study will, on one level, be a sequential follow up to the present study.

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Appendices

Appendix 1 - Focus Groups Details

Table 1: Details of the focus groups held

Stakeholder Group	Criteria for selection	Country/Region	Number of Participants	Date
Academia	Participants were selected based on publication records including relevant intersection or direct participation in pollution or circular economy topics, and by referrals from industrial participants.	Nigeria	4	Thurs, 15th Oct 2020
		Namibia	4	Wed, 7th Oct 2020
		Rwanda	3	Thurs, 15th Oct 2020
Civil Society	Participants were selected based on public track record of participation in meetings and conferences, evidence of funded projects, and their advocacy presence as documented online and via traditional media.	Nigeria	4	Tue, 29th Sep 2020
		Namibia	5	Thurs, 1st Oct 2020
		Rwanda	2	Fri, 16th Oct 2020
Digital Innovators and Start-ups	Participants were selected based on publicly available product information, business processes, and activities. This enabled us to confirm their current use of digital tools and technologies.	Namibia	8	Thurs, 1st Oct 2020
		East Africa	4	Fri, 16th Oct 2020
		Southern Africa	6	Thurs, 22nd Oct 2020
Governments, Policy makers, Parastatals and projects within government	Participants included national ministries, regional and local governments as well as parastatals (organisations owned by the national government) with traditional responsibility related to environmental management. This was to ensure current legal provisions were represented, and future decision makers could be informed with the hope of closing gaps in knowledge of the state of the art across the network.	Rwanda	3	Tue 13th Oct 2020
		Namibia	3	Wed, 14th Oct 2020
		Namibia	3	Wed, 14th Oct 2020
Investors/Funders	Participants were selected from a subset of entities who had previously participated in "green" or environmental funding programs.	Africa	3	Wed, 14th Oct 2020
		Namibia	4	Wed, 14th Oct 2020
Waste Management Organisations	Participants were selected based on being in the top 25% of waste handlers in their jurisdiction or exhibited specialty services.	Nigeria	4	Tue, 29th Sep 2020
		Rwanda	6	Tue 13th Oct 2020
		Namibia	3	Fri, 2nd Oct 2020

Appendix 2 - Focus Group Questions

1. What are the main challenges for transitioning to a circular economy?
2. What are the opportunities for transitioning to a circular economy?
3. How can Digital innovations help solve the challenges ?
4. What innovations for plastic waste management are you aware of?
5. How do you (stakeholders) use digital technologies?

Appendix ~~2~~ 3- Interview Questions

1. Overall information about the organization you represent (Location, size, turnover, number of staff, plastics collected and processed, etc.)
2. How are digital innovations used?
3. How was the digital innovation financed?
4. What are opportunities and barriers of scaling up? (prompt for technical, social, political and economic factors)
5. What are new skills needed among the staff/workforce?

Appendix ~~3~~4: Enabling Stakeholders with Digital innovations

Table 2: Enabling Stakeholders with Digital innovations

	Digital Innovation firms / Start-Ups	**Civil Society**	**Governments/ Policy Makers**	**Waste Management Organisations (WMO)**	**Academia**	**Investors/ Funders**
Artificial Intelligence (AI) *(computer vision, pattern identification, inference)*	Identification of plastic waste [7]	-Sentiment analysis of textual data on plastic pollution, -Chatbots for question and answer on circular plastic economy	-Sentiment analysis of textual data on plastic pollution, - Chatbots for question and answers on circular plastic economy	-Recognition, identification, and separation of plastic waste -Route optimisation for collection vehicles. -waste profiling and characterisation	-Bibliometric analysis for research pattern identification in plastic waste management	Identification and ranking of prospective regions of interest
Geographic Information Systems (GIS) *(geolocation, data presentation across geographical locations, visual user interfaces for spatial exploration)*	-Streamlining operations for collecting plastic waste [5] -Geolocation of waste. -Geolocation of collectors.[1],[6], -Connecting collectors to aggregators	-Visualisation of plastic waste pollution and plastic waste management efforts	-Visualisation of plastic waste pollution, the impact of government intervention, compliance information	-Route information visualisation for collection vehicles. -Visualisation of plastic waste generation per community.	-Visualisation of plastic waste pollution, plastic waste research and plastic waste management efforts	Identification and ranking of prospective regions of interest
BlockChain (trust-enabled mechanisms, accurate tracking solutions)	-Transparency in the workflow for collaboration among collectors, aggregators, recyclers and producers. -capture of the lifecycle/journey of a plastic product	-Data exchange	-Data exchange	-Data exchange	-Richer datasets on progress from sink to source of plastic waste	Hedging of foreign exchange risk and country-level policy risk, via enabling of cryptocurrency options.
Internet of Things (IoT)	-Waste identification and reporting to a central database via smart bins [8] -Automated data collection from sensors.	-Plastic waste pollution monitoring.	-Plastic waste pollution monitoring.	-Waste management service on-demand notification through waste bin sensors.	-Richer datasets to consider progress from sink to source of plastic waste	Records of business operations useful for diligence and performance monitoring

	-Conversion of recycled materials to finished and semi-finished products [4]			-Alert systems on improper sorting at source through waste bin sensors		
Robotics	-Assisted waste sorting			Automated sorting plants	-Experimental procedures	
3D Printing	-Repurposing plastic waste for filament production.			-Repurposing plastic waste for filament production. -Timely production of spare parts for equipment	Lowered cost of experimentation and other research support of innovation	New materials, products, and reuse
Serverless computing, or Function as a Service (FaaS) *(Hosting of services, software as service. Subscribing to software as a service.)*	-Scalable solutions deployment [3] -Pay-as-you-use model for infrastructural need. -Elimination of cost on infrastructural setup and deployment. -DIs focus more on their innovation rather than support systems.	-Wider dissemination and access	-Wider dissemination and access -Elimination of cost on infrastructural setup and deployment.	-Scalable solutions deployment. -Pay-as-you-use model for infrastructural need. -Elimination of cost on infrastructural setup and deployment.	Subscribing to software as a service and AI as a service. Wider access to computing resources.	Consideration of a larger number of candidate companies, through reduced transaction and registration costs
Augmented Reality/Virtual Reality (AR/VR) *(use of wearable computers for real-time, in-context data visualisation)*	-Building digital solutions for awareness, sensitisation and training on best practices			-Improved Waste profiling and characterisation	Enhanced collaboration with lowered costs.	Lowered costs of interactions during diligence and pitching activities.
5G	Real-time communication from collection centres and IoT sensors			Real-time communication from collection devices and IoT sensors		
Mobile apps	-Data collection from source, information dissemination.[8],[13] -Aggregation of data-Reward system implementation for collectors. -Scheduling of waste pickup e[1] [2],[6],[9],[12],[14],[15] -Customer and Supplier intimacy	-Awareness and information dissemination	-Awareness and information dissemination	-Platform for communication with clients and visualisation of client waste profile.	Awareness and information dissemination	

[1] Coliba Ghana, [2] Ecofuture Nigeria, [3] Ecopost Kenya, [4] GIVO Nigeria, [5] Mr Green Africa [6] OkwuEco Nigeria [7] Recyclebot Zambia [8] ScrapPays Nigeria [9] Ulubuto Zambia, [10] Virdis Kenya, [11] WasteBazaar Nigeria,[12] Wastezon Rwanda, [13] WeCyclers, [14] Yowaste Uganda,[15] Zonku Uganda,

Appendix 45: Tackling Landscape Pressures via Stakeholder Interventions

Table 3: Tackling Landscape Pressures via Stakeholder Interventions

challenge/ ***intervention***	**Regulation**	**Funding**	**Awareness/ Education**	**Data**	**Capacity**
Digital Innovation firms / Start-Ups	Collaborate with other stakeholders to lobby for	Partner with corporate partners such as Multinational Corporations to access funding from	Integrating digital tools for raising awareness initiatives. Optimise	Use technologies to capture and measure plastic waste	Identifying skills gap and strategically

	Policies that support digital firms and start-ups in waste management.	schemes such as CSR and EPR	on internet penetration	data entering the country-industry stream	programmes to close the gap.
Civil Society	Lobby for appropriate policies encouraging both incentives and penalties	Facilitate multi-layer collaboration for systematic approach to funding and investment	Extensive awareness creation and education initiatives to shift socio-cultural connotation and attitudes towards a circular plastic economy	Partner with statistical agencies and other stakeholders in data collection and collation.	Identifying skills gap and strategically programmes to close the gap.
Governments / Policy Makers	Develop market-driven and incentive-based policies, strategies, and regulatory framework to govern the use of new emerging digital innovations and promote the circular economy Enforce relevant existing policies such as Extended Producer Responsibility	Develop collaborative fora with private sector to harness funding opportunities	Support advanced technical and vocational skills in digitalisation. Support access to technology and broadband internet Release of digital platforms for increased collaboration and networking Facilitating a strong Ecosystem for the circular plastic economy	Mandating statistical agencies to capture comprehensive data on waste. Mandate plastic producers to ensure traceability o plastic products.	Encourage local context innovative technologies Initiative for building national capacity for the circular plastic economy.
Waste Management Organisations	Implement company polices to enable a balance between recycling and reduction of plastic waste	Defining and communicating critical sectors requiring funding	Engage in waste management awareness initiatives.	Implement proper data capturing technologies/ mechanism in their processes	Lobby for waste recycling hubs/centre to increase circularity of plastic in the economy
Academia	Provide Evidence based recommendations for policies to drive the circular plastic economy	Defining critical research themes suitable for funding by stakeholders of CPE	Pursue mainstreaming of the Circular Economy in the curricular Research and development to improve product development, operations, service provision	Acceleration of data to tangible output/product development	Gender inclusive student recruitment
Investors/ Funders	Issue support for implementation of low-cost innovations	Develop funding for sustaining innovations, such as growth equity for new start-ups Develop metrics for viability that acknowledge environmental and social impacts	Engage with other stakeholders to create awareness and drive the circular economy	Create opportunities to Fund initiatives for comprehensive data collection	Develop mechanism to fund capacity building activities