



BIO4HUMAN

SWOT Analysis Report

Due date: 31/05/2026

Responsible partner: PRO CIVIS

Disclaimer:

The content reflects the views of the authors only. The European Commission is not liable for any use that may be made of the information contained herein.

This document contains information that is proprietary to the Bio4HUMAN consortium. Neither this document nor the information contained herein shall be used, duplicated, or communicated by any means to any third party, in whole or in parts, except with the prior written consent of the Bio4HUMAN consortium. This restriction legend shall not be altered or obliterated on or from this document. Neither the European Commission nor the Bio4HUMAN project consortium are liable for any use that may be made of the information that it contains.

Document information

DELIVERABLE NUMBER	D6.3							
DELIVERABLE NAME	SWOT Analysis Report							
ANNEXES	Annex 1 - SWOT analysis. Integrated table Annex 2 – Template for collecting data (Task 6.3)							
TYPE*	R:	X	DMP:		DATA:		DEC:	
DISSEMINATION LEVEL**	PU:	X	SEN:		EU CLASSIFIED:			
LEAD BENEFICIARY	PRO CIVIS Foundation for Education and Social Dialogue							
DUE DATE	31.05.2026							
SUBMISSION DATE	31.05.2026							

*R — Document, report; DMP — Data Management Plan; DATA — data sets, microdata, etc; DEC — Websites, patent filings, videos, etc.

**Public — fully open (automatically posted online); Sensitive — limited under the conditions of the Grant Agreement; EU classified — restraint-ue/eu-restricted, confidential-ue/eu-confidential, secret-ue/eu-secret under decision 2015/444

Document history

ID	DATE	AUTHOR	CHANGE
1.	07.05.2026	T. Pęczek, A. Gajek A. Bądel, A. Sobolewski, D. Kuznowicz, P. Sobczyk (PRO CIVIS), C. Szablewski, P. Sebastien (WELOOP), A. Górską, W. Stupnicki (PAH), M. Smidova Skalova (PIN)	Draft D6.3 (v.1.0.)
2.	12.05.2026	W. Stupnicki, A. Górską (PAH)	Revision of document
3.	13.05.2026	J. Lugwarha, A. Nejedla, M. Smidova Skalova (PIN)	Revision of document
4.	10.05.2026 14.05.2026	A. Motola, A. Glaser (Enspire)	Revision of document
5.	26.05.2026	D. Kuznowicz (PRO CIVIS)	Final version of D6.3

Contents

Document information.....	3
Document history	4
List of abbreviations.....	6
Executive summary	7
1. Introduction.....	9
1.1 Context and aims of Bio4HUMAN Project and WP6	9
1.2 The scope of the SWOT Analysis	9
2. Methodology	10
2.1 Sources of data	10
2.2 Bio4HUMAN’s SWOT template description	11
2.3 Definitions of areas of importance.....	12
2.4 Selection of critical SWOT items	13
2.5 Methodological limitations	14
3. The multi-criteria SWOT Analysis	14
3.1 Area 1 Endogenous potential of the bioeconomy sectors in humanitarian actions.....	14
3.2 Area 2 The technical challenges posed by diverse environmental, social and economic conditions.....	17
3.3 Area 3 Waste management and waste-related environmental challenges	20
3.4 Area 4 Sustainability and circularity performances of bio-based solutions	23
3.5 Area 5 The potential of bio-products and bio-technologies to improve social benefits.....	26
3.6 Area 6 Economic, technological and scientific potential of the proposed solutions	29
3.7 Area 7 The aspect of social innovation.....	32
3.8 Area 8 Investment attractiveness and founding sources.....	35
3.9 Area 9 Existing and expected regulatory environment.....	38
3.10 Area 10 Reputational and replication potential of the proposed solutions	41
4. Impact assessment.....	44
4.1 Societal.....	46
4.2 Scientific.....	46
4.3 Economic.....	46
4.4 Environmental	47

5.	Conclusions and key recommendations	47
5.1	Conclusions for the Democratic Republic of Congo (DRC).....	47
5.2	Actionable Recommendations for the DRC	47
5.3	Conclusions for South Sudan	49
5.4	Actionable Recommendations for South Sudan	49

List of abbreviations

BSF	Black Soldier Fly
CHS	Core Humanitarian Standard
DD	Development Drivers
DRC	The Democratic Republic of Congo
GBV	Gender-Based Violence
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventories
MA	Mitigating Actions
OCC	Office Congolais de Contrôle
PDM	Post-Distribution Monitoring
RECOs	Community health workers
RMA	Risk Management Activities
SA	Supportive Actions
SSbD	Safe and Sustainable by Design
SWM	Solid Waste Management
SWOT	Strengths, Weaknesses, Opportunities, Threats
TRL	Technical Readiness Level
WP	Work Package

Executive summary

The integration of circular bioeconomy principles into humanitarian action represents a strategic step to address the systemic failures of Solid Waste Management (SWM) in crisis environments. The rapid accumulation of unmanaged waste causes significant public health hazards and environmental damage. This report summarises the Multi-factor SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis conducted within the Bio4HUMAN project in two target countries: the Democratic Republic of Congo (DRC) and South Sudan, providing a structured framework to evaluate how sustainable bio-based products can be realistically deployed in non-EU humanitarian settings with severely limited infrastructure.

The SWOT analysis methodology (Chapter 2) systematically assesses ten areas of importance, including the endogenous potential of local sectors, technical and environmental challenges, circularity performances, social innovation, investment attractiveness, and regulatory frameworks (see section ‘Definitions of areas of importance’). For each area, the framework identifies specific Strengths, Weaknesses, Opportunities, and Threats, and directly supplements them with targeted programme activities: Supportive Actions, Development Drivers, Mitigating Actions, and Risk Management Activities (see sections ‘The multicriterial SWOT Analysis’ and ‘Bio4HUMAN’s SWOT template description’). The findings directly map into four main impact pathways for the humanitarian sector: societal empowerment, scientific field validation, economic business model development, and genuine environmental pollution reduction (see section ‘Impact assessment’).

A major cross-cutting finding is that the bio-based industry and the humanitarian sector currently operate in silos. The bio-based sector does not systematically target humanitarian operations, and humanitarian actors lack awareness of available solutions. Bridging this gap requires global dialogue, cross-sectoral platforms, and targeted pilots. Rather than attempting to replace entire consumer markets, utilizing humanitarian organizations as niche entry points for specific applications provides the most realistic strategy for scaling bio-based solutions globally. The global humanitarian procurement rules, approved supplier lists, and cluster standards determine field-level adoption. Without integrating bio-based alternatives directly into these global frameworks, localized adoption remains extremely limited regardless of local demand. However, internal organizational sustainability policies and donor environmental commitments create powerful demand-side leverage, acting as a much faster and more immediate adoption pathway than waiting for national regulatory changes. This transition is highly economically viable: substituting conventional packaging with bio-based alternatives typically results in less than a 10% increase in total humanitarian kit costs, as packaging represents only a minor share of overall expenditure, substantially strengthening the global economic case for bio-based procurement.

Finally, a fundamental conclusion across the analysis is that substituting conventional materials with bio-based alternatives without addressing

infrastructure gaps will not solve environmental pollution. In both assessed regions, there is a complete absence of formal SWM, industrial composting, and source segregation. While bioplastics strictly require industrial composting to deliver environmental advantages, other variants (such as paper-based items or mycelium) can be safely managed in basic pits or latrines. Regardless of the chosen material, the most critical recommendation is to never introduce compostable or bio-based products in isolation. Deployments must be strictly bundled with parallel investments in decentralised community waste collection and segregation infrastructure to ensure genuine circularity.

1. Introduction

The integration of circular bioeconomy principles into humanitarian action represents a strategic opportunity to address the persistent weaknesses of SWM in humanitarian settings. In crisis contexts, the rapid accumulation of unmanaged waste, including plastics, organic matter, and medical residues, can generate serious public health risks and environmental degradation. . By introducing bio-based innovation, the humanitarian sector can move beyond linear "take-make-dispose" models towards circular systems focused on resource recovery and pollution prevention, and long-term sustainability.

This report summarises the Multi-factor SWOT analysis conducted within the Bio4HUMAN project. The analysis provides a structured framework for assessing how sustainable bio-based products and systems can be realistically deployed in humanitarian contexts, particularly where infrastructure, resources, governance capacity, and waste-management services are limited.

1.1 Context and aims of Bio4HUMAN Project and WP6

The main objective of the Bio4HUMAN project is to provide humanitarian aid operators and stakeholders with science-based information regarding the application potential, sustainable performance, and circularity of bio-based systems in humanitarian contexts. To achieve this, the project evaluates the feasibility and replication potential of innovative solutions to address SWM challenges in specific crisis-affected communities. Within this framework, Work Package 6 (WP6) acts as the critical bridge connecting technical Life Cycle Assessment (LCA) results with real-world field deployment. By conducting a Multi-factor SWOT analysis, WP6 evaluates the socio-economic factors, governance aspects, and legal compliance of these solutions alongside their technical performance, ensuring they are highly practical for non-EU humanitarian settings.

1.2 The scope of the SWOT Analysis

The Multi-factor SWOT analysis acts as a summary of the completed project activities, evaluating the capacity of bio-based products and systems to accelerate the transition towards a sustainable, regenerative, inclusive, just, and clean circular bioeconomy in humanitarian aid settings.

The analysis was carried out around **ten key areas (factors) of importance** determining the successful and long-term deployment of bio-based solutions in humanitarian action:

- 1) Endogenous potential of the bioeconomy sectors in Humanitarian Actions;
- 2) The technical challenges posed by diverse environmental, social and economic conditions being the background for humanitarian operations;

- 3) Waste management and waste-related environmental challenges in humanitarian aid contexts;
- 4) Sustainability and circularity performances of bio-based solutions and options suitable for humanitarian purposes;
- 5) The potential of bio-products and bio-technologies to improve the social benefits and the citizen benefits;
- 6) Economic, technological and scientific potential of the proposed solutions;
- 7) The aspect of social innovation;
- 8) Investment attractiveness and founding sources for the extended works on already existing solutions and on the development of new solutions;
- 9) Existing and expected regulatory environment;
- 10) Reputational and replication potential of the proposed solutions.

For each area, the analysis identifies the most significant strengths, weaknesses, opportunities, and threats. These findings are supplemented by proposed programme activities and actions to support implementation, scaling, and long-term integration of bio-based solutions into humanitarian SWM systems.

2. Methodology

The methodology for the Multi-criteria SWOT analysis is designed to analyse the data collected from the completed project activities in order to create a decision-making tool. The analysis evaluates the ability of bio-based products and systems to accelerate the transition towards a sustainable, inclusive, just, and clean circular bioeconomy when deployed in humanitarian aid settings. To determine the successful and long-term development of these solutions, the methodology systematically assesses ten key areas of importance. For each of these ten areas, the most significant issues are identified and mapped into the SWOT framework. Finally, the results for each area are directly supplemented with the necessary programme activities and concrete actions to be implemented.

2.1 Sources of data

To conduct the SWOT analysis (see Annex 1), data was systematically extracted and collected using a dedicated template (see Annex 2). The project partners responsible for delivering each report were directly engaged in filling out this template to provide accurate and comprehensive input for the analysis. In total, the following ten project deliverables were assessed¹:

- **D3.3 Humanitarian sector needs assessment report;**
- **D4.1 The list of bio-based solutions relevant to waste management in the humanitarian context;**

¹ All deliverables available here: <https://bio4human.eu/resources/>

- **D4.2 Gap Analysis Report;**
- **D4.3 Mid-term policy brief;**
- **D5.1 Data collection from partners: state-of-the-art and innovative solutions;**
- **D5.2 Hotspot analysis of the current and innovative solutions;**
- **D5.3 Identification of the best available innovative solutions based on environmental LCA;**
- **D6.1 Socio-economic and governance aspects analysis report;**
- **D6.2 Community Engagement Summary Report;**
- **D6.4 Final Policy Brief.**

2.2 Bio4HUMAN's SWOT template description

The Bio4HUMAN SWOT template was structured to systematically analyse ten specific areas of importance. For each area, the template provided a dedicated definition and a specific set of challenges to be addressed. The analysis identifies Strengths (S) and Opportunities (O) as internal and external drivers, proposing strengthening measures to fully exploit their potential for managing environmental challenges in humanitarian contexts. Conversely, Weaknesses (W) and Threats (T) are evaluated as barriers, with concrete actions proposed to offset their negative impacts on the development of sustainable humanitarian operations. To translate the SWOT findings into practical implementation steps, the template supplements the analysis with four targeted categories of programme activities: Supportive Actions (SA): Measures specifically designed to enhance identified Strengths; Development Drivers (DD): Actions aimed at maximising the potential of external Opportunities; Mitigating Actions (MA): Strategies developed to mitigate internal Weaknesses; Risk Management Activities (RMA): Actions focused on mitigating external Threats.

Each SWOT table was followed by a regional contextualisation section. This component adapts the SWOT recommendations specifically for humanitarian actions in South Sudan and the DRC across diverse settings, including large cities, municipalities, and displacement camps. This regional contextualisation systematically addresses three main dimensions: technological aspects (matching technologies to local capacities), operational aspects (adapting models to local realities), and resource availability (assessing local supply chains and skill bases to ensure sustainability).

Furthermore, if a specific topic or finding appeared and was mentioned in more than one deliverable, a special reference code (for example, D4.2 or D6.1) was added directly next to that point in the table. This method clearly shows when multiple reports support similar identified strengths, weaknesses, opportunities, or threats, highlighting the most well-supported findings. This helped guide the structuring of the Areas description, making clear which topics were the most critical and important to consider.

2.3 Definitions of areas of importance

To ensure a structured and precise SWOT analysis, each of the ten areas of importance was assigned a specific definition and a corresponding set of challenges to be addressed. These elements directly guided the data collection and framed the analysis within the project deliverables.

1. Endogenous potential of the bioeconomy sectors in Humanitarian Actions: This area assesses the internal capacity of local systems to implement bio-based solutions by leveraging locally available resources, workforce skills, and economic conditions within crisis-affected regions. The key challenges to address include ensuring sustainability and circularity, effectively utilising local resources, developing knowledge and skills, integrating with local economies, building resilience, and securing policy and institutional support.

2. The technical challenges posed by diverse environmental, social and economic conditions being the background for the humanitarian operations: This area evaluates the operational constraints caused by specific local ecosystems, infrastructure gaps, and socio-economic factors that define the feasibility of implementing bio-based solutions. The analysis addresses environmental challenges like infrastructure gaps and climate adaptation, social challenges like community acceptance and occupational safety, economic challenges such as resource limitations and supply chain disruptions, as well as unclear policy alignment.

3. Waste management and waste-related environmental challenges in humanitarian aid contexts: This area defines the current baseline of solid waste generation and management barriers in humanitarian operations, focusing on the resulting ecological footprint, health risks, and resource inefficiencies. The main challenges to address are the high volume of waste, the presence of hazardous waste, the severe lack of SWM infrastructure, air and soil pollution, and natural resource depletion.

4. Sustainability and circularity performance of bio-based solutions and options suitable for humanitarian purposes: This area measures the functional viability and lifecycle impact of specific bio-based solutions, contrasting their theoretical environmental value against actual performance. It addresses challenges related to logistics, material durability and performance, limited circularity, socio-economic barriers, and direct competition with conventional fossil-based products.

5. The potential of the bio-products and bio-technologies to improve the social benefits and the citizen benefits: This area examines the capacity of bio-based solutions to deliver tangible human-centric value, such as livelihood creation, health improvements, and strengthened community resilience. The specific challenges to overcome include ensuring community ownership, creating inclusive job

opportunities, improving health and sanitation, strengthening social cohesion, and changing public perceptions.

6. Economic, technological and scientific potential of the proposed solutions: This area analyses the market maturity, cost-efficiency, and technical readiness level (TRL) of bio-based solutions. It tackles economic challenges like high costs and market readiness, technological barriers regarding performance and end-of-life processing, and scientific challenges including context-specific LCA standards and knowledge gaps.

7. The aspect of social innovation: This area focuses on the collaborative processes and inclusive frameworks required to transition from top-down aid models to participatory, community-led circular bio-economy systems. The core challenges are establishing cross-sector collaboration, building inclusive value chains, securing community acceptance, developing socio-economic governance, and overcoming innovation silos.

8. Investment attractiveness and funding sources for the extended work on already existing solutions and on the development of new solutions: This area assesses the financial feasibility of bio-based solutions, identifying pathways to secure diverse funding streams for long-term scaling. The primary challenges include securing science-based validation and field feasibility to attract investment, obtaining public funding like EU grants, and establishing private or hybrid funding models to support micro-enterprises and green value chains.

9. Existing and expected regulatory environment: This area analyses the complex web of local, international, and humanitarian regulations governing waste and bio-based solutions. The critical challenges involve navigating fragmented and siloed regulatory frameworks, a lack of recognized certification and labelling standards, import restrictions, and inconsistent governance or enforcement by local authorities.

10. Reputational and replication potential of the proposed solutions: This area evaluates the ability of successful bio-based solutions to build trust among donors and stakeholders through transparent validation. It addresses reputational challenges such as quality assurance and providing fit-for-purpose evidence, alongside replication challenges caused by the extreme diversity of humanitarian contexts, regulatory fragmentation, and supply chain gaps.

2.4 Selection of critical SWOT items

The entire SWOT analysis is presented in the Integrated Table in Annex 1. However, to ensure the main report remains an actionable, highly focused decision-making tool for humanitarian operators, the narrative description of the ten areas of importance (Chapter 3) does not list or repeat every single point from the Annex 1.

Instead, a frequency-based selection methodology was applied to identify the most critical items.

During the data extraction phase, whenever a specific topic or finding was mentioned in one of the ten assessed project deliverables, a specific reference code (e.g., D4.2, D6.1) was added directly next to that point in the SWOT table. This coding system created a natural triangulation mechanism, clearly demonstrating when multiple independent reports supported the same identified Strength, Weakness, Opportunity, or Threat.

Therefore, the items included in the main narrative were selected based on their frequency of appearance: the more an item is referenced across different deliverables in the Annex 1 table, the more critical it is for the overall analysis. The narrative explicitly prioritizes these highly referenced findings, ensuring that the report highlights the most well-supported and urgent operational realities for humanitarian aid settings.

2.5 Methodological limitations

A primary methodological limitation of this multi-criteria SWOT analysis is its strict reliance on data extracted from previously finalized project deliverables. Because humanitarian crisis environments are highly dynamic, the operational and political realities in the target locations can shift rapidly, meaning that some information captured in the initial reports may become outdated by the time of publication. This took place in the DRC. While the baseline deliverables analyse operations within IDP camps and evaluate the formal Public-Private Partnerships or "synergies" handling municipal waste collection, the actual field situation has drastically evolved. Since January 2025, all IDP camps in the affected areas have been dismantled. Moreover, due to the ongoing AFC/M23 occupation, the local private waste collection businesses and synergies that previously collaborated with municipalities are now inhibited and non-operational, having been directly replaced by Rwandan waste collection companies.

3. The multi-criteria SWOT Analysis

3.1 Area 1 Endogenous potential of the bioeconomy sectors in humanitarian actions

Strengths (S) The most highly referenced strength is the abundant local workforce equipped with informal skills and a foundational community awareness of circularity driven by difficult conditions and very often poverty (S1.4). Following are the high availability and diversity of local biological resources, specifically organic feedstock (S1.2), and the strong compatibility of existing low-tech operational models (like

biogas and Black Soldier Fly) with infrastructure-poor regions (S1.3). Additional strengths include the presence of established local research and institutional hubs capable of driving knowledge transfer (S1.5), and the comprehensive diversity of available bio-based solutions (S1.1)

Weaknesses (W) The absolute most critical weakness is the shortage of technical expertise among local staff, compounded by widespread data scarcity and validation gaps preventing investment planning (W1.4). Other heavily referenced weaknesses include severe physical infrastructure deficits and logistical incapacity (W1.1), alongside inadequate internal capital and a lack of clear certification frameworks for local initiatives (W1.5). Further items include weak institutional governance and siloed cross-sector coordination (W1.2), as well as a limited industrial capacity making operations dependent on external supply chains (W1.3).

Opportunities (O) The primary opportunity is leveraging broad donor alignment and policy support for sustainability, such as DG ECHO's greening policy (O1.2). This is followed closely by the opportunity to stimulate local markets and create livelihoods by transforming waste into valuable outputs (O1.1). Additional opportunities include integrating the informal sector into formal systems for community empowerment (O1.3), capitalizing on favourable political goodwill and potential tax incentives from local authorities (O1.4), and deploying autonomous, off-grid technologies (O1.5).

Threats (T) The greatest threat across the deliverables is hostile local governance characterized by fragmented taxation, heavy administrative barriers, and market-blocking tactics from politically connected plastic importers (T1.1). Other major threats encompass extreme market distortion and unsustainable dependency on sporadic donor funding (T1.2), alongside severe physical, climatic, and security operational risks in hostile environments (T1.3). The sector is also threatened by socio-cultural resistance to waste handling (T1.4), and the critical risk of directly competing with regional food security if edible crops are used as feedstock (T1.5).

Supportive Actions (SA) The top supportive actions are maximizing the utilization of indigenous, non-food organic feedstocks to ensure circularity (SA1.1), and actively empowering trusted community channels and established women's cooperatives to operationalize production (SA1.4). Other key actions involve partnering with academic hubs for specialized skill development (SA1.3), scaling up decentralized low-tech production via local businesses (SA1.2), and channelling cash-based assistance toward local supply chains (SA1.5).

Development Drivers (DD) The most strongly supported development drivers are promoting decentralized waste-to-value market development to foster green entrepreneurship (DD1.1), and pursuing institutional advocacy to co-design pilot facilities with local authorities to secure targeted donor funding and tax exemptions (DD1.3). Additional drivers include investing in autonomous, mobile infrastructure (DD1.2) and integrating informal waste pickers into formalized systems (DD1.4).

Mitigating Actions (MA) The most crucial mitigating action is implementing a phased scale-up and infrastructural adaptation, starting with low-capital solutions to accommodate off-grid constraints (MA1.4). Other vital actions include deploying comprehensive capacity building through academic partnerships (MA1.1), generating empirical SWM data to track feasibility (MA1.3), relying on hybrid supply chain sourcing to buffer early-stage shortfalls (MA1.5), and establishing strategic cross-sector coordination (MA1.2).

Risk Management Activities (RMA) The highest-referenced risk management activity is forming strategic advocacy coalitions to navigate fragmented taxation and secure pre-approvals against rigid international procurement barriers (RMA1.2). Further activities include developing modular resilience against physical, climatic, and security disruptions (RMA1.1), deploying targeted socio-cultural integration to address waste taboos (RMA1.3), managing supply chain contingencies through phased scaling (RMA1.4), and mandating food security impact assessments before using crop feedstocks (RMA1.5)

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, bioeconomy interventions are primarily viable in large urban centres (like Kinshasa and Bukavu), as operations in formal displacement camps in the eastern regions are severely disrupted by the M23 occupation (D6.1, D6.2). This reality clearly illustrates the threat of political instability and security risks. Despite this, the DRC possesses a strong endogenous capacity. There are established institutional research hubs (like INERA and AALI) and functional, youth-led local enterprises such as *Briquette du Kivu*. These initiatives validate the identified strengths regarding the durability of local initiatives and the presence of existing bio-based practices. Furthermore, the region has abundant biological feedstock, with organic matter making up 65% (D6.1) of municipal waste in Kinshasa, representing a major strength in the utilisation of local resources. However, the local system is heavily constrained. About 90% (D6.1) of waste collection in the eastern provinces is managed by the informal sector and private cooperatives due to severe municipal deficits. This reliance on the informal sector is compounded by poor logistical equipment, such as Bukavu relying on a single collection truck. The transition to formal circularity is further bottlenecked by a severe shortage of technical expertise and the absence of industrial infrastructure. While provincial authorities show strong political goodwill to offer land for pilots, local bio-entrepreneurs face critical threats from an excessive, fragmented tax system (D6.1) and the market-blocking power of politically connected plastic importers.

South Sudan

The operating environment in South Sudan, spanning from Juba to semi-urban municipalities and camps, is defined by an almost total absence of formal SWM infrastructure. Juba only collects about 7.1% of its waste, leading to illegal dumping

(D3.3). Because comprehensive national environmental frameworks, specifically the pending National Environment Bill, are still under review by the Ministry of Justice, which presents a future opportunity to formally incorporate circular economy approaches, humanitarian actors must rely on international and donor standards (like Sphere, the Core Humanitarian Standard, and ECHO MERS) to function as their de facto regulatory and technical baseline. Operational capacity is highly dependent on external donor projects (such as those by UN-Habitat and JICA) (D3.3, D6.1). These pilots frequently struggle to survive once external funding ends, perfectly demonstrating the critical weakness of unsustainable funding. At the same time, the country also has examples of local commercial bio-based models that demonstrate endogenous potential, including a commercial bio-digester business and a women's cooperative operating a BSF unit (D6.1, D6.2), demonstrating that bio-based operations can survive beyond short-term donor funding cycles. Just as in the DRC, South Sudan benefits from strong political goodwill, with local authorities actively willing to provide physical land for installations. However, local production faces extreme structural barriers. The national tax framework is a major weakness, actively disadvantaging local suppliers because international humanitarian imports are tax-exempt while local bio-based producers must pay full taxes (D6.1). Additionally, local circular economy efforts are restricted by strict, unharmonized UN procurement protocols, which structurally favour established international imports over local green innovations.

3.2 Area 2 The technical challenges posed by diverse environmental, social and economic conditions

Strengths (S) The most critical strength is the strong baseline of community awareness, self-organization capabilities, and established grassroots networks, such as women's cooperatives (S2.2). Following this are the applicability of low-tech solutions like biogas and BSF systems, which leverage a continuous local organic feedstock (S2.1), and the demonstrated technical feasibility of bio-based alternatives in controlled scenarios (S2.3). Additional strengths include established humanitarian institutional frameworks providing technical testing capacities and zero-carbon procurement policies (S2.4), as well as demonstrable political will from local authorities ready to host pilot installations (S2.5).

Weaknesses (W) The most severe weaknesses are the critical physical infrastructure deficits, specifically the complete lack of sanitary landfills and underdeveloped road networks (W2.1), alongside the high material sensitivity of bio-products to harsh ambient field conditions like humidity and heat (W2.6). Other significant barriers include deep-rooted socio-cultural resistance and entrenched habits of reusing plastics (W2.2), chronic humanitarian institutional and funding constraints (W2.3), and a severe shortage of technical expertise among local staff (W2.4). Finally, the high risk of feedstock contamination due to the lack of source segregation remains a vital barrier (W2.5).

Opportunities (O) The greatest opportunity is bypassing infrastructure gaps by deploying tailored technological adaptations, such as autonomous containerized units and niche compostable medical bottles (O2.1). This is followed closely by the opportunity to create green jobs and stimulate entrepreneurial engagement to overcome behavioural barriers (O2.2), and a highly favourable enabling environment driven by unified institutional, political, and donor alignment regarding climate commitments (O2.3). Further opportunities involve the adoption of digital monitoring tools to resolve data gaps (O2.4) and the integration of upstream green procurement criteria to prevent waste generation at the source (O2.5).

Threats (T) The most critical threat is the hostile physical environment, encompassing harsh climates, active conflicts, and logistical disruptions that endanger staff and product integrity (T2.1). Another major threat comes from regulatory gaps and rigid, unharmonized UN procurement standards that actively restrict local supply chain integration (T2.2). Additional threats encompass deep-seated socio-cultural taboos and health misconceptions regarding waste handling (T2.3), fierce market competition from cheaper conventional alternatives (T2.4), and unresolved scientific variables like insecticide retention in netting (T2.5).

Supportive Actions (SA) The primary supportive actions involve leveraging community engagement through trusted local leaders to conduct hands-on demonstrations that build trust for source segregation (SA2.3), and utilizing internal humanitarian capacities for material testing and climatic adaptation (SA2.4). Other key actions include scaling up low-tech circular systems (SA2.1), capitalizing on institutional alignment to justify technical procurement in fragile environments (SA2.5), and formalizing local supply chains by integrating business committees (SA2.2).

Development Drivers (DD) The most strongly supported development drivers are empowering communities through behavioural education and the establishment of social cooperatives to formalize green jobs (DD2.2), and bundling bio-based product introductions with mandatory parallel investments in localized waste segregation and focused R&D (DD2.4). Additional drivers include embedding bio-based validation directly into humanitarian procurement standards (DD2.3), and deploying decentralized, data-driven technologies like autonomous units equipped with IoT sensors (DD2.1).

Mitigating Actions (MA) The most crucial mitigating action is targeting initial deployments toward highly controlled institutional environments, such as health facilities, to bypass municipal infrastructure deficits systematically (MA2.4). This is followed by selecting simple, energy self-sufficient technologies like biogas to counter grid deficits (MA2.1). Further necessary actions include providing intensive technical capacity building (MA2.2), establishing manual pre-sorting interventions to prevent feedstock contamination (MA2.3), and using phased substitution to manage technical uncertainty safely (MA2.5).

Risk Management Activities (RMA) The foremost risk management activities are proactive institutional standard-setting and coordination with cluster technical working groups to navigate regulatory bottlenecks (RMA2.2), and diversifying revenue streams while maintaining fallback conventional options as transition safeguards (RMA2.3). Other essential activities involve mandating rigorous pre-deployment environmental screenings and applied R&D (RMA2.4), developing modular and mobile system architectures for rapid relocation during sudden conflicts (RMA2.1), and deploying targeted socio-cultural sensitization strategies to address specific taboos directly (RMA2.5).

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, humanitarian operations face severe infrastructural and security constraints across diverse environments. The M23-related insecurity and territorial control dynamics in eastern provinces severely constrain formal camp operations and disrupt licensing systems (D6.1, D6.2). Consequently, operational deployments must increasingly target stable urban municipalities and highly controlled institutional settings, such as health facilities, to bypass municipal infrastructure deficits. Technologically, the Democratic Republic of Congo entirely lacks industrial composting infrastructure and specific legislation for bio-waste solutions like biogas or BSF (D6.1). The adoption of advanced technologies is structurally hindered by poor electricity access, a shortage of technical expertise, and a lack of automated waste tracking systems. Local initiatives like Briquette du Kivu operate successfully, but they remain small-scale, artisanal, and lack mechanization (D6.1). Despite these barriers, the DRC holds a major technical strength: organic matter comprises up to 65% of municipal waste in Kinshasa, offering abundant local feedstock. However, the current technical capacity to separate waste is critically lacking. Therefore, to harness this resource, it is mandatory to bundle technology deployments with parallel investments in localized source-segregation infrastructure to prevent feedstock contamination

South Sudan

The operating environment is defined by extreme infrastructure gaps and an almost total reliance on informal or donor-supported systems. In Juba, only around 7.1% of municipal waste is collected, contributing to widespread illegal dumping and burning (D3.3). Operational logistics are severely constrained by malfunctioning equipment and poor road networks, which frequently cause supply chain disruptions and product integrity failures during transport. Technologically, formal SWM is absent, and national legislation remains in draft form. As a result, international humanitarian standards, such as Sphere and the Core Humanitarian Standard, provide a strong baseline, functioning as the de facto technological and regulatory rules for operations (D6.1, D6.4). The introduction of localised technical solutions is further constrained by reliance on rigid international UN procurement standards. Furthermore, temporary donor-led pilot projects consistently fail to

achieve long-term technical sustainability due to high costs and a severe lack of local technical expertise. Despite these intense technical and operational barriers, the sector benefits from strong political goodwill; municipal authorities, such as the Juba City Council, are actively willing to provide physical land for decentralized technical installations (D6.1, D6.4). However, the Ministry of Environment has explicitly noted that source segregation is virtually non-existent, and this structural deficit must be resolved before deploying any bio-based systems that require pure feedstock. Camp-specific operational conditions also shape product-level feasibility. In displacement settings in South Sudan, soap and water scarcity create health risks for reusable hygiene products such as washable sanitary pads, which can make biodegradable single-use alternatives more appropriate than reusables in camp contexts (D6.2). This illustrates that "fit-for-purpose" assessments need to factor in displacement context as a first-order variable, not only climate and infrastructure. Overall, the findings indicate that bio-based solutions in Area 2 should not be deployed as stand-alone technical substitutions. Their feasibility depends on controlled operating environments, localised source segregation, climate-adapted material specifications, technical training, and alignment with humanitarian procurement and coordination systems.

3.3 Area 3 Waste management and waste-related environmental challenges

Strengths (S) The most critical strength is the presence of established humanitarian frameworks, such as Sphere and the Core Humanitarian Standard, alongside operational mechanisms like carbon accounting that set normative waste treatment requirements (S3.4). Following closely are the predictable waste streams offering a continuous supply of local organic feedstock (S3.1), and a strong baseline of community awareness regarding resource recovery, bolstered by growing youth engagement (S3.2). Finally, the existence of proven local bio-based models provides a tangible foundation for scaling waste-to-resource operations (S3.3).

Weaknesses (W) The most critical weakness is the severe inadequacy of waste management infrastructure, specifically the total absence of sanitary landfills and the resulting systemic reliance on open dumps or uncontrolled incineration (W3.1). Another major weakness is the profound lack of SWM data and the highly dispersed nature of waste generation across rural settings, which complicates systematic collection (W3.3). Other significant barriers include the systemic de-prioritization of waste management in favour of reactive, speed-focused humanitarian programming (W3.2), and the high risk of feedstock contamination caused by a lack of source segregation at the generation point (W3.4).

Opportunities (O) The greatest opportunity is the valorisation of organic waste, converting the dominant organic fraction of humanitarian waste into valuable resources like animal feed, fertilizer, and bio-energy (O3.1). Following this is the highly favourable enabling environment driven by unified institutional, political, and donor alignment regarding climate commitments and land provision (O3.5). Additional opportunities include the market availability of a wide spectrum of

functional bio-based technologies to replace fossil-based materials (O3.2), the integration of green procurement sustainability criteria to prevent waste generation upstream (O3.3), and bypassing permanent infrastructure gaps by deploying autonomous, mobile waste treatment units (O3.6). Integrating existing informal waste pickers into formal systems also presents a strategic opportunity (O3.4).

Threats (T) The most heavily referenced threat is that persistent uncontrolled dumping and open burning create severe public health risks and structurally block the intended environmental benefits of introducing biodegradable materials (T3.3). Other major threats include the hostile physical environment and active security constraints that disrupt supply chains and endanger staff (T3.1), along with regulatory gaps and blurred accountability between humanitarian and host community waste streams (T3.2). The high ecological footprint stemming from a structural dependence on conventional, non-degradable aid materials poses another significant threat (T3.4), as do deeply embedded socio-cultural taboos regarding the handling of specific waste streams like human excreta (T3.5).

Supportive Actions (SA) The most critical supportive action is systematically embedding environmental compliance into humanitarian funding proposals, leveraging strict donor requirements to secure dedicated financial streams for bio-waste infrastructure (SA3.4). Other heavily supported actions include targeting controlled institutional environments to secure a reliable, high-quality supply of organic feedstock for pilots (SA3.1), prioritizing upstream waste prevention and extended product lifespans over simple end-of-life compostability claims (SA3.3), and mobilizing grassroots networks to integrate the informal sector into structured recovery systems (SA3.2).

Development Drivers (DD) The primary development driver is implementing stringent upstream green procurement criteria and eco-design principles to reduce replacement frequency and prevent waste generation at the source (DD3.3). Other top drivers include financing mobile technology deployments via green funding to bypass infrastructure gaps (DD3.1), formalizing local capacity to enable decentralized waste valorisation (DD3.2), and co-designing localized municipal governance by-laws directly with willing authorities (DD3.4). Establishing standardized data tracking metrics via humanitarian WASH clusters is also a key driver (DD3.5).

Mitigating Actions (MA) The most crucial mitigating actions are bundling the introduction of bio-based products with mandatory, parallel investments in integrated source segregation and culturally tailored community education (MA3.1), alongside targeting decentralized and institutional deployments to bypass severe municipal infrastructure deficits systematically (MA3.2). Furthermore, transitioning from reactive management to data-driven solid waste management planning by establishing baseline monitoring systems is vital (MA3.3).

Risk Management Activities (RMA) The most important risk management activities involve establishing rigid internal health and safety screenings to ensure "do no harm" compliance in the absence of government enforcement (RMA3.2), and

enforcing strict end-of-life tracking while proactively communicating realistic impact assumptions to decision-makers to prevent greenwashing (RMA3.3). Additional activities include designing weather-resilient and mobile infrastructure for rapid relocation during crises (RMA3.1), establishing joint humanitarian-municipal governance committees to clarify waste accountability (RMA3.4), and executing targeted socio-cultural sensitization to address deep-seated taboos (RMA3.5).

The regional context

Democratic Republic of Congo (DRC)

Waste management interventions in the DRC span large cities, provincial municipalities, and displacement camps like Bulengo. The operational baseline is defined by a severe infrastructure deficit, specifically the critical absence of sanitary landfills and industrial composting facilities (D5.1). Formal municipal collection is highly constrained; for instance, cities like Bukavu evacuate less than 10% of generated waste to formal landfills (D6.3). Consequently, the informal sector and community cooperatives are forced to handle approximately 90% of waste collection (D6.1). While the country benefits from an abundant continuous supply of organic feedstock, representing up to 65% of municipal solid waste in Kinshasa (D6.1), harnessing this resource is fundamentally blocked by a lack of source segregation at the generation point (D3.3). Therefore, implementing strict source segregation protocols and parallel investments in decentralised composting infrastructure is strictly necessary before scaling any bio-based solutions (D6.3). Due to reactive management and a reliance on open dumps or uncontrolled incineration that causes secondary pollution, established humanitarian standards like Sphere and DG ECHO MERS act as the vital *de facto* environmental frameworks (D6.1). Furthermore, in IDP camps, the blurring of waste boundaries between humanitarian operations and host communities creates a major tracking and accountability threat.

South Sudan

Operations face similar structural barriers across urban centres like Juba, semi-urban municipalities, and highly congested camps. Formal SWM and end-of-life processing systems are entirely absent. Juba collects only 7.1% of its municipal waste, relying mostly on the Juba Controlled Dumping Site. This reality leads to widespread uncontrolled dumping and open burning, which poses a massive threat to the potential benefits of biodegradable materials. However, because end-of-life requirements vary significantly across bio-based solutions, this infrastructure gap does not eliminate all options (D6.4). While bioplastic-based products require industrial composting infrastructure to deliver environmental advantages, other variants, such as paper-based items, biodegradable sanitary pads, mosquito nets, and mycelium packaging, can be managed without industrial infrastructure through existing latrines, health facility waste pits, or basic agricultural composting (D6.4). Operational logistics are heavily constrained by malfunctioning transport

equipment. Similar to the DRC, the absence of SWM data tracking makes scientific monitoring and strategic planning nearly impossible. Baseline resource recovery relies almost entirely on informal waste pickers, and source segregation is virtually non-existent. The Ministry of Environment has explicitly noted this as a foundational barrier that must be resolved prior to deploying bio-based technologies. Without formal domestic regulations, international humanitarian frameworks like the Sphere standards and the Core Humanitarian Standard (CHS) provide the only normative baseline for regulating waste treatment

3.4 Area 4 Sustainability and circularity performances of bio-based solutions

Strengths (S) The most critical strengths are the broad availability and market readiness of diverse bio-based solutions capable of replacing fossil-based plastics (S4.1), and the verified technical, economic, and environmental performance of bio-based materials for short-turnover items (S4.4). Following these is the operational adaptability and dual functionality of localized systems, such as small-scale biogas digesters and BSF units, which solve waste disposal while simultaneously producing valuable resources like energy and fertilizer (S4.2). Another key strength is the collaborative integration of humanitarian organizations and durable local initiatives, ensuring projects are more sustainable than isolated pilots (S4.5). Finally, established standardized humanitarian logistics and procurement pathways provide a strong operational foundation for systematically introducing greener specifications (S4.3).

Weaknesses (W) The absolute most critical weakness is the severe physical vulnerability and transport efficacy failures of bio-based materials under harsh field conditions, such as extreme heat and humidity, which degrade products rapidly and disrupt bulk procurement (W4.1). Another major barrier involves operational contamination, safety, and fraud vulnerabilities, including the continuous contamination of organic feedstock, food safety concerns regarding biological byproducts, and severe product tampering risks (W4.5). This is followed by systemic procurement and economic barriers, as humanitarian supply chains prioritize rapid, cost-efficient delivery, creating resistance to bio-based solutions perceived as too complex and expensive (W4.2). Additional weaknesses include critical deficits in industrial mechanization and technical expertise required to process massive waste volumes (W4.4), and the fact that certain bio-based solutions present negative environmental trade-offs and high resource intensity compared to conventional counterparts (W4.3).

Opportunities (O) The top opportunity is the substitution of single-use plastics with advanced bio-based alternatives that feature low toxicity and high compostability (O4.1). This is closely followed by leveraging local sourcing and non-food feedstocks to create green jobs and sustain local bioplastics production without threatening regional food security (O4.3). Further opportunities include establishing supply chain

circularity through eco-design and reverse logistics (O4.2), and capitalizing on institutional demand by targeting controlled environments, like health facilities, that guarantee proper end-of-life management for biodegradable materials (O4.4).

Threats (T) The primary threat is the infrastructure mismatch and the severe risk of greenwashing. Deploying bio-based solutions without local industrial composting infrastructure renders their circularity claims purely theoretical and risks leaving products unregulated at the end of their life (T4.2). Other major threats include systemic procurement barriers paired with fierce local market competition from cheaper conventional plastics (T4.1), deep-rooted socio-cultural taboos and conflicting cultural habits of retaining and reusing conventional plastic packaging for multiple years (T4.3), and the potential for severe ecological harm and food security competition if bio-based production relies heavily on edible staple crops (T4.4). Additionally, climatic disruptions and complex local regulatory barriers can severely delay or block the deployment of new bio-technologies (T4.5).

Supportive Actions (SA) The most critical supportive actions are utilizing scientific validation and hazard screening through LCA and SSBD principles to verify environmental claims before procurement (SA4.1), and explicitly targeting institutional deployments, like hospitals, where shorter shelf-life requirements naturally align with bio-based capacities and controlled end-of-life treatment is possible (SA4.4). Another key action is ensuring agricultural integration and feedstock security by capitalizing on existing networks and non-food resources (SA4.2). Building local partnerships to operate decentralized, low-tech deployments also ensures long-term sustainability beyond the humanitarian project lifecycle (SA4.3).

Development Drivers (DD) The top development drivers include shifting toward localized sourcing and non-food manufacturing to optimize circularity and create green jobs (DD4.2), and establishing standardized technical testing and applied R&D protocols against pharmaceutical storage and safety standards (DD4.3). This is followed by promoting supply chain circularity via eco-design principles combined with the establishment of reverse logistics systems (DD4.1). Further drivers are executing economic justification through LCC tools (DD4.4), and forming cross-sector coordination groups to streamline circular economy investments (DD4.5).

Mitigating Actions (MA) The greatest mitigating action is managing physical vulnerabilities by restricting bulk procurement strategies for shelf-life sensitive items and developing localized production to avoid material degradation from harsh climates (MA4.2). This is followed by technology selection strictly on context-driven capacity assessments and socio-cultural alignment rather than relying on generic environmental claims (MA4.1). Other vital actions include enforcing sustainable sourcing to strengthen farm resilience (MA4.5), and utilizing alternative, anti-fraud packaging designs to neutralize product tampering risks (MA4.6). Implementing technical capacity building to prevent feedstock contamination (MA4.3) and upgrading manual techniques to industrial operational efficiency (MA4.4) are also necessary to scale deployments safely.

Risk Management Activities (RMA) The most heavily prioritized risk management activity is contextualizing product designs to align with local reuse practices and strictly coupling the introduction of compostable products with mandatory community education to mitigate end-of-life behavioural risks (RMA4.2). Other critical activities include mandating social and environmental LCAs to ensure ecological safeguarding and prevent food security competition (RMA4.1), and conducting continuous field monitoring to verify that theoretical resource efficiency matches actual field realities (RMA4.4). Further activities involve proactive regulatory navigation paired with stringent toxicological screening using Safety Data Sheets (RMA4.5), and proactively demonstrating the long-term economic justification of bio-based solutions to counter the prioritization of upfront logistics costs (RMA4.3).

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, local habits strongly influence the viability of bio-based products. In rural areas, a deeply embedded cultural practice of reusing conventional plastic bottles and bags for several years directly conflicts with the design of single-use biodegradable alternatives (D6.2). However, institutional settings such as hospitals and health centres present a major opportunity, offering highly viable, controlled environments capable of supporting proper, closed-loop biodegradation. Technologically, the complete absence of industrial composting infrastructure restricts the actual circularity of bio-based materials, keeping existing local operations artisanal. Furthermore, the harsh local climate exposes a critical material weakness: high ambient humidity causes fungal regrowth on mycelium packaging, while temperatures of 60–65°C under direct sunlight cause severe deformation in PLA bottles (D6.2). Despite these barriers, LCC assessments confirm a significant strength: substituting conventional packaging with bio-based alternatives generally causes only marginal increases in total kit costs. To ensure true sustainability, SSbD principles demand the mitigating action of evaluating technology selection against actual local capacities, rather than generic environmental claims. Finally, while there is high feedstock availability, we must utilize non-food agricultural waste to ensure circularity, as using staple crops like maize poses a severe threat to regional food security (D5.3, D6.2).

South Sudan

In South Sudan, operations span urban centres and highly congested displacement camps where extreme infrastructure gaps dictate the baseline. The total absence of formal SWM and industrial composting infrastructure categorically negates the theoretical circularity benefits of bio-based packaging. Without proper end-of-life processing, these materials function identically to conventional plastic litter. The physical environment and supply chains present severe barriers. Extreme ambient temperatures frequently exceeding 30°C directly degrade temperature-sensitive

bio-based materials, neutralizing bulk procurement models. Operations also face critical physical durability failures, such as biodegradable food packaging breaking during rough transport. Additionally, rigid UN procurement standards and strict global health protocols act as major structural threats by demanding extended shelf lives of 2-4 years that bio-based options cannot consistently guarantee. Despite an unfavourable tax framework that discourages local circularity, LCC scenario testing confirms that substituting conventional packaging with bio-based alternatives results in only marginal increases (typically less than 10%) in total humanitarian kit costs, because packaging represents a small share of overall kit expenditure (D6.4). This creates a clear opportunity for donors and humanitarian organisations to integrate sustainability criteria into procurement without significantly increasing budgets, particularly when leveraged through institutional sustainability frameworks (D6.4). However, to achieve genuine circularity and avoid creating new environmental litter streams, the introduction of any compostable products must be mandatorily coupled with a critical risk management activity: parallel investments in local waste collection infrastructure and community education.

3.5 Area 5 The potential of bio-products and bio-technologies to improve social benefits

Strengths (S) The most critical strength is the direct enhancement of community protection and health, such as reducing GBV risks by eliminating firewood collection needs and lowering exposure to toxic materials through bio-based hygiene products and biogas (S5.4). Following this is the significant potential for livelihood creation and women's economic empowerment through local informal recycling and female-led agricultural cooperatives (S5.3). Additional strengths include the proven regional applicability of low-tech, socially accepted models like BSF systems and briquette production (S5.1), supported by the communities' strong baseline capacity for self-organization and participatory governance (S5.2).

Weaknesses (W) The most critical weakness is the deep-rooted socio-cultural resistance, specifically taboos regarding waste handling and a pervasive cultural perception that humanitarian assistance must be strictly free, which paralyzes the scalability of community-owned solutions requiring continuous labour or cost-sharing (W5.1). This is followed by critical gaps in technical, administrative, and financial capacity among local staff (W5.2), and the economic exclusion caused by the high upfront costs of bio-based solutions, which limits accessibility for impoverished households (W5.3). Further barriers include the documented governance failures of purely community-based ownership models lacking individual accountability (W5.4), baseline health risks that must be carefully managed to prevent shifting the pollution burden (W5.6), and deficits in transparency and occupational safety for workers operating bio-based facilities (W5.5).

Opportunities (O) The top opportunity is the formalization of the informal sector and capacity building, which can permanently transition vulnerable populations from passive aid consumers to active, self-sufficient producers while creating green jobs (O5.1). This is closely followed by the opportunity to mobilize grassroots education, leveraging enthusiastic youth and traditional networks to permanently shift the public perception of waste into a valuable resource (O5.2). Another major opportunity is the multi-sectoral integration of bio-based deployments to simultaneously improve public health, provide energy independence, and address WASH and agricultural needs (O5.3). Finally, utilizing cash-based assistance alongside socially responsible providers offers a strategic pathway to stimulate local economic development (O5.4).

Threats (T) The primary threats are deep-seated cultural taboos and societal misperceptions (like fears of disease transmission) that can lead to the outright behavioural rejection of bio-based solutions (T5.1), and the risk of causing unintended social harm, such as displacing existing informal waste workers or exacerbating community inequalities if deployments are poorly aligned with local dynamics (T5.2). Another critical threat is chronic humanitarian underfunding, which enforces short-term horizons and leaves communities dependent on external experts once projects end (T5.4). The sector also faces threats from security volatility and weak institutional governance in conflict zones that endanger local workers (T5.3), as well as negative health impacts resulting from the technical mismanagement of bio-systems (T5.5).

Supportive Actions (SA) The most heavily prioritized supportive actions involve empowering existing local structures, such as informal recycling networks and women-led cooperatives, to independently manage decentralized production (SA5.1), and systematically anchoring deployments to their tangible health and protection co-benefits, e.g. respiratory disease reduction, to drive rapid community acceptance (SA5.2). Other key actions include integrating the community directly into participatory co-design processes to ensure continuous dialogue (SA5.3), and organizing inclusive awareness campaigns that target all household decision-makers (SA5.4).

Development Drivers (DD) The top development drivers are deploying formalized vocational capacity building specifically targeted at youth and waste pickers to professionalize the informal sector (DD5.1), and systematically favouring socially responsible solution providers by integrating social performance disclosure requirements directly into donor procurement criteria (DD5.4). Additional drivers include co-designing accountable, localized business models that prioritize household or commercial service provision over pure communal ownership (DD5.2), launching multi-channel educational campaigns to recruit vulnerable populations for green jobs (DD5.3), and integrating household-level health and energy deployments to eliminate baseline health risks (DD5.5).

Mitigating Actions (MA) The most crucial mitigating actions are deploying intensive, culturally tailored community education and hands-on demonstrations to dismantle deep-seated taboos and teach proper product usage (MA5.1), and privileging goods

made with known local resources while utilizing data-driven beneficiary feedback loops to ensure cultural acceptance (MA5.5). Further necessary actions include conducting mandatory pre-deployment socio-economic screenings and "Do No Harm" transition plans (MA5.2), implementing monitored pilot testing to quickly resolve technical mismanagement before scaling (MA5.3), and gradually transitioning operational models toward subsidized, commercial-based ownership to ensure accountability (MA5.4).

Risk Management Activities (RMA) The foremost risk management activities are partnering with local academic institutions to mandate knowledge transfer and technical curricula development, preventing long-term dependency on external experts (RMA5.1), and forming strategic alliances with traditional communication channels, such as village chiefs and religious leaders, to navigate sensitive implementations and secure social legitimacy (RMA5.3). Additionally, designing decentralized, low-visibility infrastructure equipped with strict safety protocols is required to protect community management teams operating in conflict zones (RMA5.2).

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, interventions operate across diverse settings ranging from stable municipalities to conflict-affected zones characterized by systemic social protection gaps (D6.1). Despite these challenges, tangible social benefits are realised through youth-led enterprises, such as Briquette du Kivu, which generate green jobs, and small camp-based businesses independently repurposing plastic waste (D4.2). However, the social adoption of novel bio-based technologies is heavily constrained by extreme poverty, limited local technical capacity, and reliance on manual processes. To guarantee safe operation and dismantle behavioural resistance, introducing new technical infrastructure mandates parallel investments in community education and hands-on demonstrations. A pervasive cultural perception that humanitarian assistance must be strictly free acts as a major behavioural barrier, fundamentally hindering the scalability of community-owned solutions that require continuous labour, maintenance, or cost-sharing (D6.1). Furthermore, while aid delivery improves food security, it carries the risk of exacerbating community dependency and creating security vulnerabilities by potentially attracting armed actors. Conversely, participatory governance remains a validated operational strength, demonstrated by community-led WASH programmes (D6.1). While humanitarian organizations indirectly stimulate local economic development through cash-based assistance, chronic underfunding structurally restricts the capacity to invest in long-term, environmentally responsible community solutions.

South Sudan

In South Sudan, operations occur within a context of fragile institutional governance and extremely low political stability. Social empowerment initiatives have primarily materialized through short-term donor-supported pilot projects that target vulnerable demographic groups by formally employing local women and youth in waste segregation to mitigate severe health risks associated with critically low municipal collection rates. However, community engagement reveals a complex three-role distinction for women regarding these interventions: they are simultaneously the primary beneficiaries, the first point of contact or handlers of the products, and the primary workload bearers (D6.2). Because of this, introducing new bio-based systems risks adding to women's unpaid labour—such as new demands for waste sorting, washing, or end-of-life management—rather than solely reducing their workload (D6.2). Moreover, adoption faces distinct cultural and ethical barriers. Culturally, there is a documented reluctance to use human waste as feedstock for biogas, which requires substantial awareness and education before communities will accept using it for cooking purposes (D6.2). Ethically, the humanitarian sector itself wrestles with funding trade-offs; as the Health Cluster representative framed it, investing in environmental solutions faces a direct ethical tension because in case of emergency, famine, cholera there are other problems than the environment (D6.2). The localized production and operation of bio-based technologies also face severe occupational safety risks due to poor general working conditions and weak national labour protections. Transitioning to community-led circular models is further bottlenecked by a critical shortage of local technical personnel, which continuously hinders long-term system resilience. Operations remain fundamentally reactive and heavily donor-dependent. Initiatives frequently collapse into dependency once external funding ceases, which actively undermines sustained community ownership. While feedback and grievance mechanisms, such as Post-Distribution Monitoring (PDM), are established to capture beneficiary dialogue, their practical effectiveness varies. Finally, the potential to create local livelihoods is critically undermined by unfavourable tax frameworks, and chronic underfunding strictly restricts the operational horizons needed to finance or validate innovative bio-based materials supporting long-term community resilience.

3.6 Area 6 Economic, technological and scientific potential of the proposed solutions

Strengths (S) The most critical strengths are the broad availability, prototyping, and piloting of diverse bio-based solutions at varying TRLs (S6.1), alongside the robust technical functionality and material performance of bio-based products, which are comparable to or exceed fossil-based alternatives (S6.3). Following these are the scientific validation of circularity and environmental safety through LCI and SSbD frameworks (S6.4), and the validated economic feasibility demonstrating minimal impacts on overall humanitarian kit budgets (S6.5). Finally, there is the operational adaptability provided by low-tech and mobile deployments (S6.2).

Weaknesses (W) The absolute most critical weakness is the elevated upfront cost and lack of competitive economic models, conflicting with strict humanitarian budgets that prioritize speed and low cost (W6.1). This is followed closely by systemic data scarcity, a lack of scientific monitoring, and the absence of geographical granularity in global environmental databases (W6.2). Further weaknesses include critical deficits in technical expertise and the specialized industrial machinery required for advanced local manufacturing (W6.3), as well as the high risk of feedstock contamination and limited availability of pure bio-based materials (W6.4).

Opportunities (O) The top opportunity is establishing localized manufacturing and decentralized mini-factories to utilize local labour, reduce unit prices, and substitute imports (O6.2). This is followed by integrating upstream green procurement criteria to achieve economies of scale (O6.3), and harnessing technological innovation through digital supply chain monitoring using IoT sensors and drones (O6.4). Another notable opportunity is the scientific validation of economic and environmental feasibility using standardized lifecycle assessment tools (O6.1).

Threats (T) The primary threat is the reliance on sporadic, short-term funding and operational horizons, which actively prevents holistic assessments and causes technologies to collapse post-project (T6.1). Other major threats include hostile physical environments and active security volatility that can destroy established infrastructure (T6.2), as well as institutional regulatory barriers, unharmonized UN procurement standards, and structural taxation frameworks that penalize domestic suppliers (T6.3). Additional threats involve severe market competition paired with high price sensitivity (T6.4), and the critical operational mismatch between the requirements of advanced bio-materials and the total absence of specialized end-of-life local infrastructure (T6.5).

Supportive Actions (SA) The most highly prioritized supportive actions involve mainstreaming green procurement integration and using LCC scenario tools to justify economic viability (SA6.1), alongside targeting deployments of low-tech, mobile units and focusing initial market-ready pilots on controlled institutional settings (SA6.3). Another key action is leveraging local research hubs for scientific validation, R&D on end-of-life scenarios, and hazard screening (SA6.2).

Development Drivers (DD) The top development drivers include implementing upstream green procurement to stimulate structured demand and executing local cost-benefit analyses to justify localized economies of scale (DD6.3). This is followed by institutionalizing scientific validation via LCA and SSbD frameworks into procurement guidelines (DD6.1), and deploying digital data tracking tools alongside the development of open-access material databases tailored to humanitarian operations (DD6.2).

Mitigating Actions (MA) The primary mitigating action is executing a phased economic integration, starting with cost-neutral substitutions and gradually transitioning into hybrid business models to build economies of scale (MA6.1). Other

vital actions involve coordinating localized R&D and mandating empirical field testing prior to procurement (MA6.2), and enforcing strict operational safety protocols such as pre-sorting to prevent feedstock contamination (MA6.3). Implementing accessible digital monitoring with simplified system interfaces is also necessary to compensate for technical expertise shortages (MA6.4).

Risk Management Activities (RMA) The foremost risk management activities are forming strategic advocacy coalitions to negotiate tax parity, clarify customs procedures, and align prototypes with global health standards (RMA6.1). Further essential activities include proactively avoiding cost volatility and providing economic justification via lifecycle data (RMA6.2), maintaining strategic spare parts buffers and restricting capital deployments to stable environments to protect physical assets (RMA6.4), and conducting rigorous contextual trade-off analyses combined with mandatory parallel infrastructure bundling before scaling (RMA6.3).

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, operational settings span from stable urban municipalities to conflict-affected zones. In the eastern provinces, the active M23 occupation severely disrupts licensing and compliance monitoring, clearly illustrating how security volatility can halt scientific piloting and destroy established infrastructure (D6.1). Technologically, there is a strong endogenous scientific baseline supported by local institutions like INERA and AALI. However, local production efforts, such as the youth-led Briquette du Kivu (which processes over 500 tons of organic waste), remain unmechanized (D4.2). This reflects a low TRL for industrial application and validates the critical deficit in specialized production technology and heavy machinery. Furthermore, conducting accurate SSbD evaluations is hindered by data scarcity and a lack of geographical granularity in global environmental databases. Economically, LCC assessments confirm the high viability of bio-based options, demonstrating that substituting conventional packaging causes minimal economic impact on overall kit budgets, and can even reduce costs (e.g., a 2.5% decrease for NFI kits) (D6.1). Despite this, transitioning to local manufacturing is crippled by structural tax frameworks that inherently disincentivize local production. While abundant organic waste is available, creating high-value circular products requires a strict trade-off analysis: deploying high-performance bio-materials faces a structural operational mismatch because the specialized end-of-life composting infrastructure they require is completely absent locally (D6.1, D6.2).

South Sudan

In South Sudan, operations across Juba, semi-urban municipalities, and displacement settings rely almost exclusively on long international supply chains. The baseline is defined by a high dependency on sporadic donor funding, perfectly illustrating the funding barrier that prevents technologies from surviving on the open market post-project. Scientifically, the country faces an extreme deficit in local

validation and quality assurance frameworks. The total absence of technology for waste monitoring and data collection prevents rigorous LCA from being executed locally. Consequently, the technological and scientific feasibility of any solution is strictly dictated by rigid, unharmonized UN procurement standards and global health regulations, which restrict direct science-to-market integration. From an economic perspective, LCC models confirm that substituting conventional packaging with bio-based alternatives causes only a marginal impact on total kit costs, such as a minimal 4.7% cost increase for Agriculture kits (D6.4). This finding substantially strengthens the economic case, demonstrating that financial feasibility should be linked directly to institutional procurement capacities rather than being constrained by household-level affordability (D6.4). However, the broader economic potential is systematically undermined by a tax framework that subjects domestic suppliers to full taxation while granting broad exemptions to humanitarian imports. Because of this, existing innovative solutions remain donor-led pilots that fail to develop sustainable, competitive business models. Ultimately, the lack of specialized technical machinery is exacerbated by chronic humanitarian underfunding, which restricts the sector's ability to conduct holistic SSbD and LCC assessments. This financial reality enforces short-term planning, resulting in theoretical bio-resources being burned or dumped rather than being scientifically valorized.

3.7 Area 7 The aspect of social innovation

Strengths (S) The most highly referenced strengths are the communities' strong baseline capacity to organize independently and manage waste collection via active business committees or informal synergies (S7.1), alongside an existing foundation for cross-sector collaboration driven by intrinsic community motivation for tangible co-benefits like improved health and agricultural outputs (S7.4). Following these is the benefit of established beneficiary dialogue through mechanisms like Post-Distribution Monitoring combined with trusted traditional communication networks (S7.3). Additionally, existing and functioning local bio-based enterprises demonstrate that waste-to-resource models are technically feasible and capable of generating sustainable income (S7.2).

Weaknesses (W) The most critical weakness is the humanitarian sector's top-down mindset and institutional silos, which prioritize speed and cost efficiency over participatory co-design, leading to missed opportunities for collaborative synergy (W7.1). This is closely followed by a widespread lack of social awareness regarding sustainable practices, exacerbated by a deficit in delivering critical immaterial resources like technical education and operational training (W7.3). Another major barrier is the systemic behavioural resistance and pervasive cultural perception that humanitarian assistance must be strictly free, severely restricting the scalability of community-owned solutions requiring cost-sharing (W7.2). Finally, purely community-based ownership models often fail due to a lack of individual accountability and critical gaps in financial and administrative skills among local groups (W7.4).

Opportunities (O) The greatest opportunities are capitalizing on youth enthusiasm to deploy comprehensive grassroots educational campaigns that transform the public perception of waste into a valuable resource (O7.2), and establishing cross-sector coordination platforms to integrate bio-based implementations into multi-sectoral programming to break down silos (O7.3). Another significant opportunity is formalizing the informal sector, such as waste pickers, to improve livelihoods and permanently transition vulnerable populations from passive aid consumers to active producers (O7.1). Further opportunities involve utilizing cash-based interventions and local procurement to foster participatory, market-driven governance (O7.4).

Threats (T) The primary threats involve deeply embedded cultural taboos regarding waste handling, which create severe behavioural resistance to new models (T7.2), and the danger of innovation silos combined with sporadic donor funding, leading to the rapid collapse of technologies once subsidies cease (T7.3). Other critical threats include the potential for unintended social harm, such as exacerbating community dependency or displacing the poorest informal workers if participatory co-design is neglected (T7.1), as well as security volatility and active conflict that disrupt collaborative processes and destroy social trust (T7.4).

Supportive Actions (SA) The top supportive action is integrating existing informal waste synergies, recycling networks, and local cooperatives into formal bio-based value chains to secure reliable feedstock and enhance their income-generating potential (SA7.1). Other vital actions include leveraging the successfully established participatory governance structures of existing WASH programs to safely pilot and scale bio-economy systems (SA7.2), and establishing robust community trust through beneficiary dialogue systems combined with hands-on physical demonstrations (SA7.3).

Development Drivers (DD) The most strongly supported development driver is launching harmonized, locally-led educational campaigns that empower youth as primary knowledge-sharing agents to link bio-based interventions to tangible health and livelihood benefits (DD7.2). This is followed by the establishment of multi-stakeholder coordination platforms to foster knowledge transfer and integrate social innovation into operational programming systematically (DD7.1), and facilitating economic transition by using cash assistance to incentivize local participation while establishing mini-factories in displacement camps (DD7.3).

Mitigating Actions (MA) The most critical mitigating action is conditioning the procurement of novel technologies on the comprehensive delivery of immaterial resources, such as mandatory financial training, health education, and culturally tailored hands-on demonstrations to dismantle behavioural resistance (MA7.2). Other essential actions include implementing a mandatory participatory co-design phase supported by cross-sectoral working groups to counteract top-down mindsets (MA7.1), gradually transitioning from direct free distribution to accountable, market-based ownership models like household or institutional ownership (MA7.3), and carefully tailoring community participation frameworks to match actual local capacities (MA7.4).

Risk Management Activities (RMA) The foremost risk management activity is calibrating project timelines to reflect the gradual nature of behavioural shifts, mandating that physical deployments are bundled with strict, parallel investments in community education (RMA7.2). Further critical activities encompass mandating rigorous socio-economic baseline assessments and utilizing inclusive governance committees to ensure innovations do not displace informal workers (RMA7.1), developing business models that transition from grant-dependency to market revenues to survive funding barriers (RMA7.3), and establishing decentralized digital communication channels to maintain operational coordination during conflict instability (RMA7.4).

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, social innovation is driven by bottom-up collaborative frameworks within urban centres like Bukavu and Goma, as well as in displacement camps like Bulengo. While humanitarian aid successfully improves food security and healthcare, it carries the unintended negative social impact of exacerbating community dependency and security vulnerabilities by potentially attracting armed actors (D6.1). The social adoption of new bio-based solutions is structurally hindered by extreme poverty, limited technical capacity, and systemic behavioural resistance to change. The scalability of community-owned solutions is fundamentally blocked by the pervasive cultural perception that humanitarian assistance must be strictly free, which restricts bio-based models that require cost-sharing or continuous maintenance (D6.1). Despite these barriers, participatory governance is a validated operational strength. This is demonstrated by successful community-led WASH programmes. Informal "synergies" manage approximately 90% of local waste collection, showcasing active cross-sector collaboration (D6.1). There is also strong social innovation potential among the youth, with young entrepreneurs and small camp-based businesses actively engaging in green initiatives. Formalising this informal waste sector is critical to achieve sustainable socio-economic governance, but chronic underfunding strictly limits the provision of essential immaterial resources like technical education and long-term resilience planning. Beneficiary dialogue remains systematically managed through established PDM systems.

South Sudan

In South Sudan, operations must strictly prioritise community engagement to empower populations and reduce external aid dependence. Inclusive frameworks are primarily initiated through donor-supported pilot projects (such as those by UN-Habitat and JICA) that formally employ local women and youth in waste segregation. Fostering local employment by integrating existing informal waste pickers, such as those at the Juba Controlled Dumping Site, is essential for developing inclusive green value chains. However, social innovation is severely bottlenecked by low public awareness of environmental policies and a critical shortage of local technical

experts, meaning that transitioning to community-led models requires intensive knowledge-sharing and capacity-building. To bridge this gap effectively, utilising trusted community channels is essential. While in the DRC, community health workers (RECOs) are specifically identified as key intermediaries who bridge technical and community knowledge, in South Sudan, religious leaders, churches, and village chiefs serve as the vital, trusted communication channels required to drive social innovation and community acceptance (D6.2, D6.4). The transition to sustainable community management is heavily challenged by an extreme reliance on short-term donor funding; initiatives frequently collapse into dependency once external financing ceases. Additionally, community-led value chain creation is heavily restricted by the traditional humanitarian aid mindset and rigid, top-down UN procurement standards, which limit the allocation of resources for long-term community technical education. Despite these barriers, local authorities show strong political will for inclusive governance, and beneficiary feedback mechanisms like PDM are established to capture community dialogue.

3.8 Area 8 Investment attractiveness and founding sources

Strengths (S) The most critical strength is the high attractiveness of bio-based solutions to impact investors and institutional buyers, driven by their capacity to create green jobs and supported by a diverse ecosystem of start-ups and institutional buyers utilizing internal NGO zero-carbon procurement policies (S8.4). Following this are the low early-stage capital barriers provided by the configuration of small-scale technologies and existing local institutional support structures that offer free physical space, training, and biological feedstock (S8.2). Additional strengths include the proven commercial viability of existing local models providing a double return on investment through waste disposal and marketable commodities (S8.1), and validated economic and environmental risk baselines established via LCA and LCC models proving only insignificant cost increases (S8.3). Finally, the continuous supply of local raw materials provides a reliable resource base that secures long-term operations (S8.5).

Weaknesses (W) The most critical weaknesses are the elevated upfront costs of bio-based solutions, which conflict directly with humanitarian procurement processes prioritizing speed and low cost over sustainability (W8.1), and systemic deficits in investment bankability caused by absent data tracking systems, lacking regulatory frameworks, and critical gaps in business administration and financial skills among community groups (W8.4). Following these is the weakness of underdeveloped business models restricted by low purchasing power and high logistical costs, leading to limited short-term financial returns (W8.2). Another notable barrier is the unsustainable dependency on sporadic donor funding, which frequently causes operations to collapse once funding cycles conclude (W8.3).

Opportunities (O) The greatest opportunity is engaging private capital and hybrid financing by demonstrating commercial viability to substitute high-value imports with local production (O8.1). This is followed by accessing public green funding by aligning with global sustainability policies and integrating upstream green

procurement criteria (O8.2), and capitalizing on statutory tax exemptions for environmental innovations by integrating bio-based inputs into national tax-exemption lists (O8.3). Further opportunities include utilizing local authority subsidies and physical asset provision to directly reduce early-stage capital expenditure (O8.4).

Threats (T) The primary threat is unregulated market competition from cheap, non-sustainable alternatives, heavily exacerbated by strong vested interests and market-blocking tactics from politically connected conventional plastic importers (T8.1). Other major threats include restricted market access and rigid institutional UN procurement standards preventing local suppliers from accessing humanitarian capital (T8.3), and the high operational risks and severe capital barriers associated with investing in large-scale infrastructure within fragile environments (T8.4). Additionally, hostile and fragmented taxation frameworks that explicitly penalize domestic bio-suppliers while exempting imported conventional goods serve as a major deterrent to investment (T8.2).

Supportive Actions (SA) The most highly prioritized supportive actions involve utilizing data-driven economic justification through LCC scenario tools to establish empirical baselines that reduce perceived risks for private investors and donors (SA8.2), and actively communicating the social impact and Green Jobs livelihood creation potential to attract impact investors and development banks (SA8.3). Other key actions include formalizing strategic institutional partnerships with local research hubs to subsidize initial costs and leveraging NGO zero-carbon policies to secure multi-year advance purchase agreements (SA8.4), as well as diversifying product portfolios via integrated bio-refineries to buffer the business model against single-product market fluctuations (SA8.1).

Development Drivers (DD) The top development drivers include structuring blended financing and hybrid business models that combine humanitarian grants with long-term commercial mechanisms to successfully transition pilots into financially self-sustaining commercial entities (DD8.1). This is followed by explicitly aligning funding proposals with global and national climate targets to unlock targeted international public climate finance (DD8.2), and executing active fiscal advocacy to formally integrate locally produced bio-materials into tax-exemption registries (DD8.3).

Mitigating Actions (MA) The most crucial mitigating action is implementing phased scale-up strategies starting with low-capex technologies to systematically bypass start-up capital barriers and gradually transition to revenue-generating business models (MA8.1). Other vital actions involve standardizing economic justification via LCC decision-support tools during procurement (MA8.2), implementing rigorous data tracking systems while embedding mandatory business administration capacity building to provide ROI metrics to private investors (MA8.3), and ring-fencing dedicated public innovation budgets specifically allocated for the field validation of bio-materials (MA8.4).

Risk Management Activities (RMA) The foremost risk management activities are executing decentralized, gradual investments utilizing mobile assets in stable

municipalities to drastically reduce financial exposure to corruption and conflict (RMA8.1), and forming strategic advocacy coalitions to actively negotiate tax parity and preferential procurement policies (RMA8.2). Further essential activities include conducting proactive political economy mapping to identify and bypass monopolies and market-blocking tactics prior to market entry (RMA8.3), and proactively communicating long-term environmental costs to justify bio-based investments to donors (RMA8.4).

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, financial interventions primarily target urban centres and institutional environments where private cooperative "synergies" handle waste collection. While local models like Briquette du Kivu prove technical feasibility, their reliance on simple, unmechanized techniques limits the science-based validation needed to attract high-level public or private funding. To bridge this early-stage capital gap, established institutions like INERA actively subsidize local start-ups by providing free physical space, training, and biological feedstock (D6.2). Furthermore, internal NGO green procurement policies, such as ACTED's CAROOT zero-carbon initiative, generate predictable institutional demand and serve as a highly reliable revenue driver for hybrid funding models (D6.1). LCC models confirm high financial feasibility, proving that transitioning to bio-based packaging causes only insignificant increases in total kit budgets, and can even yield cost reductions (D6.1). However, investment attractiveness is severely hindered by excessive and fragmented formal and informal tax systems. While statutory tax exemptions for environmental innovations theoretically exist for 2-3 years, their inconsistent application and high corruption risks deter investors. Market entry for local green enterprises is also actively threatened by vested interests and market-blocking tactics from politically connected conventional plastic importers (D6.2). Finally, the systemic lack of digital tracking tools creates a data gap that prevents the generation of robust SWM data required by impact investors to calculate returns.

South Sudan

In South Sudan, there is a weak baseline for pure private investment, requiring highly adaptable financial models such as micro-enterprise support and institutional public co-financing. Despite these barriers, localized commercial models, such as private services operating decentralized bio-digesters, demonstrate that hybrid funding models and commercial viability can succeed independently of short-term emergency relief cycles. However, donor-supported pilots employing local youth and women frequently lack financial continuity, demonstrating the critical weakness of unsustainable, sporadic donor funding (D4.2). A major structural threat to investment is the national tax framework, which actively discourages local green value chains by subjecting domestic bio-suppliers to full taxation while granting broad tax exemptions to imported conventional humanitarian goods. To overcome

this barrier and unlock competitive pricing to attract local investment, there is a strategic necessity to actively advocate for the formal inclusion of locally produced bio-based agricultural materials into the Ministry of Agriculture's (MoA) tax-exemption registries (D6.1; D6.2). Integrating these local inputs into the MoA list is a vital driver to level the economic playing field against tax-exempt humanitarian imports (D6.4). Despite these tax barriers, political goodwill provides material financial relief: local authorities, such as the Juba City Council and Yei County, are actively willing to allocate physical land for installations, which directly reduces initial capital expenditures. Finally, LCC assessments validate that adopting bio-based packaging presents a demonstrably low financial risk, causing minimal impact on overall humanitarian kit costs, such as a minimal 4.7% cost increase for Agriculture kits.

3.9 Area 9 Existing and expected regulatory environment

Strengths (S) The most critical strength is the universal humanitarian standards and donor-driven compliance culture, providing a strong normative baseline through frameworks like Sphere, CHS, and ECHO policies (S9.1). Following this are the existing domestic legislative foundations, health norms, and expressed political support that facilitate pilot installations without needing to create entirely new legislation (S9.2), along with established administrative gateways and institutions, like the Office Congolais de Contrôle (OCC), for customs clearance and quality assurance (S9.3). Additionally, there is a strength in the pre-import regulatory alignment of EU-manufactured bio-based materials with advanced EU packaging standards (S9.4).

Weaknesses (W) The most critical weakness is the severe lack of regulation, characterized by regulatory gaps, inconsistently enforced environmental policies, and a total absence of technology-specific legislation for emerging solutions like biogas or BSF (W9.1). This is followed by a critical gap in recognized local standards and certifications, creating verification bottlenecks for localized procurement (W9.4). Other major barriers include complex bureaucracy and multi-agency authorization constraints that cause procurement delays (W9.2), as well as widespread legal illiteracy and institutional silos leading to unintentional non-compliance (W9.3). Finally, highly fragmented taxation systems structurally penalize local bio-based producers (W9.5).

Opportunities (O) The greatest opportunities are leveraging the European Green Deal and donor-mandated environmental conditions to stimulate institutional demand and bypass weak domestic enforcement (O9.1), alongside anticipating ongoing national legislative developments, such as South Sudan's pending National Environment Bill, to formally integrate circular economy provisions into state law (O9.3). Further opportunities include utilizing centralized validation pathways via humanitarian clusters and health sector mechanisms for the fast-track entry of bio-based medical packaging (O9.2). Additionally, establishing stakeholder coordination platforms can formalize local suppliers and the informal sector (O9.4), while

statutory tax exemptions for environmental innovations offer a pathway to improve early-stage production economics (O9.5).

Threats (T) The highest-referenced threat is unpredictable and inconsistent governance, exacerbated by high corruption risks and active market-blocking tactics from politically connected conventional plastic importers leveraging administrative influence (T9.2). This is closely followed by the threat of rigid international UN procurement standards and the severe risk of non-compliance if local regulations fail to evolve alongside tightening EU environmental standards (T9.3). Other critical threats include geopolitical instability, active conflict, and cross-border regulatory conflicts that disrupt formal licensing and compliance monitoring (T9.4), and structural taxation frameworks that explicitly penalize endogenous production while exempting imported humanitarian goods (T9.1).

Supportive Actions (SA) The most highly prioritized supportive action is utilizing established administrative gateways and formalizing coordination with local standards bodies and health validation channels to certify specialized packaging and support customs clearance (SA9.2). This is closely followed by institutionalizing humanitarian standards by formally embedding DG ECHO and Sphere standards within internal NGO procurement manuals to bypass weak local environmental governance (SA9.1).

Development Drivers (DD) The top development driver is establishing multi-stakeholder coordination platforms to co-create technology-specific municipal by-laws, modernize fragmented regulations, and provide field data for pending national legislation (DD9.1). Other key drivers involve standardizing local suppliers by embedding validated bio-based product specifications directly into humanitarian cluster standards (DD9.2), and leveraging EU packaging standards as a benchmark to harmonize donor requirements and provide compliance co-funding (DD9.3).

Mitigating Actions (MA) The primary mitigating action is initiating cross-sectoral advocacy task forces to navigate fragmented regulatory environments, negotiate tax parity, and advance the structural development of baseline environmental bills (MA9.3). Another vital action is overcoming regulatory voids by basing immediate technology deployments strictly on local municipal by-laws rather than waiting for comprehensive national legislation, while establishing mandatory internal end-of-life tracking protocols (MA9.2). Additionally, launching targeted legal capacity building and compliance training for local businesses and NGOs reduces unintentional non-compliance (MA9.1).

Risk Management Activities (RMA) The most important risk management activities are creating strategies to ensure local operations align with evolving EU standards to prevent donor funding cuts, alongside engaging UN agencies early to secure pre-approvals (RMA9.1), and implementing rigorous traceability systems combined with strategic coalitions to negotiate tax parity and counteract established plastic monopolies (RMA9.2). Further activities include proactively bypassing regulatory paralysis in conflict zones by prioritizing decentralized deployments and mandating rigorous legal feasibility screenings prior to technology imports (RMA9.3).

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, the regulatory environment is characterised by a significant lack of awareness and weak enforcement of SWM legislation across large cities and municipalities (D3.3, D6.1). In eastern regions, formal governance is severely disrupted by the active M23 occupation, causing regulatory paralysis that halts licensing and environmental compliance monitoring (D6.1, D6.2). Furthermore, the environment completely lacks specific legislation, certification mechanisms, and labelling standards for emerging bio-waste processing technologies like biogas or BSF. Existing environmental policies, such as the 2017 decree banning plastic bags, are structurally undermined by the lack of viable market substitutes and active resistance from politically connected plastic traders. To successfully navigate market entry, product alignment must be coordinated through established institutional entities like the OCC, while nutritional and medical items require complex authorizations from bodies like ACOREP. Finally, while legal provisions theoretically offer tax exemptions for innovations, they are inconsistently applied, leaving local bio-entrepreneurs highly vulnerable to a fragmented taxation system and corruption risks (D6.1, D6.2).

South Sudan

Comprehensive environmental legislation remains in early drafting stages or is poorly enforced, meaning the country lacks formal regulatory frameworks, technical standards, or certification rules specific to bio-based technologies (D6.1, D6.3). Because imported bio-based products remain effectively unregulated after arrival, their environmental performance depends entirely on voluntary end-of-life practices rather than statutory compliance (D6.1, D6.3). Due to the absence of enforceable domestic legislation and recognized certification bodies, established international humanitarian frameworks (such as Sphere, CHS, and DG ECHO MERS) function as the essential in fact regulatory baseline governing environmental operations (D6.1, D6.3). While there is demonstrated political will to reduce plastic waste, efforts have been ad-hoc. Specifically, a 2018 announcement by the Ministry of Environment and Forestry to ban plastic carrier bags, followed by a renewed 2021 ministerial circular instructing customs to seize incoming bags, lacked implementing regulations and failed due to limited inspection capacity and overlapping mandates, resulting in inconsistent enforcement (D6.1). A major structural threat is the national tax framework, which systematically penalises endogenous production by granting broad tax exemptions to international humanitarian imports while subjecting local bio-based suppliers to full taxation (D6.1, D6.3). Despite these barriers, the pending National Environment Bill, which includes circular economy provisions and is currently under review by the Ministry of Justice, presents a strategic opportunity to formally integrate bio-based definitions into state law (D6.1, D6.3)

3.10 Area 10 Reputational and replication potential of the proposed solutions

Strengths (S) The most critical strength is the reputational credibility of the proposed solutions, firmly validated by scientific evidence such as LCAs and existing certifications, combined with the explicit willingness of solution owners to cooperate with humanitarian partners (S10.3). Following this are the proven functioning local bio-based enterprises and the established capacity of local research institutes to act as effective training and knowledge transfer hubs (S10.1). Additional strengths include the configuration of technologies as containerized, mobile, and autonomous installations that allow for simplified transfer across diverse destinations (S10.2), and a robust institutional architecture aligned with global normative standards, participatory governance mechanisms, and centralized UN procurement pathways (S10.4).

Weaknesses (W) The most critical weakness is the severe shortage of qualified personnel and targeted capacity-building efforts, leaving local staff and communities without the technical expertise to operate, maintain, or replicate advanced bio-based systems (W10.2). Another major barrier is the critical data scarcity, compounded by limited product transparency, the absence of local laboratory testing capacity, and a lack of systematic technical guidance from humanitarian clusters (W10.1). Further weaknesses include failed past implementations that act as temporary experiments, creating high community trust deficits (W10.3), severe infrastructural deficits alongside a high sensitivity to regional variables that prevent uniform replication (W10.4), and elevated environmental investment costs paired with the dependency on establishing local production (W10.5).

Opportunities (O) The top opportunities are the growing integration of ESG standards by major donors and internal organizational green policies, which creates structured institutional demand to fast-track the standardization of validated technologies (O10.1), and the establishment of stakeholder coordination platforms to standardize local suppliers, mitigate reputational risks, and facilitate cross-regional knowledge exchange (O10.3). Other significant opportunities include utilizing early-stage pilots alongside global health sector validation mechanisms to build institutional trust and recognized standards of practice (O10.2), and capitalizing on the local replication potential of highly cost-effective, small-scale, and context-adapted technologies specifically developed for African conditions (O10.4).

Threats (T) The most critical threats involve complex, unharmonized national regulations, rigid UN procurement standards, and overlapping administrative authorities severely obstructing the transition of isolated pilot successes into scaled global practices (T10.2), alongside active conflicts and severe supply chain gaps preventing the local sourcing of spare parts and halting operational replication (T10.4). Additional threats encompass the extreme diversity of humanitarian contexts, where deploying bio-based products without matching actual local

capacities leads to "burden shifting" and massive reputational damage (T10.1), and external barriers such as manufacturers' low risk tolerance and unwillingness to share intellectual property or form local consortia (T10.3).

Supportive Actions (SA) The most important supportive action is exploiting the mobility of containerized units to deploy physical "see and touch" demonstrations and establish regional "Centres of Excellence," tangibly proving local impact reduction to build essential grassroots trust (SA10.1). Other vital actions include leveraging documented successes from community-engaged WASH programs to create replicable, participatory templates while partnering with academic hubs for transparent knowledge transfer (SA10.3), and mainstreaming the use of transparent LCC and SLCA assessment tools to standardize the monitoring of bio-based environmental outcomes (SA10.2).

Development Drivers (DD) The most strongly supported development drivers are formally embedding validated bio-based product specifications and SSbD criteria directly into international humanitarian Cluster guidelines to standardize quality assurance (DD10.2), and co-designing pilot installations with local authorities to generate robust field evidence that is actively disseminated to national authorities to bypass innovation silos (DD10.3). Another key driver is establishing open-access databases and stakeholder coordination platforms to record lessons learned and standardize local suppliers to international norms (DD10.1).

Mitigating Actions (MA) The primary mitigating actions include implementing rigorous monitoring systems, transparent PDM, and context-specific cost-benefit analyses to generate hard evidence countering data scarcity and ensuring detailed hazard screening (MA10.1), and basing replication strategies strictly on actual localized capacity assessments and geographical parameters rather than theoretical environmental profiles (MA10.2). Furthermore, ensuring operational continuity and overcoming community trust deficits requires developing long-term maintenance plans and designing interventions around household or institutional ownership models (MA10.3).

Risk Management Activities (RMA) The most important risk management activities are navigating cross-border regulatory fragmentation by securing early endorsements from global health and logistics clusters prior to scaling (RMA10.3), and mitigating supply chain gaps by establishing regional spare parts hubs and continuous dialogue mechanisms between developers and logisticians (RMA10.2). A further essential activity is conducting rigorous contextual assessments and holistic pre-deployment trade-off analyses during co-design to ensure safe adaptation and prevent the reputational damage of "burden shifting" (RMA10.1).

The regional context

The Democratic Republic of Congo (DRC)

In the DRC, humanitarian deployments occur across highly diverse settings, which intrinsically complicates standardized replication. Reputational potential is proven by youth-led social enterprises, demonstrating that solutions can be fit-for-purpose when aligned with community needs (D3.3). However, security volatility, notably the M23 occupation in eastern provinces, disrupts formal governance and severely limits compliance monitoring and field validation (D6.1). Technologically, the replication of these models is challenged by their non-mechanized nature and the reliance on imported chemical formulations. A critical lack of local laboratory capacity creates severe data scarcity, preventing rigorous quality assurance for new materials (D6.1). While localized pilots supported by institutions like INERA successfully build institutional trust, transferring these models is hindered by fragile public-private partnerships. Most importantly, the severe infrastructural deficit, specifically the complete absence of industrial composting, means that deploying highly refined bio-materials without verifying local end-of-life capacities risks "burden shifting" and serious reputational damage (D6.1; D6.2). Therefore, strategic replication must strictly be mapped to actual, available waste treatment capacities.

South Sudan

Reputational potential is primarily established through international donor-led pilot projects that employ local women and youth. However, because they are donor-dependent, these initiatives are often perceived as temporary experiments rather than reliable, long-term infrastructure. The blurring of waste streams between camps and host communities further complicates accountability and the tracking of environmental impacts. A major barrier to building institutional trust is the total absence of waste monitoring technology and standardized data collection. Due to this regulatory void, the reputational integrity of operations relies almost entirely on adherence to international frameworks like Sphere, CHS, and ECHO MERS. Consequently, standardized transfer of new bio-materials strictly requires external validation through global health or supply chain mechanisms, such as the WHO or UNICEF. Importantly, because comprehensive environmental legislation remains in its early drafting stages, utilizing established humanitarian system entry points (specifically donor environmental commitments, institutional sustainability policies, and cluster-level coordination) provide a much more immediate and viable adoption pathway for scaling bio-based solutions than waiting for national regulatory change (D6.1). While there is political goodwill to provide physical land for pilot scale-ups, translating local successes into a global standard of practice is obstructed by rigid, unharmonized UN procurement protocols and severe supply chain gaps. Finally, chronic humanitarian underfunding strictly restricts the allocation of resources for comprehensive field validation and PDM, preventing the collection of robust performance evidence needed to attract long-term scaling investments.

4. Impact assessment

The ten areas of importance analysed in the Bio4HUMAN SWOT framework directly feed into the four long-term impact pathways defined in the Bio4HUMAN project. By mapping these areas onto the expected impacts, we can demonstrate how addressing specific local challenges translates into systemic changes.

The table below presents the mapping connecting the SWOT areas to the four types of impact:

Type of impact	Relevant Area
<p>Societal Impact The societal impact focuses on health and hygiene improvements, livelihood creation, and the engagement of citizens to build trust.</p>	<p>Area 5 (Potential to improve social and citizen benefits) This area directly drives societal impact by examining how bio-based solutions deliver human-centric value, such as reducing health risks from open burning and empowering communities rather than just managing waste.</p> <p>Area 7 (Social innovation) This area supports societal impact by focusing on participatory, community-led systems and inclusive frameworks. This translates into co-development of solutions that meet the real needs of local communities and marginalized groups.</p> <p>Area 1 (Endogenous potential) Utilizing local resources and workforce skills contributes to creating livelihood opportunities and green jobs, which is a core societal goal.</p>
<p>Scientific Impact The scientific impact aims to advance knowledge on the transition towards a circular bioeconomy, generate open-access LCA data, and build theoretical models for humanitarian innovation.</p>	<p>Area 6 (Economic, technological and scientific potential) This area is central to the scientific impact, as it focuses on evaluating the TRL and executing environmental LCAs to bridge the "science-to-market" gap. This directly supports the creation of new interdisciplinary research and methodological developments.</p> <p>Area 10 (Reputational and replication potential) This area ensures scientific impact by translating transparent, validated "proof of concepts" into standardised global practices. This directly connects to the scientific goal of providing evidence-based guidelines transferrable to broader research and policymaking.</p>

	<p>Area 4 (Sustainability and circularity performances) Measuring the functional viability and lifecycle impact of specific solutions provides the scientific data needed to validate theoretical environmental claims against actual field performance.</p>
<p>Economic Impact The economic impact focuses on creating green jobs, strengthening Europe's bioeconomy competitiveness, and unlocking new business models for the circular economy.</p>	<p>Area 8 (Investment attractiveness and funding sources) This area directly supports economic impact by identifying pathways to secure diverse funding streams (from public grants to impact investments) and evaluating the business case necessary to attract capital beyond short-term emergency relief funds.</p> <p>Area 6 (Economic, technological and scientific potential) By analysing market maturity and cost-efficiency, this area ensures that the proposed solutions can be competitive, thereby supporting the deployment and market uptake of innovative technologies by the private sector and SMEs.</p> <p>Area 9 (Regulatory environment) By addressing regulatory barriers and certification bottlenecks, we facilitate smoother market entry for bio-based actors, unlocking the economic potential of the bioeconomy business sector.</p>
<p>Environmental Impact The environmental impact is centred on minimizing pollution, managing natural resources sustainably, and supporting the European Green Deal and zero pollution action plan.</p>	<p>Area 3 (Waste management and environmental challenges) This area defines the baseline of ecological footprints and identifies the specific waste streams that must be addressed to reduce open dumping and pollution in humanitarian contexts.</p> <p>Area 4 (Sustainability and circularity performances) This area drives the environmental impact by evaluating the actual circularity of bio-based solutions, ensuring they reduce packaging waste and provide correct end-of-life processing.</p> <p>Area 2 (Technical challenges posed by diverse conditions) By evaluating adaptation to specific climate and ecosystem characteristics,</p>

	this area ensures that deployed solutions will function correctly in the field and genuinely reduce environmental harm without causing secondary pollution.
--	---

4.1 Societal

The societal impact of bio-based solutions relies on their capacity to transition vulnerable populations from passive aid recipients to active participants in local value chains. In the DRC, tangible social benefits are already visible through youth-led enterprises, such as Briquette du Kivu, which generate green jobs and improve living conditions by processing organic waste. In South Sudan, pilot projects formally employ local women and youth in waste segregation to mitigate health risks caused by extremely low municipal collection rates. However, to achieve long-term societal impact, interventions must overcome severe poverty and weak labour protections. Furthermore, they must dismantle the pervasive cultural expectation that humanitarian assistance must be strictly free, which currently hinders the scalability of community-owned solutions that require continuous labour or cost-sharing.

4.2 Scientific

The scientific impact will be driven by validating the actual field performance of bio-based technologies against extreme local climates, moving beyond theoretical environmental claims. In both regions, high ambient temperatures (often exceeding 30°C in South Sudan) and high humidity (in the DRC) actively degrade temperature-sensitive bio-based materials like PLA and mycelium packaging, neutralizing the benefits of multi-year storage and bulk procurement. Currently, local operations demonstrate a low TRL and lack mechanisation. Because there is an extreme deficit in local laboratory testing and waste monitoring data, the scientific impact depends on establishing basic data tracking systems and using humanitarian field deployments as live test beds to gather empirical evidence on material durability and end-of-life viability

4.3 Economic

While LCC assessments confirm that substituting conventional packaging with bio-based alternatives causes only minimal increases to humanitarian kit budgets, the broader economic impact is systematically blocked by unfavourable tax frameworks. In both the DRC and South Sudan, the national tax systems penalise local green value chains by subjecting domestic bio-suppliers to full taxation, while granting broad exemptions to international humanitarian imports. Furthermore, local bio-entrepreneurs face high corruption risks and active market-blocking tactics from politically connected conventional plastic importers. Unlocking the economic impact requires developing hybrid funding models that survive beyond short-term emergency donor grants and actively advocating for tax parity to ensure locally produced bio-based inputs are financially competitive.

4.4 Environmental

Achieving genuine environmental impact requires acknowledging that substituting materials without addressing infrastructure gaps will not solve pollution. In both the DRC and South Sudan, there is a complete absence of formal SWM, industrial composting, and source segregation. Consequently, introducing compostable or biodegradable packaging in these environments means the materials will function identically to conventional plastic litter, ending up in open dumps or rivers. Furthermore, in rural areas of the DRC, there is a deeply embedded cultural practice of reusing conventional plastic bottles and bags for several years, which conflicts directly with the introduction of single-use biodegradable alternatives. Therefore, the environmental impact relies on strictly bundling the introduction of any bio-based products with parallel investments in decentralised community waste collection and segregation infrastructure.

5. Conclusions and key recommendations

5.1 Conclusions for the DRC

The DRC presents a strong endogenous capacity for bio-based innovation, supported by established academic institutions like INERA and AALI, as well as the OCC for material testing. Tangible social and environmental benefits are already being realised through youth-led enterprises, such as Briquette du Kivu, which successfully processes over 500 tons of organic waste into cooking fuel. Furthermore, organic matter constitutes up to 65% of municipal solid waste in cities like Kinshasa, offering an abundant and continuous supply of biological feedstock. Because formal municipal waste management is severely constrained, active informal networks and private community cooperatives (known locally as "synergies") effectively manage approximately 90% of the small fraction of waste that is actually collected in the eastern provinces, though overall collection rates remain critically low.

Despite this high potential, the transition to a scaled circular bioeconomy faces severe structural bottlenecks. The active M23 occupation in the eastern regions heavily disrupts formal governance, paralyzes regulatory licensing, and destroys physical infrastructure. Technologically, the entire country lacks industrial composting facilities, keeping current local operations artisanal and unmechanised. From a social perspective, there is a deep-rooted cultural habit of reusing conventional plastic bottles and bags for two to three years, which directly conflicts with the introduction of single-use biodegradable alternatives. Finally, investment in local manufacturing is crippled by an excessive, fragmented tax system, high corruption risks, and active market-blocking tactics from politically connected conventional plastic importers.

5.2 Actionable Recommendations for the DRC

To successfully implement bio-based solutions in the DRC, humanitarian actors and project partners must execute the following targeted actions:

- **Target institutional settings for initial deployments:** Direct the first rollout of bio-based packaging and materials strictly towards highly controlled institutional environments, such as hospitals and health centres. This strategy bypasses broader municipal infrastructure deficits, avoids conflict with the community's established plastic reuse culture, and provides a closed-loop system to ensure proper biodegradation.
- **Mechanise and empower existing local models:** Instead of creating new, parallel waste management structures, invest directly in the synergies and youth-led enterprises that already handle the majority of waste collection. Provide these groups with small-scale mechanised equipment and formal business administration training to increase their processing capacity and formalise "Green Jobs".
- **Form strategic advocacy coalitions:** Initiate cross-sectoral alliances involving UN agencies, humanitarian clusters, and local authorities to proactively navigate the fragmented tax system. These coalitions must actively counteract the market-blocking tactics of conventional plastic importers and advocate for the transparent application of existing 2-3 year statutory tax exemptions for environmental innovations.
- **Bundle product introductions with local infrastructure:** Never distribute compostable or bio-based products in isolation. Because source segregation is currently lacking, every introduction of biodegradable materials must be mandatorily coupled with parallel investments in decentralised source-segregation and community composting infrastructure.
- **Dismantle behavioural barriers through demonstrations:** Overcome systemic behavioural resistance and cultural taboos regarding waste handling by deploying culturally tailored, hands-on demonstrations. Leverage trusted community health workers (RECOs) and religious leaders to present the tangible co-benefits of bio-based systems, such as reduced respiratory illnesses and improved local energy independence.
- **Strictly utilise non-food feedstocks:** Ensure that local bioplastic and bio-energy production relies exclusively on indigenous agricultural waste (e.g., cassava peels) rather than staple crops like maize. This prevents direct competition with local diets and safeguards regional food security.
- **Deploy LCC Tools in Procurement:** Use transparent LCC scenario tools to prove to humanitarian donors the financial viability of substituting conventional packaging with bio-based alternatives, as LCC data empirically

demonstrates only minimal or insignificant impacts on overall humanitarian kit budgets

5.3 Conclusions for South Sudan

Humanitarian operations in South Sudan navigate highly challenging environments across urban centres like Juba, semi-urban municipalities like Yei, and congested displacement camps. The operational baseline is defined by extreme infrastructure gaps; for example, Juba collects only 7.1% of its municipal waste, leading to widespread illegal open burning and river dumping. Formal SWM and industrial composting infrastructure are entirely absent nationwide. Consequently, introducing biodegradable packaging without proper end-of-life processing means these materials will function exactly like conventional plastic litter.

Technologically, extreme temperatures, which frequently exceed 30°C, directly degrade temperature-sensitive bio-based materials during transport and storage, neutralizing the efficiency of bulk procurement. The complete absence of automated waste monitoring technology and a critical shortage of local technical experts make scientific tracking and long-term planning extremely difficult. Furthermore, source segregation is virtually non-existent, which the Ministry of Environment identifies as a foundational barrier to deploying any bio-based technologies.

From an economic and regulatory perspective, the environment is highly dependent on short-term donor funding. Donor-supported pilots often collapse into dependency and cease operations when external emergency funding ends. Because national environmental legislation remains in draft form, international humanitarian standards (Sphere, CHS) act as the in fact regulatory baseline. A major structural threat is the national tax framework, which heavily penalises local green value chains by charging full taxes on domestic bio-suppliers while granting broad tax exemptions to imported humanitarian goods. Despite these barriers, there is strong political goodwill, with local authorities showing active readiness to provide physical land for decentralized technical installations.

5.4 Actionable Recommendations for South Sudan

To successfully integrate bio-based solutions in South Sudan, project partners and humanitarian actors must focus on the following concrete actions:

- **Leverage humanitarian system entry points as a fast-track pathway:** Rather than waiting for the slow enactment of national environmental legislation, utilise donor environmental commitments, institutional sustainability policies, and cluster-level coordination as immediate adoption pathways. Engaging global health, WASH, and logistics clusters early is critical to bypass rigid, unharmonized UN procurement standards.

- **Differentiate end-of-life requirements by material:** Avoid treating all bio-based products uniformly, which creates a logical flaw in feasibility planning. While bioplastics strictly require industrial composting to deliver environmental benefits, other variants (such as paper-based items, mycelium packaging, or biodegradable pads) can decompose in existing latrines, waste pits, or through basic agricultural composting. Product selection must rigorously reflect the actual waste infrastructure available in the target area
- **Differentiate economic viability by market type:** Shift the economic feasibility focus from household affordability to institutional procurement. While local communities are highly price-sensitive, institutional buyers and humanitarian programmes can absorb moderate cost premiums for bio-based inputs when backed by donor greening policies
- **Mandate infrastructure bundling:** Never introduce compostable or bio-based products in isolation. Because source segregation is currently non-existent, any deployment of biodegradable materials must be strictly bundled with parallel investments in basic community waste collection and segregation infrastructure to prevent these products from becoming conventional litter
- **Target managed camp settings for integrated pilots:** Utilise formally managed displacement camps as controlled environments to pilot these integrated approaches. Unlike dispersed rural settings, camps offer centralised services and established coordination structures that facilitate combined product introduction and waste collection.
- **Capitalise on political goodwill for land:** Co-design decentralized pilot production facilities directly with local authorities, such as the Juba City Council or Yei County. Securing free physical land from the government directly lowers initial capital expenditures and provides essential institutional backing for long-term operations.
- **Advocate for tax parity:** Actively negotiate with national authorities to include locally produced bio-based agricultural and technical inputs (such as compost or biogas equipment) on the Ministry of Agriculture's formal tax-exemption registries. This is a necessary step to unlock competitive market pricing against tax-exempt humanitarian imports.
- **Secure food security by mandating non-food feedstocks:** Ensure that any future local production planning explicitly prioritises agricultural waste and non-food feedstocks. This actively prevents direct competition with staple crops and safeguards regional food security.
- **Embed gender and trust-building into deployments:** Recognise women as primary users and workload bearers of solutions like biogas and BSF, but

actively involve men, village chiefs, and religious leaders in awareness campaigns to dismantle behavioural resistance,,. Because abstract concepts fail in these contexts, deployments must include "see and touch" physical demonstrations to build essential grassroots trust.

- **Formalize the informal sector with labour protections:** Focus on integrating existing informal waste pickers, such as those at the Juba Controlled Dumping Site, into formal green value chains. However, because general working conditions are poor, deployments must actively incorporate strict occupational health and safety standards to protect these vulnerable workers.
- **Transition from short-term grants to hybrid funding:** Design financial models that move away from pure emergency grants. Develop hybrid financing models and support micro-enterprises to ensure that local bio-based service providers can become commercially viable and self-sustaining after donor projects end, defining clear exit strategies and ownership models at the outset.