

BIO4HUMAN

D6.1

*Socio-economic and governance
aspects analysis report*

Due date: 15/05/2026

Responsible partner: PAH

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Document information

DELIVERABLE NUMBER	6.1							
DELIVERABLE NAME	Socio-economic and governance aspects analysis report							
ANNEXES								
TYPE*	R:	x	DMP:		DATA:		DEC:	
DISSEMINATION LEVEL**	PU:	x	SEN:		EU CLASSIFIED:			
LEAD BENEFICIARY	PAH							
DUE DATE	15/05/2026							
SUBMISSION DATE	15/05/2026							

*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, confidentiel-ue/eu-confidential, secret-ue/eu-secret under decision 2015/444

Document history

ID	DATE	AUTHOR	CHANGE
1.	19/12/2025	Emilie Guilvert WeLOOP, Carolina Szablewski WeLOOP, Perrine Sebastien WeLOOP	First draft S-LCA and LCC
2.	21/01/2026	Ludwika Klejnowska PAH, Katarzyna Pokoronowska PAH, Anna Górska PAH, Atefeh Moghimi Bidhendi PAH, PIN,	First draft Governance

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3.	30/01/2026	Piotr Barczak	Governance draft revision
4.	02/02/2026	Aleksandra Czyrko PAH, Witold Stupnicki PAH	Governance draft added to the full body
5	18/02/2026	Maria, Llàcer Llàcer AIMPLAS	First draft SSbD
6	19/02/2026	Carolina Szablewski WeLOOP	Comments and modifications on SSbD chapter
7	17/03/2026	Carolina Szablewski WeLOOP, Perrine Sebastien WeLOOP	Details about reference items (answers to PAH comments)
	20/04/2026	Anna Górska PAH, Aleksandra Czyrko PAH, Witold Stupnicki PAH and Marie Smidova PIN, Anna Nejedla PIN, Julien Lugwarha PIN review	Governance and general parts review
	28/04/2026	Perrine Sebastien, WeLOOP	Add of global conclusions
	05/05/2026	Aleksandra Czyrko PAH, Anna Górska PAH, Marie Smidova PIN, Anna Nejedla PIN, Julien Lugwarha PIN	Revision of global conclusions
	14/05/2026	Aleksandra Czyrko PAH	Final revision and technical cleaning

Contents

Document information.....	2
Document history	2
Table of figures	6
List of Tables.....	6
Publishable Summary	8
List of Abbreviations	9
I. Introduction.....	13
II. Context overview.....	14
III. Bio-based solutions under study.....	16
A. Assistance kits composition	16
B. Description of selected bio-based solutions.....	18
1. Multipurpose packaging products.....	19
2. Food and drinks packaging products	20
3. Hygiene products	20
4. Other products potentially applicable in the context of humanitarian interventions.....	20
IV. Governance aspects	21
A. Introduction	21
B. Waste Management Regulations.....	22
C. Recycling and Packaging Regulations.....	27
D. Environmental Regulations and Climate Commitments.....	32
E. Humanitarian Sector Governance	34
F. Stakeholder Perspectives on Governance.....	36
G. Legal Feasibility Assessment by Solution	39
V. Life Cycle Costing.....	44
A. Introduction	44
B. Objectives and scope	46
1. Alignment between LCA and LCC.....	47
2. Analysis period	48
C. LCC Inventory	49
1. Packaging and Item cost	49
2. Storage and Delivery Costs:.....	50

3.	Kits Costs	51
D.	Limitations of the LCC Assessment.....	54
	Improvement Pathways for Future LCC Applications	55
VI.	Social Life Cycle Assessment (S-LCA).....	56
A.	Introduction to Social LCA.....	56
B.	Methodology.....	57
C.	Goal and scope definition	57
D.	Identification of most relevant social themes	58
1.	Survey design.....	58
2.	Analysis of the survey	59
3.	Relevant social themes for Humanitarian Organisation and Solution Providers.....	61
E.	Social Life Cycle Inventory (S-LCI) and Data Collection	62
1.	Questions for Humanitarian organisations' social themes	62
2.	Questions for solution providers' social themes	63
F.	Social Impact Assessment and Interpretation	66
1.	Humanitarian Organisation social impact	66
2.	Solution providers' country-specific social impacts.....	68
3.	Solution providers' company-specific social impacts	69
G.	Social Insights for Humanitarian Operations and Solution Providers.....	71
VII.	SSbD framework	74
A.	SSbD.....	74
B.	B4H project and SSbD	75
C.	S-LCA conclusions.....	78
D.	LCC Conclusions	79
VIII.	Global conclusion	80
A.	Feasibility	80
B.	Replicability.....	81
C.	Determinants of Scalable Implementation.....	82
IX.	Annexes	86
A.	LCC tool and Kits Cost Details.....	86
B.	Survey Questions and Participants.....	88
C.	Comments of survey respondents on other social categories.....	89
D.	References used for HOs social theme assessment.....	91
E.	S-LCA Scoring of Humanitarian Organisations Activities	93

F. References used for SPs social theme assessment	95
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Table of figures

Figure 1 WASH kit cost comparison.....	51
Figure 2 NFI kit cost comparison.....	52
Figure 3 Food kit cost comparison.....	53
Figure 4 Agriculture kit cost comparison	54
Figure 5 Relevant social themes based on the survey (red: not relevant, orange/yellow: potentially relevant, green: relevant)	59
Figure 6 Social theme scores for humanitarian organisations (literature review in black and partner adjustment in blue).....	66
Figure 7 Workers/Employees stakeholder scores for solution production countries	68
Figure 8 World Governance Indicators (WGI) for solution production countries	
Figure 9 Social performance results for bio-based solution items	70
Figure 10 Social performance results for technology-based solutions.....	71

List of Tables

Table 1. Food basket composition	16
Table 2. Agriculture kit composition	17
Table 3.WASH kit composition	17
Table 4. Non-Food Item kit composition	18
Table 5 Functional units of selected solutions and their reference item	47
Table 6 Methodological choices and assumptions of the Life Cycle Costing (LCC) assessment.....	49
Table 7 Packaging market price	50
Table 8 Delivery costs by different means of transport	51
Table 9 Scoring scale used to identify relevant social themes in the survey.....	58
Table 10 Target audience for each selected social theme.....	61
Table 11 Scoring scale for the evaluation of social themes.....	62
Table 12 Humanitarian organisation (HO) evaluation questions per social theme..	62
Table 13 Solution Providers evaluation questions per social theme (company and country specific)	64
Table 14 Relevance of World Governance Indicators (WGI) for assessing working conditions.....	65
<i>Table 15 Bio-based solution providers and corresponding production countries</i>	65
Table 17 Overview of bio-based solutions performance, based on environmental, social, economic and governance assessments	83
Table 16 WASH kit cost comparison	86
Table 17 NFI kit cost comparison.....	86

Table 18 Food kit cost comparison.....	87
Table 19 Agriculture kit cost comparison.....	87
Table 20 Survey Questions.....	88
Table 21 List of survey participants	89
Table 22 Detailed Scoring of HO S-LCA questions (yellow: beneficiaries, blue: children, red: local communities, purple: society, green: supply chain actors)	93

Publishable Summary

This deliverable extends the environmental assessment of selected bio-based solutions conducted in D5.2 *Hotspot analysis of the current and innovative solutions* by evaluating their economic and social impacts in humanitarian contexts through Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA). The analysis aims to support more informed decision-making by humanitarian organisations operating in South Sudan (SSD) and the Democratic Republic of Congo (DRC).

The LCC assessment applies a life cycle perspective to compare selected bio-based items and packaging with reference items used in humanitarian kits. Costs are evaluated from the perspective of humanitarian organisations and include production, storage, and transportation stages. Due to data limitations and the high variability of disposal pathways, end-of-life costs were not monetised. To support transparency and practical use, an Excel-based LCC tool was developed and provided alongside the report. The tool enables scenario-based comparison of alternative kit configurations by allowing users to adjust key parameters such as materials, packaging options, transport modes, storage duration, and country context.

Results show that, across all assessed kits, replacing conventional packaging with bio-based packaging generally leads to only small changes in total kit cost. This is because packaging represents a relatively small share of overall kit costs, meaning that higher unit prices for bio-based packaging have a limited effect on total expenditure. Cost variations are more pronounced in cases where functional constraints of the bio-based solution require unrealistic assumptions (e.g. the use of large quantities of small packaging units).

The complementary S-LCA, conducted in line with the UNEP 2021 Guidelines,¹ assesses potential social impacts across workers, local communities, beneficiaries, and society. The S-LCA results indicate that humanitarian organisations generally perform consistently across core social themes, reflecting the application of established humanitarian standards, while structural constraints in emergency contexts limit transparency at the product and supply-chain levels. For solution providers, social aspects such as working conditions and local economic contributions are less visible than environmental claims, leading to a cautious assessment of social performance. Overall, the findings highlight that the social outcomes of bio-based solutions depend strongly on governance, transparency, and implementation choices, reinforcing the importance of integrating social considerations alongside economic and environmental assessments.

Moreover, the analysis of the governance aspects examines the legal, regulatory, and institutional frameworks influencing the feasibility of implementation of ten

¹ Life Cycle Initiative. (2021). Methodological Sheets for Subcategories in Social Life Cycle Assessment. <https://www.lifecycleinitiative.org/library/methodological-sheets-for-subcategories-in-social-life-cycle-assessment-s-lca-2021/>

bio-based solutions in the DRC and South Sudan that were selected based on D4.2.1 (List of bio-based solutions relevant to waste management in the humanitarian context), which identified 27 bio-based products then consolidated into 10 solution categories for further assessment. This assessment is based on desk review, comparative legal analysis, and key informant interviews with national and local authorities in both countries. The key finding is that both countries do not have a dedicated regulatory framework for bio-based materials, compostable packaging certification, or bio-waste processing technologies (such as BSF and biogas). At the same time, the situation is slightly different in both countries. While in the DRC, a basic legal framework exists (for example, 2017 national decree banning plastic bags and sachets) but its enforcement is rather weak, and there are no mechanisms regarding the certification or verification of compostable products. Office Congolais de Contrôle (OCC) would have to certify compostable products if they are locally produced or imported. They carry out quality control tests on all imported or certify locally produced products. As for South Sudan, the country’s environmental and waste management legislation is in its early stage, with several legal solutions still being drafted - though political will exists at local and national levels. In both countries, humanitarian and donor standards, including Sphere², the Core Humanitarian Standard³, and DG ECHO’s Minimum Environmental Requirements⁴ are often the *de facto* regulatory framework for solid waste management in crisis settings. Stakeholder consultations also confirmed that adoption of bio-based solutions within humanitarian supply chains is influenced by donor procurement rules, cluster standards, and global-level requirements (WHO, UNICEF Supply Division), all of which are structural prerequisites for scale. The tax framework in South Sudan creates an additional barrier to local production, as humanitarian imports are tax-exempt while local suppliers are not. Finally, because imported bio-based products are not effectively regulated after arrival in both countries, their environmental benefits depend on voluntary end-of-life practices rather than regulatory compliance. This creates a need for parallel investment in waste management infrastructure and community education, together with product implementation.

List of Abbreviations

Abbreviation	Meaning
AALI	African Agriculture Leadership Institute

² Sphere Association. (2018). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response* (4th ed.). Geneva. <https://spherestandards.org/handbook/>

³ CHS Alliance, Group URD, and the Sphere Project. (2014). *Core Humanitarian Standard on Quality and Accountability*. <https://corehumanitarianstandard.org/the-standard>

⁴ European Commission, Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO). (2022). *Minimum Environmental Requirements and Recommendations for EU-funded Humanitarian Aid Operations*. https://civil-protection-humanitarian-aid.ec.europa.eu/what/humanitarian-aid/mainstreaming-environment-and-climate-humanitarian-aid_en

B4H	Bio4HUMAN
DRC	Democratic Republic of Congo
DX.X	Deliverable X.X
eLCC	Environmental Life Cycle Costing
EoL	End-of-Life
EU	European Union
FU	Functional Unit
HA	Humanitarian Aid
HDPE	High-Density Polyethylene
HO(s)	Humanitarian Organisation(s)
ISO	International Organization for Standardization
INERA	Institut National pour l'Étude et la Recherche Agronomiques
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LDPE	Low-Density Polyethylene
NFI	Non-Food Items
NGO(s)	Non-Government Organisation(s)
PAH	Polska Akcja Humanitarna/Polish Humanitarian Action (Bio4HUMAN partner)
PDM	Post-Distribution Monitoring
PE	Polyethylene
PIN	People in Need (Bio4HUMAN partner)
PP	Polypropylene
PS	Polystyrene
PSLICA	Product Social Impact Life Cycle Assessment (S-LCA database)
REACH	Registration, Evaluation, Authorisation, and Restriction of Chemicals
RUTF	Ready-to-Use Therapeutic Food
SDS	Safety Data Sheet
S-LCA	Social Life Cycle Assessment
S-LCI	Social Life Cycle Inventory
SP(s)	Solution Provider(s)
SSD	South Sudan
SSbD	Safe and Sustainable by Design
UNEP	United Nation Environment Programme
USA	United States of America
WASH	Water, Sanitation and Hygiene
WGI(s)	World Governance Indicator(s)
WPX	Bio4HUMAN Work Package X

I. Introduction

Building on the findings of Deliverable D5.2 Hotspot Analysis of Current and Innovative Solutions, which assessed the environmental performance of selected bio-based solutions using Life Cycle Assessment (LCA), this deliverable expands the analysis by integrating Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA). Developed under Work Package 6 (Socio-economic and Governance Aspects Evaluation), the report shifts the focus from environmental and technical performance to a broader assessment of socio-economic feasibility and governance conditions influencing the implementation of bio-based solutions in humanitarian contexts.

The objective of this report is to provide a structured understanding of the potential for replicating bio-based solutions in South Sudan (SS) and the Democratic Republic of the Congo (DRC). It assesses whether - and under what conditions - these solutions are economically viable, socially acceptable, institutionally supported, and responsive to the needs of different stakeholder groups, including affected communities, humanitarian actors, local authorities, and market participants.

The assessment is based on an integrated feasibility framework that examines bio-based solutions through three complementary lenses: economic, social, and governance. Economic feasibility is assessed through Life Cycle Costing (LCC), focusing on cost structures, key cost drivers, and affordability compared to conventional humanitarian solutions. Social feasibility is analysed through Social Life Cycle Assessment (S-LCA), following the UNEP 2021 Guidelines, with attention to social acceptance, health and safety, working conditions, and stakeholder impacts. Governance feasibility is examined through an analysis of legal, regulatory, and institutional frameworks, assessing whether existing policies, capacities, and enforcement mechanisms enable or constrain implementation and scale-up. Together, these dimensions provide the analytical basis for evaluating overall feasibility and replicability across the assessed contexts.

A key contribution of this report is the integrated analysis of trade-offs between economic costs, environmental performance, and social and governance considerations. LCC and S-LCA results are systematically interpreted alongside governance constraints to identify cases where solutions are cost-efficient but socially weak, environmentally beneficial but institutionally constrained, or socially promising yet financially unviable or misaligned with humanitarian procurement practices.

This cross-dimensional analysis demonstrates that environmental performance assessed in previous deliverables of Work Package 5 alone is not a sufficient indicator of feasibility and that gains in one dimension may introduce constraints in others, with direct implications for scalability and replicability.

Based on the combined socio-economic and governance analysis, the report draws conclusions on the replicability potential of each bio-based solution in the assessed contexts. Replicability is understood not as technical reproducibility, but as the

ability of a solution to be adopted, sustained, and scaled under prevailing market conditions, governance arrangements, and social norms.

The findings demonstrate that, in both SSD and DRC, the feasibility of bio-based solutions depend less on formal regulatory approval and more on their capacity to operate within, or compensate for, systemic governance gaps. Socio-economic conditions - particularly affordability, purchasing power, and reliance on donor-driven procurement - emerge as critical determinants of adoption. Without complementary measures such as waste management infrastructure, stakeholder engagement, market development, and end-of-life solutions, bio-based innovations risk remaining confined to pilot projects with limited long-term impact.

Overall, this report provides a comprehensive socio-economic and governance-based evaluation of bio-based solutions in humanitarian contexts. It demonstrates that successful implementation requires a system-oriented approach that balances cost, environmental ambition, social outcomes, and institutional realities. By explicitly analysing trade-offs and replicability conditions, the report offers evidence-based guidance for decision-makers seeking to support bio-based solutions that are not only environmentally sound, but also socially accepted, economically viable, and contextually sustainable.

Different methodologies were applied across governance, economic, and social dimensions of the study. The governance analysis combined desk reviews, legal and comparative analysis, and key informant interviews to assess regulatory frameworks and feasibility. The economic assessment used Life Cycle Costing (LCC) with a Net Present Value approach to evaluate cost implications of bio-based solutions. The social dimension was analysed using Social Life Cycle Assessment (S-LCA) to examine impacts on stakeholders and communities across the value chain. Each methodology is described in detail in the respective sections.

II. Context overview.

South Sudan

South Sudan, which gained independence in 2011, continues to undergo a complex state-building process following years of conflict. The 2018 Revitalised Peace Agreement established a transitional governance framework and has helped create greater political stability, although institutional development at national and sub-national levels remains gradual. Service delivery responsibilities, including environmental management, are shared across national, state, and local authorities, with varying levels of capacity, particularly in rapidly growing urban and peri-urban areas.

Humanitarian assistance plays a central role in supporting basic services and resilience, as a large proportion of the population continues to be affected by

displacement, food insecurity, and limited access to infrastructure. Within this context, waste management is closely linked to public health, environmental protection, and humanitarian outcomes. Bio-based and community-level waste management solutions are well aligned with existing humanitarian and early-recovery efforts, as they can be implemented incrementally, complement ongoing aid programming, and support livelihoods while strengthening local systems in a pragmatic and context-appropriate manner.

Democratic Republic of Congo

The Democratic Republic of the Congo (DRC) is characterized by a complex interplay of political fragility, persistent insecurity, and structural socio-economic challenges. Governance is constrained by weak institutional capacity, uneven territorial control, and systemic issues such as corruption and limited accountability. While national institutions are formally established, their effectiveness varies significantly across regions, with more limited state presence in peripheral and conflict-affected areas.

The security situation remains volatile, particularly in the eastern provinces, where the presence of multiple armed groups continues to undermine stability, contribute to population displacement, and weaken state authority. Since 2021, the resurgence and expansion of the M23, including its association with broader coalitions such as the Alliance Fleuve Congo (AFC), has further fragmented control in parts of North Kivu and South Kivu since January and February 2025. In these areas, the emergence of parallel or informal governance arrangements has been reported. Continued insecurity involving armed groups, including the M23 and the Allied Democratic Forces (ADF), has led to large-scale displacement and heightened humanitarian needs.

Socio-economically, despite significant natural resource wealth, a large proportion of the population lives in poverty and depends on informal livelihoods, including subsistence agriculture and small-scale trade. These dynamics are particularly acute in eastern DRC, where protracted conflict has disrupted local economies and further weakened governance systems.

The DRC hosts one of the largest and most complex humanitarian responses globally, with national and international actors providing essential assistance to displaced and vulnerable populations, particularly in the eastern regions. Rapid urbanization, combined with ongoing displacement and limited infrastructure, places significant strain on basic service delivery. In many urban, peri-urban, and displacement settings, access to adequate water, sanitation, and waste management services remains limited. Insufficient waste collection and treatment contribute to the accumulation of organic and plastic waste, increasing environmental and public health risks. These challenges underscore persistent structural gaps in service provision and highlight the growing importance of sustainable and context-appropriate waste management solutions in humanitarian settings.

III. Bio-based solutions under study

The Bio4HUMAN project identified multiple bio-based solutions that could be implemented in humanitarian aid settings, replacing current petroleum-based items or packaging delivered in assistance kits. The kits and their composition were defined based on a comprehensive state-of-the-art review of humanitarian aid delivered across Africa, with a particular focus on the Democratic Republic of the Congo (DRC) and South Sudan. This review analysed the types of assistance provided, the items included in standard kits, and their typical composition across key sectors such as WASH, NFI, Food, and Agriculture. The proposed kit configurations were then validated through consultations with humanitarian practitioners, including PIN and PAH, to ensure their relevance and representativeness of field practices. Country-specific needs were identified through an extensive review of humanitarian reports, including needs assessments and response plans. All references, data sources, and additional methodological details are provided in [Deliverable 5.1](#).

A. Assistance kits composition

The kits composition has been defined with the project partners PIN and PAH at the beginning of the Bio4HUMAN project. The kits were constructed based on data from UNHCR (United Nations High Commissioner for Refugees), Joint initiative, Shelter Cluster, WFP (UN World Food Programme), FAO (Food and Agriculture Organization), ISSD Africa (Integrated Seed Sector Development), USAID (United States Agency for International Development), UNICEF (United Nations Children's Fund), Logistic cluster, Oxfam and UNFPA (United Nations Population Fund). The detailed composition of the reference kits composition can be found in Table 1, Table 2, Table 3, and Table 4.

Table 1. Food basket composition

Food basket composition			
Item		Quantity for 1 family for 1 month	
Wheat flour		60kg	
Rice		29kg	
Vegetable oil		6L	
Pulses (like beans)		14kg	
Salt		1kg	
Sugar		6kg	
RUTF		7 sachets per week per child ⁵ = 2*7*4 = 56 sachets of 92 g = 5.15kg	
Item	Primary packaging	Secondary packaging	Tertiary packaging

5

[Optimal quantity of RUTF for the treatment of severe wasting and or nutritional oedema_r535872.pdf](#)

Solids	PE bag	PP woven bag	Tape and Wooden Euro pallet
Liquid	HDPE jerry cans	Cardboard	Tape and Wooden Euro pallet
RUTF	Metallized Sachets	Cardboard	Tape film, tape and Wooden Euro pallet

Table 2. Agriculture kit composition

Agriculture kit composition			
Item		Quantity for 1 family	
Crop seeds		5kg per types of seeds	
Vegetable seeds		50g per types of seeds	
Hoe		1 unit	
Rake		1 unit	
Spools of twine		2 units	
Filament		1 unit	
Box of hooks		2 units	
Fertilizer DAP/urea		50 kg	
Item	Primary packaging	Secondary packaging	Tertiary packaging
Seeds	PE bag	PP woven bag	PE film and Wooden Euro pallet
Objects	Cardboard	/	PE film and Wooden Euro pallet

Table 3. WASH kit composition

WASH kit composition			
Item		Quantity for 1 family	
Water container without logo (3)		2	
Bucket with lid (3)		1	
Soap bar wrapped (1)		12	
Water purification tablets (50 tablets /unit) (2)		6	
Torch handheld self-powered (2)		1	
Child potty		1	
Multipurpose cloth (1)		2	
Reusable menstrual pads set (1)		2	
Female disposable sanitary pads with wings (1)		2	
Whistle (3)		1	
Female underwear set (1)		1	
Laundry detergent (3)		1	
Guidance on kit use (1)		1	
Item	Primary packaging	Secondary packaging	Tertiary packaging
(1)	PE bag	Cardboard	PE film and Wooden Euro pallet
(2)	Cardboard	Cardboard	PE film and Wooden Euro pallet
(3)	/	Cardboard	PE film and Wooden Euro pallet

Table 4. Non-Food Item kit composition

Non-Food Item kit			
Item		Quantity for 1 family	
Plastic sheet / tarpaulin (1)		2	
Sleeping mat (1)		3	
Blankets (1)		3	
Jerrycans (3)		2	
Kitchen set (2)		1	
Solar lamp (2)		1	
Mosquito net (1)		2	
Family tent (occasionally)		1	
Item	Primary packaging	Secondary packaging	Tertiary packaging
(1)	PE bag	Cardboard	PE film and Wooden Euro pallet
(2)	Cardboard	Cardboard	PE film and Wooden Euro pallet
(3)	/	Cardboard	PE film and Wooden Euro pallet

B. Description of selected bio-based solutions

Out of these items, 8 solutions were identified⁶ as substitutes for the current items. The following substitutes are presented in the Table .

Table 5. Reference and solution items

Solution Item	Reference scenario substitution
PLA bottle for water	LDPE Water container without logo
PLA bottle for oil	HDPE jerry cans
Compostable sachet for RUTF	Metallized sachets
PLA + natural adhesive	Adhesive tape
Biodegradable laminating film	PE film for tertiary packaging
Mycelium protective material	Expanded PS
Disposable bag from renewable sources	PP/PE bag
Foams for insulation	Glass wool

⁶ building insulation materials or end-of-life management solutions mentioned in D5.1 and D5.2 solutions are not taken into account within this study, as they are not part of the kits.

Wool Insulation material	Glass wool
Bio-based insulation	Glass wool
Organic disposable Sanitary pads with wings	Female disposable sanitary pads with wings
Monofilaments fishing nets/Mosquito net	Mosquito net

This section includes a brief description of the innovative bio-based solutions that underwent LCC and S-LCA. Please take into consideration that no brands are given in this deliverable since the inventories that have been considered are generic.

1. Multipurpose packaging products

The solutions included in the “Multipurpose packaging products” are intended to cover the functionality of fastening or protection elements in all the kits (Transport packaging).

a) Mycelium protective material

This innovative bio-based solution consists of a combination of protective mailers made from mycelium and waste from the woodworking or agricultural industry. The function is to offer product protection while it is transported. The technology could be transferred to African locations. It is a 100% biodegradable material, according to ASTM D5988-18 (aerobic degradation in soil at 21 ± 2 °C for 104 days)⁷.

b) Adhesive tape

This self-adhesive tape is made from about 90% renewable resources, featuring a bio-based PLA film with natural rubber adhesive. It offers strong adhesion, low elongation, and easy hand treatability. Designed for sealing biodegradable bags, films, and sustainable packaging, it is also suitable for sealing medium to heavy cardboard boxes and manual dispensers. The tape is certified as home compostable and biodegradable.

c) Biodegradable laminating film

This packaging features a 100% biodegradable laminating film made from renewable resources like corn. It is toxic-free, printable and water-resistant, offering protective packaging. Compatible with standard laminators, it ensures product safety during handling and distribution. It is 100% certified as industrial compostable.

⁷ Technical data sheet for Myco material. Online: [Myco-Technical data sheet-202505_EN](#)

2. Food and drinks packaging products

The products included in this section are intended to substitute primary packaging items from the Food basket or jerrycans within the WASH kit.

a) PLA bottle for water or for oil

This packaging solution consists of 100% plant-based water bottles made from sugar cane and non-GMO materials, including the cap and label. More commonly available in capacities from 0.1 to 2 litres, they offer a durable, sustainable alternative for bottled water and oil. The bottles are industrially compostable. For larger capacities, additional complementary assessments must be conducted to ensure the design meets mechanical requirements.

b) Compostable Pouch for RUTF

This solution is made from multi compounds: PLA, cellulose metallized and cellophane. This compostable pouch can be used to contain Ready-to-Use Therapeutic food (RUTF). This solution is fully biodegradable and compostable in natural conditions; therefore, it can be considered as home compostable.

3. Hygiene products

In this section are included the sanitary pads from the WASH kit that intend to substitute the conventional ones.

a) Sanitary pads

The sanitary pads are made from jute, bagasse, banana fibre, and water hyacinth, using agricultural plant waste materials. In a composting environment, they biodegrade within 180 days and can be used in agriculture. They are manufactured in simple factories with the potential to be transferred to humanitarian destinations. They are 100% home compostable and certified.

4. Other products potentially applicable in the context of humanitarian interventions

a) Disposable bag from renewable sources

This item is an alternative to disposable bags, made from renewable resources and available in various sizes. They can be disposed of with organic waste and break down within a maximum of 180 days under composting conditions, DIN EN 13432 Compostable certified⁸.

b) Monofilaments fishing nets/Mosquito net

Monofilaments fishing/mosquito nets use bioplastic (PLA) formulations. It replaces conventional thermoplastics, reducing environmental impact, and integrates by-products for local valorisation. They are biodegradable.

⁸ Bio4Pack compostable certificate for Waste bags. Online: https://www.bio4pack.com/wp-content/uploads/2025/01/7P0333_en-S1.pdf

The functional units associated with these solutions are available in Table 5.

IV. Governance aspects

A. Introduction

This section looks at the legal, regulatory, and institutional governance frameworks that shape the feasibility of implementation of bio-based solutions for solid waste management in humanitarian contexts of the DRC and SSD. It is based on a desk review of national legislation, comparative legal analysis, key informant interviews with government authorities, humanitarian actors, and regulatory bodies, and draws on some findings from D3.3 (Humanitarian Sector Needs Assessment Report) and D6.2 (Community Engagement Summary Report).

The governance analysis includes four different sections, with each of them focusing on: national waste management regulations, recycling and packaging regulations, environmental regulations and climate commitments, and humanitarian sector governance standards. It then provides an overview of governance-related community feedback from D6.2 and finishes with a legal feasibility assessment for bio-based solutions.

It is important to say that the legal and policy frameworks on solid waste management in the DRC and SSD are fragmented, weakly enforced, and in many areas incomplete. At the same time, they do provide the baseline context against which the feasibility of bio-based solutions must be assessed. In both countries, national legislation exists to varying degrees, but enforcement capacity remains limited, and practical implementation falls largely to local authorities with uneven technical and financial resources. Regulations specific to recycling, extended producer responsibility (EPR), or compostable packaging remain largely absent in both contexts, and while some provincial and municipal initiatives exist, they have not yet established systematic source separation or large-scale composting infrastructure. While both contexts share structural weaknesses, the degree and nature of these challenges differ between the DRC and South Sudan.

Importantly, humanitarian standards and donor requirements (e.g., Sphere, Core Humanitarian Standard, and ECHO's Minimum Environmental Requirements) often function as *de facto* operational regulatory frameworks, and they actually set stricter operational and environmental management requirements for humanitarian actors than national laws, particularly in camp and displacement settings.

Together, these overlapping but inconsistent frameworks create both constraints and entry points for bio-based solutions. Weak enforcement, limited infrastructure, and the absence of targeted regulations constrain large-scale and

systematic adoption. At the same time, humanitarian standards and donor requirements provide a more stringent operational framework, particularly in displacement settings, effectively shaping implementation practices. In this context, pilot initiatives in composting, biogas, and BSF, combined with the absence of rigid technological prescriptions, create opportunities to introduce and test bio-based and circular solutions where local authorities and humanitarian actors are open to pragmatic, needs-driven approaches. The analysis reflects available legislation and reported enforcement practices, recognising that formal frameworks often diverge from implementation realities.

The implications for the ten Bio4HUMAN solutions are pathway-specific rather than uniform. Solutions entering humanitarian supply chains directly will need to comply with regulation that comes from within the humanitarian supply chain specifically, such as cluster standard or donor requirement, WHO/UNICEF Supply Division standards. In this case, since the national regulatory environment does not impact their ability to enter the market, the primary mechanism of adopting these regulations will be through global standards and cluster validation.

Solutions intended to be adopted at a community level will benefit from an existing regulatory framework in the DRC (plastic ban) which provides a potential basis for developing and enforcing new national regulations for locally produced bio-based substitute products and therefore can potentially create additional regulatory authority. Since there is no existing regulatory framework in South Sudan, it creates an opportunity to develop by-laws at the county level.

In all cases, the lack of EPR frameworks and composting infrastructure mean that the environmental advantages of biodegradable materials cannot be realized until additional investments are made in waste management - although there are differences among the various solutions regarding what needs to occur after use.

Donor environmental commitments and institutional sustainability policies provide a more immediate adoption pathway for several solutions than waiting for national regulatory change.

B. Waste Management Regulations

Democratic Republic of the Congo

The legal framework governing non-hazardous waste management in the DRC is primarily based on Law No. 11/009 of 9 July 2011 on the Protection of the Environment⁹, which establishes general principles for environmental protection and pollution control. The law introduces the polluter-pays principle (Article 4) and defines environmental pollution to include activities such as improper waste

⁹ Democratic Republic of the Congo. (2011). Environmental Protection Law No. 11/009

disposal or handling. While the law provides the legal basis for regulating waste-related activities, it functions mainly as an overarching framework legislation and does not establish detailed operational requirements for waste management systems, such as mandatory waste separation, recycling obligations, or specific treatment standards for non-hazardous waste streams.

Public hygiene and sanitation aspects of waste management are regulated by the Hygiene Code of 2015¹⁰, which focuses primarily on sanitation practices and the protection of public health. The code establishes responsibilities related to household hygiene, sanitation of public spaces, and environmental cleanliness, but similarly does not provide a comprehensive operational framework for municipal solid waste management.

The national regulatory framework also includes Decree No. 17/018 of 30 December 2017¹¹, which bans the production, import, marketing, and use of plastic bags and sachets as a measure to reduce plastic pollution.

Institutionally, waste management responsibilities are shared across several levels of government. Municipal authorities are primarily responsible for waste collection and disposal services, while provincial environmental authorities, operating under the Ministry of Environment and Sustainable Development, monitor compliance with environmental regulations. The Ministry of Health is responsible for sanitation, hygiene, and public-health-related aspects of waste management. At the provincial and local levels, authorities may also adopt specific sanitation and waste management by-laws; for example, in South Kivu, Decree No. 019/040/GP/SK of 28 August 2019¹² regulates sanitation in urban and rural areas of the province and decree No. 003/2013 of 09 September 2013 relating to sanitation and environmental protection in the City of Kinshasa.¹³

Despite the existence of these regulatory instruments, the operational framework for non-hazardous waste management remains limited. National legislation does not mandate systematic source separation of waste or establish detailed requirements for recycling or treatment of municipal waste. Waste collection services are particularly constrained due to the limited financial and operational capacity of municipal authorities - organized waste collection is estimated to cover only around 25% of Kinshasa's population¹⁴, while many rural and peri-urban areas remain largely unserved. In several provinces, particularly North and South

¹⁰ Democratic Republic of the Congo. (2015). Hygiene Code.

¹¹ Democratic Republic of the Congo. (2017). Decree No. 017/018 banning the production, import, marketing and use of plastic bags and sachets.

¹² South Kivu Province. (2019). By-law No. 19/040/GP/SK on sanitation.

¹³ Ville Province de Kinshasa. (2013). *Édit n° 003/2013 du 9 septembre 2013 relatif à l'assainissement et à la protection de l'environnement de la Ville de Kinshasa* [Decree No. 003/2013 of 9 September 2013 relating to sanitation and environmental protection in the City of Kinshasa]. <https://www.fonak.gouv.cd/documents/Edit%20N%C2%B0%20003-2013%20du%209%20Septembre%202013%20relatif%20a%CC%80%20L'assainissement%20e%20a%CC%80%20la%20Protection%20de%20l'environnement%20de%20la%20Ville%20de%20Kinshasa.pdf>

¹⁴ Democratic Republic of the Congo Snapshot. (2024). Solid Waste Management overview.

Kivu, private sector actors play a central role in waste collection. Many of these actors operate through cooperative structures or local “synergies”, i.e. formal or semi-formal associations of private operators coordinated by the Townhall that manage waste collection activities at neighbourhood level, and are estimated to collect around 90% of waste, which is typically transported to privately managed open dumpsites due to the absence of public sanitary landfills and formal treatment facilities. The informal sector also plays a significant role in waste collection, recovery, and recycling, although its integration into formal governance structures remains limited.¹⁵

At present, this waste collection system does not represent a viable opportunity, as waste is not sorted at source. Mixed waste cannot be used effectively for composting or for feeding BSF larvae as it commonly contains chemical contaminants (heavy metals, pesticides, hydrocarbons), biological hazards (pathogens, human/animal faecal matter), physical hazards (plastics, glass, metals), and inconsistent nutrient profiles; all of which create risks to larvae, to the safety of derived products (feed/fertiliser), and to workers/collectors. As a result, organic waste recovery through these technologies remains technically and economically unfeasible under current conditions. This approach would become viable only if waste sorting and separation were implemented at the household, institutional, and restaurant levels, and if end products such as compost, frass, and BSF larvae demonstrated strong market demand and competitiveness compared to available alternatives.

At the same time, the DRC currently lacks formal regulatory frameworks in several areas directly relevant to bio-based solutions: there is no framework regulating the importation of biodegradable materials; a national certification system exists and is administered by the Office Congolais de Contrôle, which oversees conformity and certification for all locally produced and imported materials (this can include compostable packaging and bioplastics); and no specific provisions exist for emerging bio-waste solutions such as BSF larvae for feed or biogas-related processes. For Black Soldier Fly (BSF), AALI is actively working to address the existing regulatory gap. As noted, there is currently no dedicated legislation governing BSF in the DRC. In response, AALI, in collaboration with INERA and the Ministry of Agriculture, has developed a draft law to formally recognise the technology and its benefits. This proposal is currently under discussion at ministerial level. Provincial authorities have expressed interest to accompany such initiatives, but progress has been constrained by the absence of viable alternative products available on the market. This challenge is particularly acute for plastic packaging such as sachets and plastic bottles. Alternatives to plastic bags are typically paper-based; however, differences in material properties and intended use mean they cannot replace plastic across all applications. Paper packaging is not appropriate for liquid products and has inherent limitations in high-load scenarios.

¹⁵ D3.3 (Humanitarian Sector Needs Assessment Report)

A potential alternative emerged in the form of partially biodegradable packaging, for which discussions were initiated between provincial authorities and a Burundian company. However, this initiative was never implemented mainly due to the security crisis linked to the AFC/M23 situation. Additionally, for an equivalent level of service and volume of goods packaged and transported, paper-based packaging is more costly than plastic bags. With regard to bottles, authorities have so far been unable to identify viable bio-based or biodegradable alternatives. Should such alternatives become available, they would need to demonstrate competitiveness with plastic packaging in terms of cost, performance, and availability.

The approval of new technologies in the DRC depends on the raw materials used, the complexity of the production process, and, most importantly, the nature of the final products. For composting technologies, technical verification is conducted by the Congolese Control Office (OCC), with certification provided by the Ministry of Agriculture. PLA-based products require OCC verification of quality and biodegradability, followed by validation from the Ministry of Industry and the Ministry of the Environment and Sustainable Development. Technologies such as biogas and Black Soldier Fly (BSF) systems, which involve biological agents and waste management, are subject to additional oversight by the Ministry of Agriculture, Fisheries and Livestock and the Ministry of Health to ensure compliance with environmental and public health standards. Licensing responsibilities vary by end product. The Ministry of Agriculture licenses digestate, compost, and frass; biogas is licensed by the Ministry of the Environment and Sustainable Development in coordination with the Ministry of Energy; BSF larvae fall under the Ministry of Livestock; and PLA-based products require approvals from the Ministries of Environment, Industry, and Economy. National and provincial authorities support product uptake through legislation and oversight, although effective enforcement can be constrained by governance challenges.

South Sudan

South Sudan does not yet have a comprehensive national legal framework governing solid waste management, and existing regulations remain fragmented, underdeveloped, and weakly enforced. The Transitional Constitution guarantees the right of every person to a clean and healthy environment, providing a high-level legal foundation for environmental governance. This is complemented by several relevant instruments, including the Environmental Protection Act (2016), which established the South Sudan Environmental Protection Agency (SSEPA) and sets out general provisions for environmental protection, pollution control, and waste disposal, including requirements for Environmental Impact Assessments (EIAs) for major projects including waste facilities. Additional instruments include¹⁶, which empowers county and municipal authorities to enact local

¹⁶ Republic of South Sudan. (2015). Environmental Protection and Management Bill.

environmental and public-health by-laws, including sanitation and waste management, as well as, which regulates forest conservation and land-use practices relevant to waste disposal.

Several relevant legal developments remain pending approval, including National Environment Bill supported by UNEP, which is expected to introduce stronger waste management provisions and incorporate elements of circular economy approaches. At the time of the data collection, this bill was reported by the Ministry of Environment to be under review by the Ministry of Justice, reflecting the ongoing and incomplete nature of the regulatory framework.

In practice, responsibility for solid waste management is highly decentralised, with implementation primarily structured at the local administration level, with roles and responsibilities varying according to settlement type, land authority, administrative capacity, and available resources. At the municipal level, the Department of Environment and Sanitation under the Juba City Council holds the core responsibility for collection and transportation of municipal solid waste, either using municipality-owned vehicles or through contracts with private companies, though overall collection coverage remains low. Collected waste is transported to designated dumping sites, including the only semi-controlled Juba Controlled Dumping Site under Juba County jurisdiction¹⁷, where fees are levied and waste volumes recorded, with informal waste pickers actively engaging in material recovery.¹⁸ The Solid Waste Management Master Plan for Juba City (2021-2030), developed with JICA support and approved in 2022, represents the first formal framework for municipal waste management, setting objectives for collection, treatment, and disposal, although implementation has been limited. The Juba City Council representative said during interview with PAH that they cover 67 of Juba's areas through waste collection services and that a 5,000 SSP fine exists for improper waste disposal, though enforcement remains a challenge.

At broader sub-national levels, Payam and County administrations are involved in local planning and oversight of disposal sites. The national government, through the Ministry of Environment and Forestry, provides the overarching environmental mandate and guides legal and policy frameworks, although specific waste legislation is still under development. The Ministry of Environment representative acknowledged that “the challenge is the knowledge on those policies, the awareness is very low,” and emphasized waste segregation as a foundational prerequisite for bio-based solutions: “Without this, all solutions are difficult to introduce.” This lack of segregation significantly limits the feasibility of bio-based solutions such as composting, biogas, or black soldier fly (BSF) systems, all of which depend on relatively clean and separated organic waste streams.

No sources indicate the existence of legally mandated separate collection at national or municipal levels. The informal sector contributes to collection and

¹⁷ D3.3 (Humanitarian Sector Needs Assessment Report)

¹⁸ UN News. (2024). Zero waste, more hope in South Sudan. and South Sudan Snapshot. (2024). IDP camp waste management.

recycling, for instance through the recovery of plastic bottles traded across borders to Uganda. UNEP has carried out a preliminary environmental assessment of the Juba dump site, a review of existing SWM legislation and procedures, and a waste-composition analysis, and has identified significant reliance on informal waste pickers at the site.

At the same time, the absence of detailed and prescriptive regulatory frameworks creates a degree of flexibility for the introduction of innovative waste management approaches. Unlike more regulated environments, there are currently no formal barriers to piloting bio-based or circular solutions from a legal standpoint, particularly in humanitarian or donor-supported contexts. However, this flexibility is counterbalanced by high levels of uncertainty, including unclear approval processes, limited institutional capacity for oversight, and low awareness of existing environmental policies among both authorities and communities.

The governance and waste management context in South Sudan is strongly centred on Juba, where most regulatory instruments, institutional capacity, data, and donor-supported initiatives are located. This creates a capital city bias that does not reflect conditions in rural areas and secondary towns, where formal waste collection is largely absent, administrative capacity is minimal, and waste management is predominantly informal. As a result, bio-based solutions that may appear feasible in Juba cannot be readily replicated in rural contexts without substantial adaptation, with important implications for scalability and national-level impact.

Overall, South Sudan's governance context presents both constraints and opportunities for bio-based solutions: weak regulation, enforcement, infrastructure, and waste segregation limit sustainable scale-up, while ongoing policy development, donor involvement, and regulatory flexibility enable piloting and adaptation, particularly in humanitarian settings.

C. Recycling and Packaging Regulations

Extended Producer Responsibility and Plastic Bans: International Context

EPR is a policy approach in which producers are made financially and operationally responsible for the post-consumer phase of their products, particularly for collection, recycling, and safe disposal. Originating in the European Union's Waste Framework Directive (2008/98/EC) and reinforced under the Single-Use Plastics Directive (EU 2019/904), EPR schemes have become a cornerstone of circular-economy policy in the EU, typically operating through producer-financed take-back systems or collective producer organisations.

In Africa, EPR frameworks are at different stages of development. Countries such as South Africa and Kenya have adopted mandatory EPR regulations for packaging

and plastic waste, while others (including Ghana and Nigeria) are piloting voluntary or sectoral schemes. In humanitarian or low-infrastructure contexts, simplified EPR principles can be adapted through collective responsibility models, where suppliers or implementing partners jointly manage packaging take-back or financing for recovery.

Plastic bans are regulatory measures prohibiting or limiting the production, import, or use of selected plastic products, often targeting lightweight carrier bags and single-use packaging. In humanitarian operations, plastic bans create both constraints and opportunities: they restrict the import of conventional packaging but can stimulate bio-based or compostable alternatives, aligning with circular-economy objectives. In Africa, pioneering countries such as Rwanda (2008) and Kenya (2017) implemented comprehensive bans covering both manufacture and import, achieving notable reductions in visible litter and catalysing regional replication (e.g., Tanzania 2019, Uganda 2023). However, enforcement success depends on the availability of affordable alternatives, public awareness, and consistent inspection capacity.

In practice, EPR principles and plastic-reduction measures in humanitarian and low-infrastructure contexts are typically implemented through pragmatic, simplified arrangements rather than formal regulatory systems. Suppliers take-back mechanisms may involve contractual obligations for suppliers to retrieve packaging waste upon delivery of goods, participate in reverse-logistics pilots, or contribute financially to collection and recycling schemes, often on a collective rather than individual basis. NGO-managed recovery models are more common, with humanitarian or local NGOs organising waste collection, segregation, and disposal or recovery at distribution sites, camps, or urban service points, sometimes in partnership with informal waste pickers. Donor requirements increasingly complement these approaches by embedding environmental conditions into procurement and project design, such as preferences or mandates for reduced packaging, reusable or bio-based materials, reporting on waste volumes, or contributions to local recovery initiatives. Together, these mechanisms operationalise EPR and plastic reduction principles in contexts where formal enforcement capacity remains limited, while shifting part of the responsibility for post-consumer waste management upstream to suppliers and programme implementers.

EU Packaging and Packaging Waste Regulation (PPWR)

The regulatory framework for recycling and packaging is increasingly influenced by international standards, particularly those established within the European Union. This is relevant to the humanitarian and development sectors because several of the bio-based products under consideration (such as PLA bottles, compostable pouches, and mycelium-based packaging) may be manufactured in or imported from the EU. The forthcoming Packaging and Packaging Waste Regulation (PPWR,

Regulation (EU) 2025/40) introduces a comprehensive framework governing the entire life cycle of packaging, from design and labelling to collection, reuse, and recycling.

The PPWR sets out clear definitions of “biodegradable” and “compostable” packaging (Article 3), which are critical for ensuring consistent terminology in procurement and product labelling. These definitions can help humanitarian actors align product specifications with recognized international standards. Articles 6 to 8 establish design and recyclability requirements, mandating that all packaging placed on the EU market be recyclable, reusable, or compostable - provisions directly applicable when evaluating the feasibility of bio-based products such as mycelium packaging or compostable carrier bags. Article 9 outlines specific compostability and biodegradability requirements, including categories of products that must be compostable, providing a valuable precedent for the humanitarian sector when assessing the environmental soundness of compostable items proposed for field deployment. Article 11 sets binding targets for recycled content in plastic packaging, establishing a governance precedent for the use of recycled materials in procurement. Finally, Articles 39 to 45 define EPR obligations, requiring producers to finance the collection, sorting, and recycling of packaging waste - a framework that could be adapted by host governments or local authorities to engage producers, importers, and humanitarian actors in financing and managing post-consumer packaging waste.

Although the PPWR will not apply directly outside the European Union, it serves as an influential benchmark for global supply chains. EU-based manufacturers increasingly align with these standards, meaning that packaging materials supplied to humanitarian operations in the DRC and South Sudan will often already comply with PPWR requirements. For humanitarian organizations, this alignment supports objectives such as minimizing plastic waste, increasing transparency through standardized labelling, and ensuring verifiable end-of-life pathways. However, the extent to which these materials can be effectively utilized or disposed of in-country will depend on local regulatory frameworks, infrastructure, and institutional capacity.

Democratic Republic of the Congo

In the DRC, there is no operational EPR system for packaging, and no comprehensive regulation on compostable or biodegradable materials. Imports of bio-based packaging are handled case-by-case under general product conformity rules. The government introduced Decree No. 17/018 of 2017 to restrict plastic usage; however, enforcement has remained limited. This may be linked to the absence of viable alternatives and the influence of plastic value chain actors, with trader associations reportedly engaging in repeated lobbying following initial enforcement. These provisions target conventional single-use plastics and have not been expanded to recognize compostable or bio-based alternatives. While the ban can restrict imports of non-compostable packaging, the OCC, however, can

certify and verify compostable products to support enforcement of the ban on non-compostable packaging.

There are no national labelling, quality, or licensing standards specific to compostable or recyclable materials. Product conformity and import controls are led by the Office Congolais de Contrôle (OCC), which issues “marquage RDC” conformity marking but has no compostability label or test protocol.¹⁹ In the absence of a local norm, importers sometimes reference ISO 17088 (compostable plastics) or EN 13432 to make claims, yet these are not automatically recognized in the DRC as ²⁰

Organic waste treatment remains limited, with only small-scale composting and pilot anaerobic digestion or BSF initiatives documented²¹ in the target locations, and no separate collection systems for organic fractions of municipal solid waste, and import pre-clearance with OCC referencing internationally recognized standards, until a national certification exists. More broadly, waste audits in Kinshasa show an estimated composition of 65% organics and 15% plastics.²²

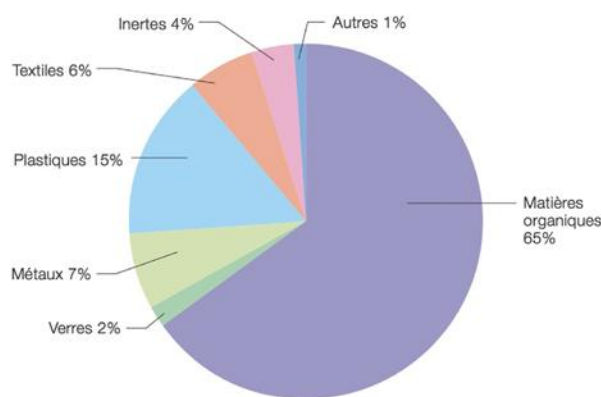


Figure 1: Waste composition breakdown in Kinshasa (source: Waste Composition Survey, Kinshasa (2023))

South Sudan

South Sudan similarly lacks national legislation on EPR or compostable packaging. The Imports and Exports Act (2012)²³ governs import processes but does not contain packaging-specific provisions. Several announcements of plastic bag bans have been made since 2018, when the Ministry of Environment and Forestry announced a nationwide ban on the import, manufacture, and use of plastic carrier bags, following regional precedents set by Kenya and Uganda. However, the announcement lacked implementing regulations or penalties, resulting in minimal enforcement. In 2021, a renewed ministerial circular reiterated the ban and

¹⁹ D3.3 (Humanitarian Sector Needs Assessment Report)

²⁰ Democratic Republic of the Congo. (2023). Waste Composition Survey, Kinshasa.

²¹ RUNRES/IITA. (2023). Pilot documentation on circular organic waste management.

²² Democratic Republic of the Congo. (2023). Waste Composition Survey, Kinshasa.

²³ Republic of South Sudan. (2012). Imports and Exports Act.

instructed customs and border agencies to seize incoming plastic bags; however, implementation was again inconsistent due to limited inspection capacity and overlapping mandates. Pilot plastic-reduction initiatives supported by UNEP and UNDP (2022-2024) in Juba and Wau remained voluntary. As of January 2026, no comprehensive decree or legally binding regulation has entered into force, though discussions are ongoing to align national policy with the East African Community regional framework on plastic waste management. These repeated but partial attempts demonstrate both political will and institutional constraints, suggesting that future enforcement will depend on the adoption of an operational EPR system and coordinated municipal by-laws. The Manufacturers Association has expressed intent to develop an EPR system for plastic waste, and the Ministry of Environment indicated that EPR provisions are expected in the forthcoming National Environment Bill.

Moreover, there are no formal systems for organic waste separation, composting, or recycling beyond small-scale initiatives supported by humanitarian or local organizations. No specific technical standards or labelling rules for biodegradable or compostable packaging exist.

The tax framework in South Sudan creates a structural incentive relevant to bio-based solutions. The National Revenue Authority (NRA) representative clarified that humanitarian actors benefit from tax exemptions on imported goods, but local suppliers do not: “If the supplier is located in Juba - the supplier pays the taxes. If humanitarians buy abroad - humanitarians are exempted.” He said that bio-based products should be tied to humanitarian action to benefit from exemptions – and that the Ministry of Agriculture manages a list of exempted items that could potentially include bio-based inputs. This creates an unintended incentive to import rather than procure locally, directly undermining the local production potential identified as an enabler across multiple solutions in D6.2.

Under the Taxation Act 2009 and the annual Financial Acts in South Sudan, humanitarian organizations importing goods directly are eligible for customs duty exemptions through a process managed by the Relief and Rehabilitation Commission and the Ministry of Finance. However, when humanitarian organizations procure through local tenders, the supplier bears all applicable taxes on inputs, production, and sales; these costs are then naturally included in the final price for the humanitarian actor. The Investment Promotion Act 2009 does provide duty exemptions for agricultural equipment and inputs, which could potentially extend to BSF or biogas equipment if classified under the agricultural sector, and the NRA representative confirmed that the Ministry of Agriculture’s exemption list could actually become a pathway for bio-based products. That being said, the current framework disadvantages local production when compared to humanitarian import.

Finally, while EU regulations such as the PPWR provide a model of comprehensive packaging governance, the lack of parallel national frameworks in both the DRC and South Sudan means that imported bio-based or compostable products are

effectively unregulated after arrival. Their environmental benefits thus depend less on import compliance than on the presence of functional waste-management systems capable of processing them responsibly.

D. Environmental Regulations and Climate Commitments

At the global level, the Paris Agreement of 2015²⁴ provides an overall framework for national climate action, and both the DRC and South Sudan are parties to it. The Agreement commits countries to limiting the global temperature increase to well below 2°C above pre-industrial levels and to pursue efforts to limit it to 1.5°C. It further emphasizes the need to strengthen climate resilience, align financial flows with low-emission pathways, and integrate mitigation and adaptation efforts into sustainable development. These provisions form the policy foundation for integrating bio-based and circular approaches, such as anaerobic digestion, BSF processing, and composting, into national climate and waste management strategies, given their potential to reduce methane emissions, support soil regeneration, and improve local resilience.

Under Article 4, each Party must prepare, communicate, and implement its own Nationally Determined Contribution (NDC), outlining domestic mitigation and adaptation measures. For low- and middle-income countries such as the DRC and South Sudan, these contributions often prioritize sectors with both environmental and developmental co-benefits, including renewable energy, forestry, and waste management. Article 7 establishes the global goal on adaptation enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change.

At the international level, European Union legislation also plays an indirect role in shaping the market and regulatory environment for bio-based products that could be introduced or exported from Europe to humanitarian contexts. The European Commission's 2022 policy framework on bio-based, biodegradable, and compostable plastics sets requirements on product composition, biodegradability, and labelling to ensure environmental integrity and avoid misleading claims. These standards, combined with the EU Waste Framework Directive and Circular Economy Action Plan, establish rigorous quality, safety, and end-of-life performance criteria that indirectly influence the procurement and use of European bio-based products in humanitarian operations abroad.

Democratic Republic of the Congo

²⁴ United Nations Framework Convention on Climate Change. (2015). Paris Agreement: Nationally Determined Contributions - DRC

The DRC ratified the Paris Agreement in 2016 and submitted its updated NDC in December 2021 under the UNFCCC. The updated NDC outlines mitigation commitments across forestry, energy, agriculture, and waste management, aiming to reduce greenhouse gas emissions through sustainable forest management, renewable energy, and improved waste treatment. However, the plan provides limited technical or quantitative detail regarding the waste sector, and implementation capacity remains low.

Environmental governance is shaped by a range of policy instruments, including the National Action Plan under the Minamata Convention on Mercury (2018). National health and environmental regulations require medical facilities to maintain waste pits and incinerators, but there are no technology-specific sanitary or environmental safety standards for BSF, biogas, or composting systems. The absence of such technical regulations could constrain the scaling of bio-based technologies, as their operation and environmental safety are not formally recognized or supervised. While the DRC's policy framework includes cross-sectoral references to sustainable agriculture, energy, water, and sanitation, these remain largely uncoordinated in practice. Existing national strategies acknowledge the importance of the circular economy, but operational guidance for waste valorisation or organic resource recovery is still underdeveloped.

South Sudan

In South Sudan, environmental regulation remains at an early stage of development. The country ratified the Paris Agreement in 2017²⁵ and submitted its first NDC in 2021, followed by a second iteration prepared under UNDP's Climate Promise initiative. The NDC identifies adaptation priorities in agriculture, forestry, and energy, and recognizes waste management as an area of environmental concern, though it does not set measurable targets or define specific mitigation actions for the waste sector. South Sudan has also developed its First National Adaptation Plan (2021), which emphasizes improving resilience to floods, droughts, and public health risks but does not mention bio-based technologies. As of 2025, no public progress reports on NDC implementation have been submitted to the UNFCCC.

Like the DRC, South Sudan does not have formal sanitary or environmental safety standards for biogas digesters, BSF systems, or composting facilities. Waste-related regulations are limited to general environmental provisions and municipal by-laws, which are unevenly enforced. Cross-sectoral engagement spans the ministries of Environment and Forestry, Water Resources and Irrigation, and Lands, Housing and Urban Development, but institutional linkages remain weak and fragmented.

²⁵ United Nations Framework Convention on Climate Change. (2017). South Sudan NDC submission.

In summary, both the DRC and South Sudan have ratified the Paris Agreement and prepared NDCs, signalling policy alignment with global climate objectives. However, progress toward their implementation remains limited, with no specific regulatory frameworks or technical standards for bio-based or circular waste technologies. In the absence of national standards, humanitarian and international donor frameworks continue to set the *de facto* environmental and safety benchmarks for waste management interventions in both countries.

E. Humanitarian Sector Governance

Humanitarian operations in both the DRC and South Sudan are governed primarily by a layered framework of international standards, donor requirements, and coordination mechanisms, rather than by national waste management legislation. In the absence of comprehensive or enforceable national solid waste management frameworks, humanitarian standards function as the *de facto* regulatory system for camp settings, influencing both operational practice and procurement choices.

At the global level, the Sphere Handbook (2018)²⁶ and the Core Humanitarian Standard (CHS, 2014; updated 2024)²⁷ provide the most widely accepted guidance on quality, accountability, and environmental responsibility. Although not legally binding, the Sphere standards are endorsed by UN agencies, the Red Cross and Red Crescent Movement, major INGOs, and most bilateral donors, giving them the status of a normative and practical benchmark that often complements, and in many cases substitutes for, local municipal or national regulations.

Within the Sphere framework, the WASH Chapter (Standard 5.1) establishes minimum requirements for the collection, segregation, treatment, and disposal of solid waste in humanitarian settings to minimize public health risks and environmental impacts. This standard provides an implicit policy foundation for introducing bio-based and circular solutions. Products such as mycelium-based packaging, compostable pouches, and PLA bottles are consistent with Sphere emphasis on reducing toxic and non-biodegradable waste, while technologies such as BSF systems and biogas digesters support compliance by converting organic waste into valuable resources, reducing vectors, and improving soil and water safety.

Moreover, the Core Humanitarian Standard (CHS, 2024 update) complements the Sphere Handbook through nine commitments underpinning quality, accountability, and responsible practice. Commitment 4 states that “communities and people affected by crisis access support that does not cause harm to people or the environment,” underscoring that all humanitarian activities, including waste management and product procurement, must avoid creating new environmental or

²⁶ Sphere Association. (2018). The Sphere Handbook.

²⁷ CHS Alliance. (2014). Core Humanitarian Standard on Quality and Accountability.

public-health risks. Commitment 9 requires agencies to “manage resources responsibly and use them for their intended purpose, while minimizing negative effects on people, the environment, and natural resources.” Together, these commitments provide a normative foundation for integrating environmentally sustainable approaches into humanitarian supply chains and field operations.

As the lead agency for camp coordination and management, UNHCR issues detailed guidance on solid waste management within its WASH²⁸ and shelter manuals. In many refugee and IDP settlements, it functions as the *de facto* regulator of waste systems, defining technical standards, approving landfill and composting sites, and contracting NGOs or private firms for collection and disposal. UNHCR’s procurement frameworks shape which products enter humanitarian supply chains, and larger-scale bio-based systems such as BSF or biogas digesters may require UNHCR’s technical approval, as they influence camp design, land use, and safety management.

At the donor level, the (DG ECHO) sets mandatory environmental conditions for all EU-funded humanitarian actions. Through the Minimum Environmental Requirements for Humanitarian Aid (MERS, 2020)²⁹, DG ECHO obliges partners to conduct environmental screenings, minimize and segregate waste, prioritize biodegradable or recyclable materials, and ensure proper disposal of residual waste in coordination with local authorities. These requirements apply across sectors, including WASH, health, and logistics, and are equally relevant in refugee and IDP camps. DG ECHO’s funding guidance explicitly encourages environmentally responsible procurement and could extend to supporting the implementation of BSF or biogas systems when they demonstrably improve environmental performance. In this way, donor funding and guidance act as governance levers, encouraging both humanitarian actors and host governments to adopt more sustainable, bio-based waste management solutions.

However, humanitarian import exemptions, whether framed through customs or tax codes, do not always extend to environmental or packaging-related standards. As a result, the importation of bio-based packaging, environmentally compliant materials, or specialized waste-management equipment may still require full conformity assessments, additional documentation, or supplementary regulatory clearances. In practical terms, technologies such as BSF units or anaerobic digestion systems may require temporary import waivers, sanitary approvals, or case-by-case authorizations. Early coordination with customs authorities and leveraging existing humanitarian facilitation mechanisms is critical to avoid clearance bottlenecks.

In the DRC, humanitarian waste management is guided by national cluster coordination under the Ministry of Environment and Sustainable Development, with provincial sanitation offices and local authorities providing oversight.

²⁸ United Nations High Commissioner for Refugees (UNHCR). (2015). WASH Guidelines.

²⁹ European Civil Protection and Humanitarian Aid Operations (ECHO). (2020). Minimum Environmental Requirements for Humanitarian Aid (MERS).

However, implementation remains weak due to capacity constraints. Humanitarian standards are typically stricter than national enforcement, with aid organisations applying donor-aligned procurement and waste-handling policies that exceed domestic legal requirements.

In South Sudan, humanitarian and donor standards function as the *de facto* regulatory framework. The national WASH Cluster, co-led by UNICEF and the Ministry of Water Resources and Irrigation, coordinates SWM activities in camps, health facilities, and host communities. The Sphere, MERS, and CHS standards guide operations in the absence of enforceable local legislation, with strong donor influence from ECHO, USAID/BHA, and the UN.

As highlighted in D3.3 Humanitarian Needs Assessment, humanitarian operations in both countries face the practical challenge that waste generated in camps and settlements often becomes indistinguishable from community waste once disposed, blurring accountability for environmental management. While humanitarian standards and donor frameworks provide robust operational guidance, their enforcement relies heavily on the internal policies of implementing organizations and coordination with local authorities.

Overall, humanitarian governance mechanisms provide a coherent though non-binding system for managing solid waste in crisis settings. These frameworks not only enable the adoption of sustainable waste management practices but also open a regulatory space for introducing bio-based products and technologies. The integration of such solutions into humanitarian procurement and infrastructure, if coordinated with national authorities, could gradually support the development of more formalized and locally owned waste governance systems in both countries. Systematic waste quantification remains rare in humanitarian reporting frameworks, with limited data on waste composition, treatment outcomes, or greenhouse gas impacts. Developing harmonized monitoring methods could support the integration of bio-based waste solutions and evidence-based environmental performance tracking.

F. Stakeholder Perspectives on Governance

The community engagement study (D6.2) collected stakeholder perspectives on governance and regulatory conditions in both the DRC and South Sudan through key informant interviews with government authorities, humanitarian actors, businesses, and academia. These perspectives can support the legal analysis by showing how communities and different stakeholders view these aspects.

Democratic Republic of the Congo

In the DRC, stakeholders confirmed that multiple laws and regulations relevant to bio-based solutions exist, including: the 2011 Environmental Protection Law, the 2015 Hygiene Code, and regulations from 2013 and 2016 including the provincial decree on sanitation of urban areas. At the same time, technology-specific legislation is absent, there is no biogas-specific legislation, and no laws on BSF exist in the DRC, though AALI reported being in the process of proposing a law to the government in collaboration with INERA and the Ministry of Agriculture.

The 2017 decree banning plastic sachets illustrates the gap between policy and enforcement. Local producers of alternatives described their frustration that the decree “is not implemented and does not support us,” while another stakeholder explained that “there is no substitute that can cover the demand, so the ministry is looking for the substitute.” This shows that regulatory enforcement may depend on the availability of viable market alternatives and suggests, that scaling local production of bio-based substitutes could directly enable stronger enforcement. Recent political engagement suggests potential for change, with the Minister of Environment meeting young entrepreneurs in January 2025 to discuss local bio-sachet production.

Several institutions expressed their support for bio-based solutions. INERA provides space, training, and larvae for BSF development free of charge. Provincial-level institutions (HSO, AGRIPPEL, DPS) expressed readiness to issue recommendations, accompany mini-factory installations, and integrate bio-based solutions into existing health and agricultural programming. The OCC is the primary standards body for product quality and imports, and stakeholders confirmed that products must be tested by the OCC to confirm biodegradability and composition. For nutrition and medical products, additional authorization is required through ACOREP, which oversees imports of nutritional and medical items.

Humanitarian stakeholders that were interviewed in the DRC were clear about the fact that adoption within humanitarian programming depends on donor procurement rules and cluster standards. Donors often maintain recommended supplier lists, and organizations cannot procure from suppliers not on these lists. Also, WHO standards influence packaging requirements for food and medical products. At the same time, several humanitarian actors noted that internal organizational environmental policies (such as ACTED’s CAROOT zero-carbon policy and WFP’s environmental policy³⁰) could support institutional demand for biodegradable alternatives.

Moreover, taxation was often mentioned as a barrier to scaling, with the tax system being fragmented, and with formal and informal taxes payable to various departments. Tax exemptions for innovations reportedly exist (2-3 years) but are not systematically applied. Several stakeholders also warned of potential resistance from established plastic importers with political connections, saying

³⁰ World Food Programme (WFP). (2017). Environmental Policy. https://executiveboard.wfp.org/document_download/WFP-0000037327

that plastic bottle importers “may resort to corruption to block these bottles” and that “politico-administrative and military authorities” could be leveraged to block competing bio-based products at borders.

Finally, in conflict-affected areas of North and South Kivu’s, formal governance capacity is limited - according to those interviewed, the M23 occupation disrupted licensing systems, regulatory oversight, and compliance monitoring.

South Sudan

In South Sudan, stakeholders at all levels described the regulatory framework as weak or incomplete. Yei authorities described it as “weak enforcement of environmental laws and waste management by-laws” while the County Health Department Director identified “policy and regulation gaps, absence of clear waste management policy and enforcement mechanisms”. The S/NFI Cluster representative said that “South Sudan is a new country, there is not many existing legislations” and that the legislative process can take years.

Despite these gaps, political will exists at local and national levels. Yei County and Juba City Council authorities confirmed readiness to host pilots and provide land for installations. The Ministry of Environment welcomed bio-based solutions, identified concrete waste streams, and highlighted the issue of waste segregation being a foundational prerequisite. The Ministry confirmed that a National Environment Bill incorporating circular economy provisions is under review, expressing hope for its enactment and noting that “once the bill is enacted, the enforcement will take place.”

Stakeholders that were interviewed also confirmed that the tax framework creates a structural disincentive for local production. The NRA representative confirmed that humanitarian actors receive tax exemptions on imported goods, while local suppliers pay taxes, which creates an incentive to import rather than procure locally.

Given the above, humanitarian system governance plays important role. The Health Cluster representative emphasized that adoption of solutions like compostable RUTF sachets would need to be “introduced on the higher level, maybe global WHO or global UNICEF,” with pharmaceutical company testing as a prerequisite. The S/NFI Cluster representative also confirmed that UN procurement standards are very strict and not harmonized across sectors, and that donor agreement is essential for any new solution. The Health Cluster representative also articulated an ethical tension specific to acute emergency contexts: “In case of emergency, famine, cholera there are other problems than the environment” suggesting that the adoption pathway for environmentally motivated substitutions may be more viable during stable programming phases than during acute emergency response.

Across both contexts, stakeholders indicated that regulatory engagement is often relationship-driven and may depend on demonstrating pilot success before formal regulatory pathways are established. Health sector pathways were identified as potentially the most structured - in the DRC through PRONANUT for RUTF sachets and the Ministry of Health for mosquito nets, and in both countries through established cluster validation mechanisms. Early engagement with donors, UN agencies, and cluster technical working groups was identified as critical for accelerating adoption pathways.

G. Legal Feasibility Assessment by Solution

The preceding analysis of national legal frameworks, international regulatory benchmarks, humanitarian governance standards, and stakeholder perspectives allows for a preliminary legal feasibility assessment for each solution category. This assessment reflects the current regulatory environment and does not account for potential future legislative developments.

In the DRC, recycling and plastics-related interventions are feasible in principle but rely heavily on the informal sector and face weak infrastructure. Composting has been demonstrated at pilot level and is legally feasible with local authority endorsement. Biogas and anaerobic digestion are possible under general environmental law, though implementation requires secure sites, operational capacity, and an environmental authorization and EIA in accordance with Decree 14/019 (2014). BSF is technically feasible at pilot level, but feed and frass use will require coordination with the Ministry of Agriculture and veterinary authorities for sanitary clearance, as no insect-feed or frass-use standards currently exist; AALI is actively working on draft legislation. It should be noted that although compost is formally recognized as a fertilizer in the DRC, the country still lacks a comprehensive national regulatory framework governing fertilizers and soil-improvement inputs. While existing provisions allow compost, digestate, and BSF frass to be treated as organic agricultural inputs, their classification remains ambiguous and subject to ministerial interpretation, limiting their full commercialization potential. Compostable packaging (including RUTF sachets, PLA bottles, and biodegradable bags) is not currently feasible at scale due to the absence of compostable packaging certification, industrial composting infrastructure, and end-of-life management systems, though individual solutions may be viable in niche applications with controlled end-of-life pathways, such as health facility waste management.

In South Sudan, recycling and plastics interventions are feasible through local by-laws, though implementation is constrained by limited capacity, and the feasibility of any plastics-related intervention must account for the regulatory volatility around announced but unenforced plastic bans. Environmental Impact Assessments are mandated under the Environmental Protection Act (2016) for

projects with significant environmental impact, including waste facilities. Composting is feasible and practised at small scale, aligning with humanitarian environmental requirements; local authorities regulate solid waste under the Local Government Act (2009), and UNEP confirms they must approve waste-sector operations. The Juba City Council and Ministry of Environment both recommended specific pilot locations and identified waste streams that could support bio-based initiatives. Biogas is feasible at pilot level under general safeguards with no dedicated standards, and operational precedent exists through the Kaku Sanitation Services commercial model and the Yei Hospital institutional installation. BSF is possible under local approvals and is not explicitly regulated, with operational precedent from the UNHCR-supported pilot in Yei. Compostable packaging is not feasible given the lack of composting infrastructure and the complete absence of any regulatory pathway (no definitions, certifications, or labelling rules exist).

Severe infrastructure limitations apply across both countries. Waste systems rely on open dumping, and no industrial composting or formal recycling exists at scale. In both countries, the absence of dedicated regulatory frameworks for bio-based solutions means that imported compostable or biodegradable products are effectively unregulated after arrival. Their environmental benefits thus depend on voluntary adoption of end life practices, which confirms the finding from D6.2 Community engagement study, that product introduction must be accompanied by investment in composting infrastructure and community education.

Integrated governance analysis and implications for bio-based solutions in the DRC

The governance context for waste management in the DRC is characterised by a dual dynamic combining the presence of a formal legal framework with significant operational limitations. On one hand, the country has established a set of overarching regulatory instruments, including the Environmental Protection Law (2011), the Hygiene Code (2015), and the plastic bag ban (2017) in some provinces especially in North and South Kivu, which collectively provide a general legal basis for environmental protection and pollution control. These frameworks introduce important principles, such as the polluter-pays principle, and signal political recognition of waste management challenges. On the other hand, these instruments remain largely framework-oriented and do not translate into detailed operational requirements for waste management systems, such as mandatory waste separation, recycling obligations, or clearly defined treatment standards. The general legal framework is in place in the DRC; however, the detailed operational requirements (mandatory sorting, recycling targets, uniform technical standards for processing) remain incomplete or are not sufficiently implemented through specific, enforceable regulations. For more specific requirements, one must look to ministerial decrees and sector-specific measures. For example, in Kinshasa, REGEDEK refers to the application of the ministerial decree of 9 April 2018, which makes the separate collection of household and similar waste

mandatory and regulates authorised operators. However, this provincial decree is not being enforced³¹.

As a result, the governance system is not primarily rule-driven but rather shaped by institutional capacity, local practices, and the involvement of non-state actors. Responsibilities for waste management are distributed across multiple levels of government, including municipal, provincial, and national authorities, often with limited coordination and insufficient financial and technical capacity. This fragmentation is reflected in low service coverage rates, particularly in urban areas such as Kinshasa, and even more so in rural and peri-urban settings. In practice, waste management is largely carried out by informal and semi-formal actors, including private operators and community-based “synergies”, which play a central role in waste collection and recovery. However, due to the absence of formal treatment infrastructure, most waste ultimately ends up in open dumpsites, limiting the effectiveness of these collection efforts.

Within this context, several structural barriers affect the development and implementation of bio-based solutions. These include gaps in the operationalisation and enforcement of regulatory frameworks for biodegradable and compostable materials, limited alignment and application of certification systems and technical standards (under the responsibility of OCC and relevant ministries), weak enforcement of existing policies such as plastic bans, and the near absence of infrastructure for waste segregation and treatment. Together, these factors constrain the environmental effectiveness and scalability of bio-based solutions, as their performance depends heavily on appropriate end-of-life management conditions that are currently not in place.

At the same time, the governance context also presents a number of enabling factors. The existence of a general environmental legal framework provides policy legitimacy for environmentally sustainable interventions, while the plastic ban, even if weakly enforced, signals a policy direction that favours alternatives to conventional plastics. The absence of strict and prescriptive regulations lowers entry barriers for innovative solutions, allowing for piloting and experimentation. Furthermore, the presence of informal and private waste collection systems offers an operational base that could potentially be leveraged for decentralised waste management approaches, including composting or bio-waste valorisation. The high organic fraction of municipal waste also increases the technical relevance of bio-based and circular solutions. In addition, the lack of entrenched waste management infrastructure creates opportunities for leapfrogging towards alternative systems, particularly if supported by external actors such as humanitarian organisations, which often play a key role in shaping operational standards and procurement practices.

Taken together, these dynamics can be summarised as a governance system that is permissive but not supportive. While there are no significant regulatory barriers

³¹ [Kinshasa : la REGEDEK impose des normes strictes pour la collecte des déchets – Congo Profond](#)

preventing the introduction of bio-based solutions, there is also no structured system in place to ensure their proper use, management, and scaling. This creates a situation in which bio-based solutions are technically and legally feasible, particularly at pilot level, but their environmental and socio-economic benefits are not guaranteed.

The implications of this governance context extend beyond technical feasibility and directly affect socio-economic outcomes. The absence of formal waste management systems leads to the externalisation of costs to communities and the environment, while the reliance on informal actors raises concerns related to working conditions, income stability, and social protection. At the same time, the complexity and fragmentation of the regulatory framework create market uncertainty, limiting investment and hindering the development of local value chains for bio-based products. While verification and certification processes formally exist - involving the OCC and multiple ministries depending on the product or technology - the multiplicity of actors and procedures reduces clarity and predictability for market participants. As a result, many solutions risk remaining dependent on imports and external support, rather than contributing to the development of local circular economies.

Overall, the feasibility of bio-based solutions in the DRC depends less on regulatory approval and more on their ability to operate within, or compensate for, systemic governance gaps. At the same time, socio-economic conditions - particularly the limited purchasing power of end users and local actors - represent a critical determining factor, as more expensive alternatives are unlikely to be adopted or sustained in contexts where financial capacities are highly constrained. This implies that successful implementation requires a system-oriented approach that goes beyond product substitution and includes considerations related to waste management infrastructure, stakeholder engagement, affordability, and end-of-life management. Without such complementary measures, bio-based solutions may be introduced but will not achieve their intended environmental and socio-economic impacts.

Integrated governance analysis and implications for bio-based solutions in South Sudan

The governance context for waste management in South Sudan is shaped by a nascent institutional framework, prolonged political instability, and limited state capacity following years of conflict. While environmental protection and public health are referenced in national policy frameworks - such as the Environmental Protection Act (2013) and sectoral policies under health, urban development, and local government - waste management remains weakly regulated and largely underdeveloped in practice. Existing legal instruments provide only broad principles and do not set out detailed operational requirements for waste

segregation, treatment standards, recycling obligations, or extended producer responsibility.

As a result, waste management governance in South Sudan is highly fragmented and practice-driven rather than rule-based. Responsibilities nominally lie with municipal and county authorities, but these institutions face severe constraints in terms of financing, technical expertise, equipment, and administrative reach. Formal waste collection services are extremely limited, particularly outside central areas of Juba, and are virtually absent in secondary towns and rural settlements. Waste management in practice relies heavily on informal arrangements, community-level initiatives, and ad hoc private service providers, often operating without regulatory oversight. Most waste is disposed of through open dumping or burning, posing significant environmental and public health risks.

Within this governance environment, the implementation of bio-based solutions faces several structural barriers. These include the absence of regulatory frameworks for biodegradable and compostable materials, a lack of product standards and certification mechanisms, minimal enforcement capacity, and the near-total absence of infrastructure for waste segregation and organic waste treatment. Bio-based solutions that depend on controlled end-of-life conditions - such as composting, anaerobic digestion, or bio-waste valorisation - are therefore difficult to scale sustainably. In many cases, their environmental performance risks being undermined by inappropriate disposal practices.

At the same time, the governance context in SSD also presents enabling conditions. The lack of rigid or prescriptive regulation lowers formal entry barriers for piloting innovative and decentralised bio-based solutions. Humanitarian and development actors play a central role in service provision, procurement, and standard-setting, creating potential leverage points for introducing alternative materials and circular approaches within camps, institutions, and aid-supported urban services. The high organic content of municipal and market waste further increases the technical relevance of composting and other bio-waste recovery solutions, particularly at small or community scale.

Moreover, the limited existing waste management infrastructure creates opportunities for leapfrogging, allowing bio-based and decentralised systems to be integrated without competing against entrenched, capital-intensive alternatives. Community-based and informal waste actors, while operating under challenging conditions, could form the basis for locally adapted circular economy models if supported through training, basic equipment, and demand-side incentives.

Overall, the governance system in South Sudan can be characterised as permissive but weakly supportive. There are few explicit regulatory barriers to the introduction of bio-based solutions, but also no institutional mechanisms to ensure their consistent performance, environmental integrity, or long-term sustainability. As a result, such solutions are technically feasible - particularly in

pilot or humanitarian settings - but their broader environmental and socio-economic benefits are uncertain.

The implications extend beyond technical feasibility to socio-economic outcomes. Weak governance and reliance on informal systems externalise environmental and health costs to communities, while offering limited income security or protection to waste workers. The absence of standards and certification also creates market uncertainty, discouraging private investment and limiting the development of local value chains for bio-based products. Consequently, many initiatives remain dependent on donor financing and imported inputs.

In this context, the feasibility of bio-based solutions in South Sudan depends less on regulatory approval and more on their ability to operate within, and partially compensate for, systemic governance and infrastructure gaps. Affordability and financial sustainability are critical, given the very limited purchasing power of households and local institutions. Successful implementation therefore requires a system-oriented approach that integrates bio-based solutions with waste collection practices, community engagement, market development, and end-of-life management. Without such complementary measures, bio-based solutions are unlikely to achieve durable environmental or socio-economic impact.

V. Life Cycle Costing

To complement the governance analysis, a Life Cycle Costing (LCC) assessment was conducted to examine the economic feasibility of implementing bio-based solutions. Drawing on cost data provided by the humanitarian partners PIN and PAH for conventional items and market data for solutions, this analysis evaluates the potential impact of bio-based alternatives on the overall cost of humanitarian kits. The results indicate that integrating bio-based items leads to a moderate increase in kit costs. However, when robust conventional secondary packaging is replaced with mechanically constrained bio-based packaging solutions, the cost increase can become significant, highlighting the need to carefully balance economic, functional, and governance considerations.

A. Introduction

Life Cycle Costing (LCC), also known as whole-life costing (WLC), is a method used to calculate the costs associated with the entire life cycle of a product or service, from raw material extraction to end-of-life.

The first uses of this approach appeared in the USA during the 1960s, where the Department of Defence applied LCC to defence systems such as aerial and ground vehicles³². Since then, the method has continuously evolved and has been extended to various industrial sectors.

³² Sherif, Y.S.; Kolarik, W.J. Life Cycle Costing: Concept and Practice. *Omega* 1981, 9, 287–296, doi:10.1016/0305-0483(81)90035-9.

The analysis considers all life cycle stages relevant to the product in question, usually in reference to a specific stakeholder. Economic analysis has become increasingly important across all sectors, and LCC is one of the most suitable tools for informed decision-making thanks to its life-cycle-wide perspective.

Unlike environmental Life Cycle Assessment (LCA), which is standardised internationally through ISO 14040 and 14044 for evaluating environmental sustainability (ISO, 2006a, 2006b), LCC does not yet benefit from a single global standard. Although several guidelines and standards exist for LCC, such as UNE 60300-3-3:2017, BS 3843-3:1992, and AS/NZS 4536, these tend to be sector-specific, often focusing on industries like construction (e.g., ISO 15686, Davis Langdon Management Consulting, 2007) or fossil fuels (ISO 15663:2021). This specialisation can complicate the consistent application of LCC across different fields. To help address this, the SETAC LCC Working Group and Task Force have developed core principles for environmental LCC (eLCC), as discussed by Hunkeler et al. (2008)³³ and Swarr et al. (2011)³⁴.

In the EU, efforts have been made to establish a framework to promote the use of full economic LCC (feLCC) within public procurement. This approach includes costs borne not only by the contracting authority but also by other users, covering acquisition, operation (energy and resource consumption, maintenance), and end-of-life phases. It also factors in environmental externalities such as greenhouse gas emissions, climate mitigation costs, and other pollutant-related expenses. These principles are embedded in directives such as 2014/24/EU (Article 68), 2014/25/EU (Article 83), and 2009/33/EC (policy measure 2c). However, methodological differences and inconsistencies remain across these documents, highlighting the need for further harmonisation (Bianchi et al., 2021).³⁵

Because of its life cycle perspective, LCC offers a valuable means to assess economic aspects within Life Cycle Sustainability Assessment (LCSA). Still, it has faced criticism for focusing too narrowly on costs, often overlooking broader economic factors like value creation and growth (Gluch and Baumann, 2004³⁶; Wood

³³ Hunkeler, D.; Lichtenvort, K.; Rebitzer, G. *Environmental Life Cycle Costing*; CRC Press, 2008; ISBN 9780429140440.

³⁴ Swarr, T.E.; Hunkeler, D.; Klöpffer, W.; Pesonen, H.-L.; Citroth, A.; Brent, A.C.; Pagan, R. Environmental Life-Cycle Costing: A Code of Practice. *Int. J. Life Cycle Assess.* 2011, 16, 389–391, doi:10.1007/s11367-011-0287-5.

³⁵ Bianchi, M.; Bachmann, T.M.; van der Kamp, J.; Riemer, M.; Riva, F.; Préat, N.; Taelman, S.E. D1.3 Critical Evaluation of Economic Approaches – Orienting. *Orienting D1.3 Publ.* 2021, 1–84.

³⁶ Gluch, P., & Baumann, H. (2004). The life cycle costing (LCC) approach: A conceptual discussion of its usefulness for environmental decision-making. *Building and Environment*, 2004, 39(5), 571-580. <https://doi.org/10.1016/j.buildenv.2003.10.008>

and Hertwich, 2013³⁷). To expand the economic evaluation, Neugebauer et al. (2016)³⁸ proposed a wider set of impact categories - including profitability, productivity, business diversity, and long-term investment - that bring the economic dimension closer to the comprehensive approach of LCA, especially during the impact assessment phase. They called this expanded framework an “economic LCA” to distinguish it from traditional eLCC. Building on this, Arulnathan et al. (2023)³⁹ proposed specific indicators aligned with these categories to make this broadened economic evaluation more practical within LCC.

The economic assessment of the project was carried out using the Net Present Value (NPV) approach within the Life Cycle Costing (LCC) framework. NPV allows all future costs to be converted into present values by applying appropriate discount and inflation rates. This method ensures a consistent comparison of costs over time, accounting for investment, operating, and maintenance expenses. As a result, the analysis provides a clear and consolidated view of the project’s overall economic performance.

B. Objectives and scope

The objectives of such a study should always be clearly defined, including the intended audience and the expected use of the results. It is also important to establish the scope of the study as well as any constraints that may affect its implementation.

The first goal of this LCC study is to evaluate the economic feasibility of bio-based solutions identified in WP4, thus identifying the relevant contributors to costs. The LCC allows for the identification of hotspots and the evaluation of potential cost-reduction measures.

The second goal of this LCC study is to benchmark the bio-based solutions with the reference scenario. For this, primary data have been collected from humanitarian organisations regarding the reference items and packaging used for the aforementioned kits. The definition of reference kits is given in D5.1⁴⁰.

An Excel-based tool was developed to support this LCC study. The tool is intended as a decision-support tool, not as a precise cost forecasting model. Its main purpose is to compare different options and understand how costs change as key parameters are modified. The tool is attached as an Annex A.

³⁷ Wood, R. & Hertwich, E. Economic modelling and indicators in life cycle sustainability assessment; *Int J Life Cycle Assessment*, 2013, 18, 1710-1721. <https://doi.org/10.1007/s11367-012-0463-2>

³⁸ Neugebauer, S., Forin, S. and Finkbeiner, M. (2016) “From life cycle costing to economic life cycle assessment-introducing an economic impact pathway,” *Sustainability (Switzerland)*, 8(5). Available at: <https://doi.org/10.3390/su8050428>.

³⁹ Arulnathan, V. et al. (2023) “Economic Indicators for Life Cycle Sustainability Assessment: Going beyond Life Cycle Costing,” *Sustainability (Switzerland)*. MDPI. Available at: <https://doi.org/10.3390/su15010013>.

⁴⁰ <https://bio4human.eu/wp-content/uploads/2025/07/Bio4HUMAN-D5.1-FV-for-resubmission.pdf>

The tool allows users to select kit items, packaging options, transport modes (road, sea, air, helicopter), storage duration, and country context. Based on these selections, it calculates and compares total costs from the perspective of humanitarian organisations.

Given the limited data availability and uncertainty typical of humanitarian operations, the tool is used for comparative analysis and scenario testing rather than exact cost estimation. All assumptions, unit costs, and calculations are transparent and can be adjusted by the user.

This assessment is complementary to the environmental LCA conducted in WP5, and to S-LCA, also developed in WP6. Thus, a complete life cycle sustainability assessment is conducted to find the most suitable solutions in the scope of the Bio4HUMAN project.

1. Alignment between LCA and LCC

When a LCA is conducted in parallel to an LCC, it is essential to align both the environmental and economic analyses with the same objectives, scope, and functional unit.

The kits' composition has been defined in D5.1 and adjusted in D5.3. *Identification of the best available innovative solutions based on environmental LCA.* As defined in D5.3, the functional units of items and packaging materials that could be replaced are the following:

Table 5 Functional units of selected solutions and their reference item

Solution Item	Reference scenario substitution	Functional Unit	Type of kit	Reference flow of reference scenario	Reference flow of bio-based solution
PLA bottle for water	LDPE Water container without logo	10-litre water container(s) capable of storing and dispensing water	Primary Packaging in WASH basket	1*210g of PE	5*69g of PLA
PLA bottle for oil	HDPE jerry cans	6-litre oil container(s) capable of storing and dispensing edible oil	Primary Packaging in Food basket	2*157g de HDPE	3*69g of PLA
Compostable sachet for RUTF	Metallized sachets	To contain 92 g RUTF	Primary Packaging in Food basket	5g of RUTF pouch	4.2g of RUTF pouch
PLA + natural adhesive	Adhesive tape	1 m ² of adhesive tape	Tertiary packaging in all kits	54,56g of regular tape	50.7 gr of bio-based tape
Biodegradable laminating film	PE film for tertiary packaging	1 m ² of film to be used as tertiary packaging	Tertiary packaging in all kits	27,6g of HDPE film	37.2 gr of bio-based film

Mycelium protective material	Expanded PS	Inserts, designed to fit a standard U.S. Postal Service shipping box (31.12 × 30.48 × 15.24 cm)	Packaging for fragile goods	0.286 kg of expanded PS	1.4 kg of mycelium
Disposable bag from renewable sources	PP/PE bag	To contain 10 kg	Primary packaging in all kits	10.69 g of HDPE film and PP (double layer)	10,621g * 50 bags of bio-based bag material
Foams for insulation	Glass wool	To thermally insulate 1 m ² of surface with an R=1 W/m ² K	Construction material	2.6kg of glass wool	1.72kg of bio-based PUR foam
Wool Insulation material	Glass wool	To thermally insulate 1 m ² of surface with an R=1 W/m ² K	Construction material	2.6kg of glass wool	1.1kg of sheep wool insulation
Bio-based insulation	Glass wool	To thermally insulate 1 m ² of surface with an R=1 W/m ² K	Construction material	2.6kg of glass wool	1.76kg of hemp-based insulation
Organic disposable Sanitary pads with wings	Female disposable sanitary pads with wings	Covering the needs of a menstruating person for one year	Wash kit	0.01*240=2,40 kg of regular pads material	0.0095*240=2,28kg of cotton and bio-based plastics
Monofilament s fishing nets/Mosquito net	Mosquito net	Provide protection for one person for one year	Non-food item kit	206.4 g of polyester mosquito net	240.8 g of PLA mosquito net

2. Analysis period

The analysis period is also one of the parameters to fix during an LCC. It refers to the timeframe considered in the economic assessment; this period accounts for the relevant costs and benefits associated with the system analysed. The analysis period may differ from the expected lifespan of a product because economic projections over long timeframes involve greater uncertainty. Furthermore, it is important to note that future expenditures and revenues diminish in value compared to present values, a factor addressed through the use of a discount rate. As a result, costs projected far in the future contribute progressively less to the overall economic outcome. In the present study, however, this effect is negligible because most costs occur in the same year. Consequently, the application of a discount rate does not significantly influence the final cost results.

The analysis period is 2025, which is the time period within which the costs were collected by humanitarian aid organisations, to evaluate the costs of kits' items, transportation, and storage. The costs of packaging are based on material market costs from 2024-2025.

To ensure transparency and clarity in the LCC approach, the main methodological choices and assumptions applied in this assessment are summarised in Table 6.

Table 6 Methodological choices and assumptions of the Life Cycle Costing (LCC) assessment

Question	Answer
From which perspective is the economic assessment intended to be undertaken?	The economic assessment will be addressed in the context of the humanitarian organizations. Therefore, based on the origin of the primary information obtained, the selected perspective corresponds to the “intermediate consumers”.
Will only costs be considered or also positive cash flows (e.g. revenues)?	Only negative cash flows.
Will only private effects be considered or also external effects? If so, in which way will they be monetized?	External effects (such as monetized environmental or social impacts) will not be considered. Only private effects (such as investment, operation and maintenance expenses).
Can available, but confidential data be used?	Primary data from humanitarian organizations are used and generic data from bio-based innovative solution providers.
Which time horizon is considered?	2025.
Is discounting of future cash flows (and also externalities) envisaged?	This effect is negligible in this study because most costs occur in the same year.
Which life cycle stages are intended to be distinguished?	Production (including raw materials and manufacturing), distribution, and storage.
Will capital goods (infrastructure and equipment) and overhead costs be considered?	Capital goods and overhead costs were not included due to limited data availability and the difficulty of obtaining reliable and comparable information across humanitarian organisations and solutions.

C. LCC Inventory

The LCC of materials includes the production and manufacturing costs, as well as the storage and transportation costs. End-of-life (EoL) costs are more complex, as each material follows a different EoL pathway. For example, food consumables (aside from their packaging) do not generate EoL costs within the humanitarian supply chain, whereas disposable items such as sanitary pads are discarded after use and may incur environmental and health impacts. In addition, the exact lifespan of several non-consumable items was not available. For these reasons, EoL costs were not included in the assessment. The following section evaluates the costs incurred at each included life cycle stage.

1. Packaging and Item cost

A cost database was established for packaging materials. The estimated cost of kit items was acquired from PIN and PAH. Since the cost of packaging was not differentiated from the cost of the items themselves, an estimation approach was required. The amount of packaging for each item was first estimated, and the cost of packaging materials was then calculated based on publicly available cost ranges. To avoid over- or underestimation, minimum, average, and maximum values were considered. The estimated packaging cost was subsequently deducted from the total item cost to derive the cost of the item itself. The formula below explains this calculation:

Primary data have been collected from PIN and PAH for the reference kits used in both SSD and the DRC. For the bio-based innovative solutions and packaging, market data have been used. Details of the market prices for packaging are given in USD in the table below.

Table 7 Packaging market price

Type of packaging	Min price	Average	Max price	Unit	Source
Film PE/LDPE/LLDPE	1,18	1,555	1,93	USD/kg	D5.1
Cardboard	0,2	0,245	0,29	USD/kg	https://businessanalytiq.com/procurementanalytics/index/corrugated-paper-price-index/
PP bag	1,13	1,315	1,5	USD/kg	https://salesplastics.com/polypropylene-price-per-kg/ https://businessanalytiq.com/procurementanalytics/index/polypropylene-price-index/
PE liner	1,28	1,34	1,4	USD/kg	https://businessanalytiq.com/procurementanalytics/index/polyethylene-price-index/
Metallized sachets	0,02	0,115	0,21	USD/unit	D5.1
Wood pallet	0,642	0,963	1,284	USD/kg	D5.1
HDPE	1,07	1,175	1,28	USD/kg	D5.1
Tape	6,46	13,075	19,69	USD/kg	D5.1
Polyester straps	1,5	2,5	3,5	USD/kg	D5.1
Polycotton canva	4	7	10	USD/kg	D5.1
Master bundle	1	3	5	USD/unit	D5.1
Biodegradable film	7,02	8,19	9,36	USD/kg	D5.1: Between 6 and 8€/kg of film
PLA + natural adhesive tape	26,49	27,15	27,81	USD/kg	D5.1: Between 1.786 1.875 €/unit. In 1 unit there is approximately 80m*0.05m= 4m ²
Bio-based bag	2,23	2,87	3,5	USD/kg	D5.1
PLA bottle for oil and water	0,65	0,70	0,75	USD/unit	69g/unit for 2L:3*69 for 6L
Pouch for RUTF	0,055	0,055	0,055	USD/unit	210 Metallized sachets/kit
Organic Sanitary pads	2,5	2,5	2,5	USD/unit	30 pads at 6 USD
Mosquito net	10,53	10,53	10,53	USD/kg	D5.1: 9€/kg

2. Storage and Delivery Costs:

The storage cost is considered to be 20,83 USD/m³.month according to PIN and PAH.

Given that the source of kits and the type of delivery may differ, the tool provides three modes of transport: road, sea, and air. Air transport includes the option of

helicopter transport for emergency situations as well as plane. The prices for each transport mode are presented in the following table.

Table 8 Delivery costs by different means of transport

Delivery Type	Cost
Road	7,31E-4 USD/kg.km
Sea	3,75E-4 USD/kg.km
Air, Plane	1,43E-2 USD/kg.km
Air, Helicopter	Manual input (no cost could be acquired)

3. Kits Costs

To compare the prices of the bio-based solutions and packaging with the reference materials, the following comparison is made. In this comparison, storage time and transportation time are not considered, as it is assumed for this case study that changes in materials and packaging do not considerably affect storage requirements or volume. If these parameters change in other contexts, please use the tool developed to assess the results.

a) WASH kit

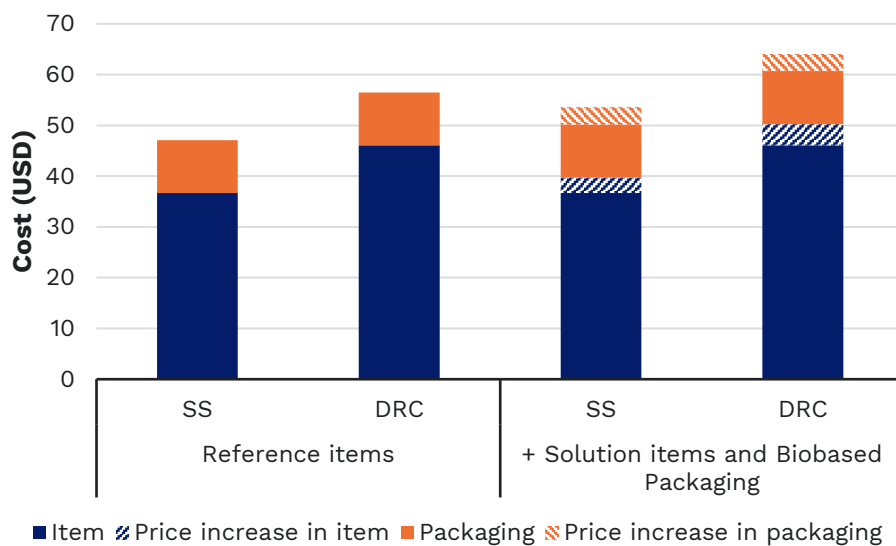


Figure 1 WASH kit cost comparison

South Sudan (SSD)

The whole WASH reference kit is \$47.1, and with the implementation of biobased items, the cost of the item is expected to increase by \$3.08 (+6.5%). With the packaging also replaced by bio-based packaging, the cost increases by an additional \$3.36 (+7.1%), with the total price reaching \$53.54 (+13.7%).

By replacing some of the reference items with the proposed solutions, some components, such as the water container without a logo, became slightly cheaper. However, the cost of sanitary pads increased substantially, driving the overall rise in cost.

Democratic Republic of Congo (DRC)

In the DRC, the biobased WASH kit is priced at \$56.5 overall. Introducing biobased items adds \$4.18 (+7.4%), bringing the price to \$60.68. If biobased packaging is also included, the overall price increases by an additional \$3.36 (+5.9%), with the total price reaching \$64.04 (+13.3%).

Similar to the kit in SSD, the increase in price of the sanitary pads offsets the small savings from the water container.

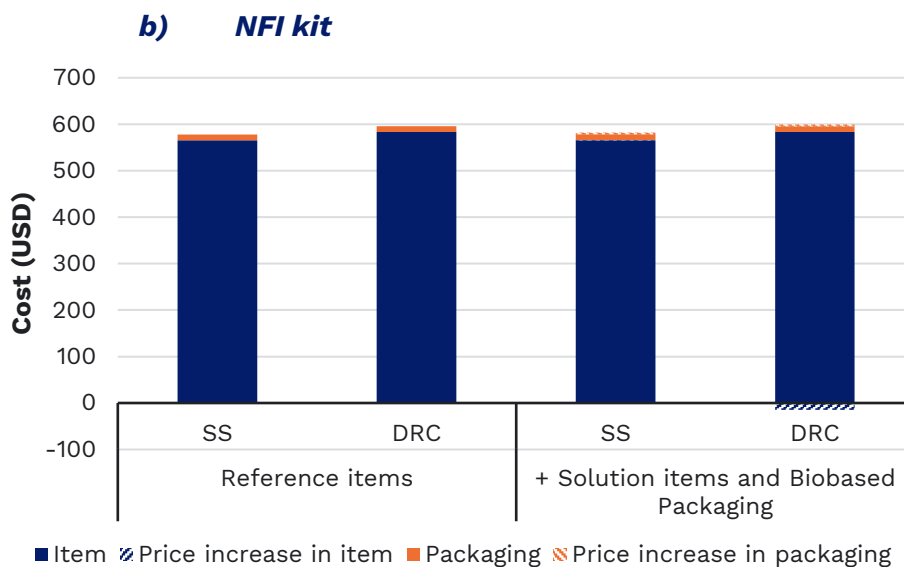


Figure 2 NFI kit cost comparison

South Sudan (SSD)

The cost of the reference NFI kit is \$578, with the majority of the cost driven by the tent accounting for \$391, and the rest is from kitchen sets and sleeping mats. When the biobased items replace the reference items, the change in price is negligible. If the biobased packaging is also used, the packaging cost increases slightly by \$3.28 (+.6%), making the total price \$581.74.

Democratic Republic of Congo (DRC)

For the DRC, the NFI cost is \$596. By including the biobased items, the price decreases by \$14.54 (-2.4%) and with the biobased packaging, it increases by \$3.28 (+0.5%), making the total price \$584.74. This cost reduction is mainly due to significantly lower item purchase costs (for Jerry cans and Mosquito nets).

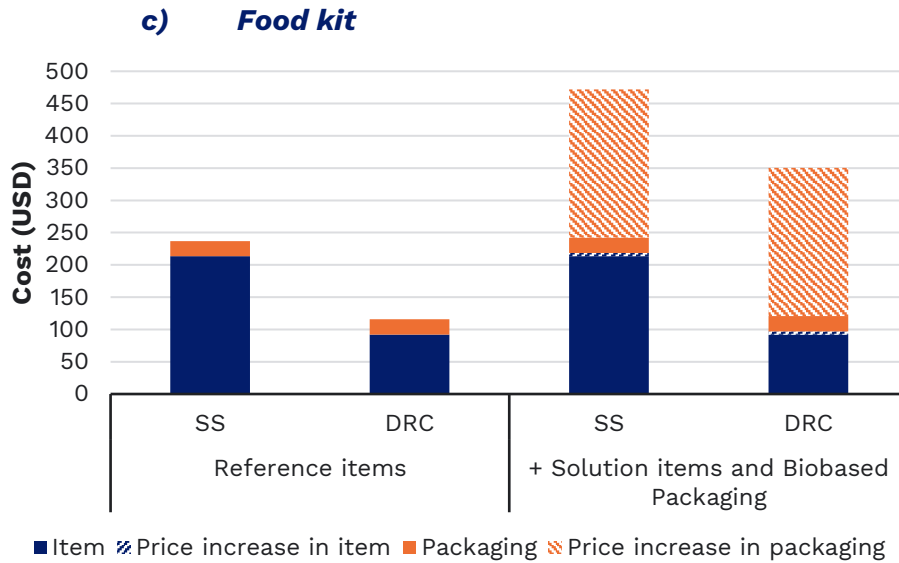


Figure 3 Food kit cost comparison

South Sudan (SSD)

The food kit cost is \$237. If the primary packaging of the RUTF sachet is replaced, the overall cost increases by \$5 (+2.1%), whereas if the secondary packaging is also replaced, the total cost increases by \$229 (+96%). The high price increase results from the assumption that large quantities of small bio-based packaging are required. This assumption is not realistic and, as explained in detail in D5.3, reflects the limited functionality of the bio-based bag option assessed in this study.

Democratic Republic of Congo (DRC)

The food kit for DRC is \$115. The increase in cost for the primary, secondary and tertiary packaging is the same as SSD, for RUTF it is \$5 (+4.34%) and for secondary and tertiary packaging it is \$229 (+199%).

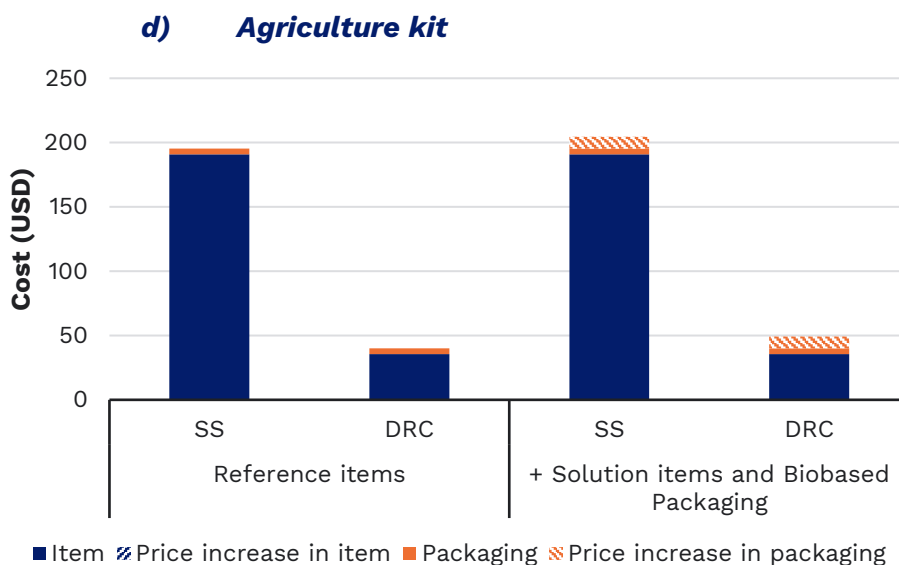


Figure 4 Agriculture kit cost comparison

South Sudan (SS)

The price of the agriculture kit is \$195.3, and since no biobased item was proposed for this kit, only the packaging was replaced with biobased packaging, which increases the cost by \$9.17 (+4.7%).

Democratic Republic of Congo (DRC)

The kit price for DRC is \$40, and if biobased packaging is included, the price increases by \$9.17 (+22.9%).

Overall, packaging represents only a small share of the total reference kit cost and replacing it with bio-based packaging does not significantly increase the total cost. Item-level changes are more difficult to interpret because only a limited number of items were substituted; however, these substitutions also lead to only modest cost variations.

D. Limitations of the LCC Assessment

This LCC assessment was conducted in a humanitarian context characterised by data scarcity, operational variability, and short planning horizons. As such, several limitations should be acknowledged when interpreting the results.

1. Positive cash flows and external effects (such as environmental externalities, public health impacts, or costs transferred to local authorities or beneficiaries) were not considered, as the objective of the LCC assessment is not to analyse how humanitarian organisations manage revenues or cash flows, but to compare the costs associated with alternative solutions. External effects, in particular environmental and social impacts, were also not considered in order to avoid double counting, as these aspects are addressed separately through the environmental LCA and the S-LCA conducted within the project.

2. EoL costs were not included in the quantitative LCC. Disposal pathways for different items and packaging vary widely depending on their type, and reliable data on actual end-of-life practices are often unavailable. From the Humanitarian Organisations' (HOs) side, the only direct EoL costs that could be identified relate to RUTF packaging, while for other items, such costs could not be consistently collected. In addition, for several non-consumable items, precise information on lifespan and post-use management was unavailable. For these reasons, EoL aspects were excluded to avoid introducing speculative assumptions that could distort comparative results. The time horizon of the assessment is restricted to the year 2025, corresponding to the period for which primary cost data were available from humanitarian organisations. Moreover, there are no future costs that are taken in the study. This exclusion may affect the comparison between bio-based and conventional plastic-based solutions, as potential differences in disposal costs, recyclability, biodegradability, or waste management requirements are not reflected in the results. Consequently, the findings should be interpreted as reflecting primarily the acquisition and operational cost phases rather than the full life-cycle economic performance of the assessed solutions.
3. Cost data for packaging materials and innovative bio-based solutions are partly based on secondary market sources and price ranges rather than contract-specific procurement data as they are usually confidential and hard to obtain for external party. While minimum, average, and maximum values were collected to reduce bias, price volatility and regional market differences remain the primary source of uncertainty.
4. Due to the operational focus of humanitarian supply chains, overhead costs and capital goods could only be included where relevant and where data were available. In several cases, such costs are embedded in aggregated procurement or logistics figures and cannot be disaggregated at the item level.

Improvement Pathways for Future LCC Applications

Despite these limitations, the current assessment provides a robust comparative basis and highlights several pathways for improving future LCC analyses in humanitarian contexts.

1. The inclusion of EoL considerations through qualitative or semi-quantitative approaches could strengthen the analysis. Even where monetisation is not feasible, a structured comparison of disposal pathways and waste management options would improve the interpretation of cost differences between conventional and bio-based solutions. Current disposal practices often involve open dumping, which typically results in no direct financial cost. Alternative treatment options such as composting, black soldier fly, or biodigesters would likely increase direct costs; however, they could significantly reduce environmental burdens and social risks.

2. Future assessments would benefit from enhanced primary data collection, particularly on logistics, storage, and procurement practices across different humanitarian organisations and regions. Harmonised data collection frameworks could substantially improve the consistency and comparability of LCC results over time.

Overall, the limitations identified are primarily structural and reflect the realities of humanitarian operations rather than methodological shortcomings. Within these constraints, the LCC assessment provides meaningful comparative insights and demonstrates the potential of life cycle costing as a decision-support tool for humanitarian procurement and program design, especially when combined with environmental and social assessments.

VI. Social Life Cycle Assessment (S-LCA)

Building on the governance and LCC analyses, which primarily address institutional framework and economic viability, the Social Life Cycle Assessment (S-LCA) aims to identify potential social risks and benefits associated with bio-based packaging and items. This assessment draws on a stakeholder survey and a detailed review of suppliers' social initiatives, as well as existing and potential social improvement pathways for humanitarian organisations (HOs). Social performance was evaluated across 18 relevant social impact categories. The results highlight both the scope and limitations of solution providers' social engagement, as well as the strengths and areas for improvement related to HO practices.

A. Introduction to Social LCA

A Social Life Cycle Assessment (S-LCA) is a methodology that evaluates the social impacts of products and services across their entire life cycle. It extends the traditional environmental LCA framework (ISO 14040/44) by focusing on people and communities rather than emissions and resources (Benoît & Mazijn, 2009a⁴¹). In practical terms, an S-LCA examines how activities at each stage of a product's life cycle affect various stakeholder groups – workers, local communities, consumers, society at large, etc. – with respect to issues such as labour rights, health and safety, human well-being, and social justice (Benoît & Mazijn, 2009a). The primary goal of an S-LCA is to promote improvements in social conditions and the overall performance of organisations (Benoît & Mazijn, 2009a).

For humanitarian organisations and donors, S-LCA offers a systematic way to ensure that aid operations “do no harm” and ideally create positive social value. Humanitarian NGOs often operate supply chains that deliver relief items (e.g. shelter materials, non-food items, food aid) and services (e.g. WASH programmes), frequently in fragile contexts. S-LCA helps these organisations measure and manage social risks within their supply chains and field programs. By assessing social issues at each link of an aid delivery chain, NGOs and their donors can identify potential

⁴¹ Benoît, Catherine., & Mazijn, Bernard. (2009). Guidelines for social life cycle assessment of products. United Nations Environment Programme.

problems such as exploitative labour practices by suppliers, impacts on local livelihoods, community health and safety concerns, or inequities in who benefits from a programme. This allows for proactive mitigation – for example, choosing suppliers with fair labour conditions, adjusting procurement to support local markets, or implementing safeguards to protect the well-being of affected communities. This can enhance an NGO’s accountability and credibility with stakeholders, including beneficiaries, donors, and host governments. By using S-LCA, humanitarian organisations can strengthen their social performance – for instance, by ensuring fair wages and safe working conditions in aid item manufacturing, engaging communities in program design, and avoiding negative side-effects on local social structures. Such efforts align with core humanitarian principles and emerging ESG (Environmental, Social, Governance) standards that are increasingly influencing funding and partnerships.

B. Methodology

The S-LCA methodology in the Bio4HUMAN project follows a structured approach in line with the UNEP "Guidelines for Social Life Cycle Assessment of Products"⁴² to systematically evaluate the social and socio-economic impacts of the identified bio-based solutions (Benoît & Mazijn, 2009b). The methodology encompasses five main phases: Goal and Scope Definition, Identification of relevant social themes for the humanitarian sector, Social Life Cycle Inventory (S-LCI), Impact Assessment, and Interpretation.

C. Goal and scope definition

The objective of the study is multifaceted. The assessment seeks to evaluate the social impacts associated with products and technologies designed to reduce waste in the context of humanitarian interventions, in line with the UNEP Guidelines. The scope of the analysis encompasses activities undertaken to produce solution items and their effect on the population in SSD and the DRC.

This S-LCA study applies a gate-to-grave scope. The overall production of a product begins with raw material extraction and continues with transportation to manufacturing companies, which are primarily located in China, India, or Europe. Then, these products are managed by Humanitarian organisations, collected, and transported to affected populations, who distribute and consume them. After this, most waste ends up in open dumps. In the case of technologies, they are transported to the affected countries so that they can be assembled and partially handle or remedy the waste treatment problems. In this assessment, we will only focus on the social effects of products and technologies on the affected population.

Beyond the specific case studies conducted (SSD and the DRC), the study also aims to contribute to the development of a broader roadmap for replicability. The study is designed to be transferable and adaptable, thereby supporting the application of

⁴² <https://www.unep.org/resources/report/guidelines-social-life-cycle-assessment-products>

the S-LCA framework to other humanitarian contexts and geographical settings facing similar waste management challenges.

D. Identification of most relevant social themes

This section aims to identify relevant social themes, key stakeholder categories, and their associated sub-categories, or impact categories, within the field of humanitarian action. It involved designing a structured survey and then processing the data and responses collected through these instruments. The identified themes are aligned with broader concepts and are applicable across humanitarian contexts, serving as a roadmap to improve the social performance of humanitarian actions.

The following sections provide a more detailed explanation of these steps.

1. Survey design

In the currently available S-LCA databases, no general activities related to humanitarian action are included that could support the identification of relevant social themes. To address this gap, the themes (stakeholder subcategories) were identified through a survey distributed to project partners and their affiliates across the supply chain. The survey was designed to determine the most relevant social themes in the context of humanitarian actions, based on a comprehensive list of stakeholder groups and impact categories. Participants were asked to evaluate two key aspects: (1) the extent to which each stakeholder group may influence the implementation of proposed solutions or activities, and (2) the relevance of specific sub-categories (impact categories) associated with each stakeholder in relation to these solutions or activities. The questions asked can be found in Annexe IX.B.

In addition, the survey provided an open section where respondents could suggest social issues not included in the predefined list of themes. Each social theme and impact category was assessed according to the perceived influence of partners and the relevance of the sub-categories. The scoring system applied to the responses is presented in Table 9.

Table 9 Scoring scale used to identify relevant social themes in the survey

Answer	Score
N/A	Not considered
No Influence/Relevancy	0
Slight Influence/Relevancy	1
Influence/Relevancy	5
High Influence/Relevancy	10

As there were 17 respondents (participants' complete list in Annexe IX.B), the maximum scoring for a given social theme is 170 points. Yet the results were normalised to a scale of 0 to 200. The social themes were selected based on a 50% threshold with a $\pm 30\%$ bandwidth for discussion: social themes scoring less than 70 points are excluded (red colour), those scoring more than 130 points are included (green colour), those scoring between 70 and 100 points are included only if justified

(orange colour), and those scoring between 100 and 130 are excluded only if justified (yellow colour). The results are presented in Figure 5.

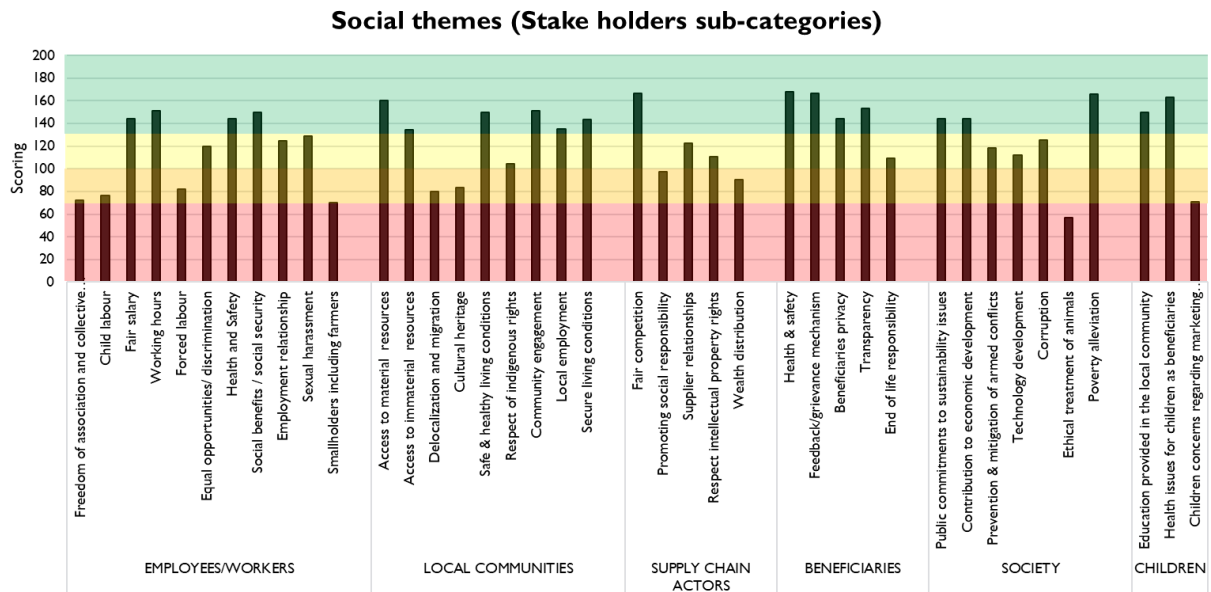


Figure 5 Relevant social themes based on the survey (red: not relevant, orange/yellow: potentially relevant, green: relevant)

Children are generally considered part of the local community stakeholder group. However, in line with the latest UNEP Guidelines, they are treated as a distinct stakeholder category to highlight the importance of their well-being as future generations who will inherit both society and the planet.

2. Analysis of the survey

a) Relevance of the selected social themes

The selected social themes reflect the critical humanitarian needs observed in crisis-affected regions. In environments marked by conflict and displacement, ensuring fair wages, decent working conditions, and safe labour environments is essential not only for workers in manufacturing and supplying humanitarian items but also for workers in crisis-affected local populations.

Access to resources - such as safe water, adequate shelter, clean energy, and reliable sanitation - together with healthy living conditions, aligns with the “Consumers” and “Local Communities” stakeholders. These themes are essential because humanitarian items are intended to reduce vulnerability and promote well-being among populations living in unstable and often hazardous conditions. Social risks such as exposure to toxins, unsafe materials, or insufficient product durability can have immediate and dire consequences for people who depend heavily on distributed items for their daily survival.

Themes related to *community engagement* and *local employment* opportunities reflect the importance of empowering affected communities and strengthening local capacities. These considerations correspond to the “Local Communities” and

“Society” stakeholders in S-LCA. They also recognise that humanitarian interventions can support job creation and market functioning - even if only temporarily - while encouraging long-term resilience. Similarly, themes such as poverty alleviation and contributions to broader economic development underscore the role humanitarian actions can play in supporting recovery pathways beyond immediate relief.

b) Relevance of Themes Initially Rated Low (Hidden or Emerging Priorities)

Several social and environmental themes were initially rated as low- or medium-relevance by humanitarian partners, not because they are unimportant, but because the operational realities of crisis response constrain organisations. *End-of-life responsibility* for distributed items, particularly plastic waste, is a good example. It was ranked low in the initial survey, yet that is one of the main reasons for this project. The low ranking reflects the fact that HOs historically prioritise rapid distribution and life-saving assistance, while waste management remains outside their immediate mandate and logistical capacity. This does not mean the issue is minor - rather, it indicates a hidden hotspot that has not yet been systematically addressed.

In the same way, other categories that received low relevance scores may also represent overlooked risks or emerging priorities, simply because humanitarian organisations have not traditionally viewed them as integral to emergency programming. They may therefore slip through the cracks in short-term emergency operations, even though they have significant implications for resilience, environmental degradation, and community wellbeing. It is worth noting that some highly relevant categories were ranked as important precisely because they are more visible in daily humanitarian work, which field teams experience directly and are measured by donor requirements.

The same recurring pattern appears in the discussion on technology development. Again, PIN and PAH rated this theme as low to medium relevance, not because it lacks importance, but because it falls outside the traditional scope of humanitarian response. Humanitarian actors only occasionally engage in solid waste infrastructure or advancing technological capacity, as these responsibilities are typically associated with government institutions, development agencies, or long-term programmes. Yet, from a broader sustainability perspective, strengthening local waste management systems and transferring appropriate technologies could have profound long-term benefits - reducing reliance on external aid, creating skilled employment, and providing more sustainable solutions to chronic waste challenges.

This recurring pattern across categories suggests that the initial relevance scores may reflect organisational mandates and operational limitations rather than the true significance of the themes themselves. As environmental and social sustainability become more central to humanitarian action, issues previously considered marginal

will likely be increasingly recognised as essential for minimising harm and supporting long-term resilience in crisis-affected regions.

Additional comments from partners highlight critical social dimensions that extend beyond the immediate scope of material selection or kit design but are highly relevant to decision-makers working on humanitarian strategies, sustainability agendas, and long-term resilience planning. They are not going to be assessed in the study but are mentioned in Annexe IX.C for further social assessment in the humanitarian sector in the future.

3. Relevant social themes for Humanitarian Organisation and Solution Providers

In the current humanitarian aid context, both HOs and solution providers (SPs) influence the social conditions of the communities they serve, but their roles differ depending on the social theme. Some actors may have a substantial impact on specific social aspects while having little or no influence on others. Some social themes are also affected by both HOs and SPs.

For example, themes related to employees are mainly connected to SPs, as they are responsible for manufacturing the products and technologies used in humanitarian operations. In contrast, HOs shape themes such as fair competition among suppliers by managing procurement processes and coordinating the delivery of aid. *Beneficiary privacy* and *secure living conditions* for local communities were not considered within the scope of the project, as the actions do not address these themes, even when the score is above 130. Meanwhile, it is important to note that these social themes remain relevant in the global context of humanitarian aid for other projects dealing with these issues. Indeed, none of the items or technologies threaten the privacy of the beneficiaries or affect the security of the living conditions. They would not serve to differentiate the solutions and have therefore been excluded.

Identifying the target audience helps define more relevant questions to assess each party's performance on the social theme. Table 10 presents the target audience for each social theme.

Table 10 Target audience for each selected social theme

Stakeholder	Social themes	Target Audience
BENEFICIARIES	Health and safety	SP + HO
	Feedback/grievance mechanism	HO
	Transparency	HO + SP
CHILDREN	Health issues for children as beneficiaries	SP
	Education provided in the local community	HO + SP
EMPLOYEES/WORKERS	Working hours	SP
	Social benefits / social security	SP
	Fair salary	SP
	Health and Safety	SP
LOCAL COMMUNITIES	Access to material resources	SP + HO
	Community engagement and delocalisation	HO + SP
	Safe & healthy living conditions	SP + HO
	Local employment	SP
	Access to immaterial resources	SP + HO
SOCIETY	Poverty alleviation	SP

	Public commitments to sustainability issues	SP
	Contribution to economic development	SP + HO
SUPPLY CHAIN ACTORS	Fair competition	HO

E. Social Life Cycle Inventory (S-LCI) and Data Collection

After identifying the relevant social themes and the intended target audience, each solution was assessed against them. This was done to determine whether the solution has the potential to contribute positively to these themes from both the (HO and SP perspectives).

The assessment followed these steps:

1. Develop tailored questions for each social theme in accordance with the UNEP methodological sheet guidelines, addressing both the HO and SP viewpoints (UNEP, 2021).
2. Collect data through literature review, interviews with partners, and other relevant sources.
3. Analyse the results to evaluate how each solution performs in relation to the social themes, considering the roles and responsibilities of both HOs and SPs.

All questions were scored using the scoring system presented in Table 11. The scoring reflects whether the responses meet legal requirements or demonstrate active efforts toward improvement. A higher score indicates stronger social performance and greater positive implications.

Table 11 Scoring scale for the evaluation of social themes

4 (Committed conduct)	Continual improvements are mainstream in the company/product design
3 (Proactive conduct)	Initiatives remain at the individual level or occur as isolated events
2 (Legal conduct)	Minimum legal requirements are respected
1 (Risk conduct / No information)	The minimum legal requirements are not met / The supplied information is insufficient for a precise assessment.

1. Questions for Humanitarian organisations' social themes

Based on the social themes relevant to HOs identified in Table 10, Table 12 presents the questions selected to score each theme.

Table 12 Humanitarian organisation (HO) evaluation questions per social theme

Social theme	Questions
Health & safety	Are data about defects (number, quality) assessed?
	Are suppliers obliged to use labels to justify quality?
	Is there a Quality and/or Product Safety Management System?
Feedback/grievance mechanism	Is there a mechanism for customers to provide feedback?
	Are there management measures to improve feedback mechanisms?
Transparency	How would you qualify the transparency regarding the content of products, regarding substances that might produce a toxic impact?
Education provided in the local community	Are there any policies to support local education for children?
	Does the organisation provide material resources to the communities?

Social theme	Questions
Access to material resources	Does the organisation provide infrastructure (school, hospital)?
Community engagement and Delocalisation	Does any project have impacts on community engagement?
	Does any project have impacts on helping NGOs or local projects?
Safe & healthy living conditions	How would you qualify the effort of the sector to improve the safe and healthy living conditions?
Access to immaterial resources	Are there any community education initiatives within the company?
	Does the organisation collect funds and distribute it?
	Does the organisation organise or support mental health programs?
Contribution to economic development	Do any projects contribute to the economic development of countries? By creating jobs, doing trainings?
Fair competition	Is the procedure for selecting suppliers well-documented, transparent and harmonised?
	Are there any price agreements in the sector regarding the selection of suppliers?
	Are there any current claims from suppliers regarding unfair competition?

To maintain consistency with the environmental LCA and Life Cycle Costing, considering different aid kits (Food, Agriculture, WASH, and NFI), the questions were asked for the Food, WASH, and NFI aid sectors. Agriculture was merged with Food as answers to questions were the same as the literature revealed they have the same objectives. An average score per question and per social theme was calculated to provide a representative score of humanitarian sector activities. The scores are given in Annexe IX.E.

In the first step, a literature review was conducted using several HO websites and communication channels. For questions regarding stakeholders other than supply chain actors, literature was searched on HO initiatives in the two countries of interest to the Bio4HUMAN project, the DRC and SSD, or at least in Africa. In a second step, PIN and PAH, the HO partners of the Bio4HUMAN project, were asked to review the scores, provide expert opinion, and collect local opinion on the inputs and results.

2. Questions for solution providers' social themes

The design of questions for SPs follows a similar structure to those used for the HOs' social themes. As no interviews could be conducted with the SPs, a literature review was conducted to assess the questions using the solution providers' websites and communications.

However, for social themes related to Employees/Workers, SPs did not communicate any company-specific information on working conditions. Applying a methodology solely based on disclosed information would therefore have resulted in artificially low scores driven by a lack of transparency rather than actual performance. To avoid this bias, an alternative methodology was implemented using country-specific indicators and contextual conditions. Working conditions, including working hours, wages, and access to social benefits, are derived from the country's regulatory framework, labour standards, and socio-economic norms. Although individual companies may exceed national requirements, such practices are rarely documented or publicly available through corporate communication channels.

Consequently, a conservative and pragmatic approach was adopted, whereby performance was assessed against country-level benchmarks for the relevant criteria.

Since the questions and scores are either specific to the management practices in the company or to production countries, they are presented below for each item's solutions:

Table 13 Solution Providers evaluation questions per social theme (company and country specific)

Company-related Questions	
Social Theme	Question
Health & safety	Are there health and safety labels for the product?
	Is there a Quality and/or Product Safety Management System?
Transparency	Will monitoring data (e.g., emissions, energy output, waste treatment quality, impacts) be shared with HOs, communities, or regulatory bodies?
	If there are problems or failures, what is the communication protocol to local stakeholders and the HO?
Health issues for children as beneficiaries	Is the product or technology designed in a way that makes it safe for children to use, touch, or be around?
	Does your organisation plan to promote children's physical and psychological health to families and communities?
Education provided in the local community	Are there any initiatives planned during the implementation period (such as workshops, site visits, or awareness campaigns) specifically focused on local education for children?
	Do you anticipate any difficulties (social barriers) regarding children's education?
Access to material resources	Does your company offer access to material resources? Infrastructure, items?
Community engagement and Delocalisation	Does any project have an impact on community engagement?
Safe & healthy living conditions	Does the company seek to provide secure conditions of living?
	Does the company seek to improve the living conditions?
Local employment	Do you plan to hire local people in the destination countries?
Access to immaterial resources	Does your company offer access to immaterial resources? Education, funds, mental health?
Poverty alleviation	Does the organisation/production site have policies to support poverty alleviation?
Public commitments to sustainability issues	Is there engagement to improve the sustainability performance? Please provide more details.
Contribution to economic development	Will there be training on how to operate or maintain this technology so they can eventually manage it themselves?
	Could businesses or services grow around this technology (e.g., selling fertiliser, providing maintenance, collecting waste)?
Country-related questions	
Working hours	What are the working hours compared to international standards?
	Are there any existing agreements/expectations regarding working hours? When agreements exist, are there any deviations possible from these agreements?
Social benefits / social security	Are any benefits provided to employees/workers in your region? When these exist, clarify them.
	Is any insurance provided to employees/workers in your region? What about their kids?
	Are retirement savings or old-age benefits common in your area? If not, how do older workers survive when they can no longer work?

Fair salary	Salary for employees? Would that be enough to cover food, rent, and other essential needs for a household?
	Do you know of any local groups, cooperatives, or traditional authorities that help set or negotiate fair pay in the community?
Health and Safety	Are there accident prevention measures and management practices?

Complementary to the S-LCA, the Employees/workers' social themes results were compared to World Governance Indicators (WGI) from the World Bank to contextualise and interpret the resulting scores within the broader governance and institutional environment of each country.

WGIs provide a global framework for assessing the quality of governance across over 200 countries. They measure six key dimensions: *Voice and Accountability*, *Political Stability*, *Government Effectiveness*, *Regulatory Quality*, *Rule of Law*, and *Control of Corruption*. Each dimension is scored from -2.5 (weak governance) to +2.5 (strong governance). In the context of social conditions, these indicators help explain how institutional quality influences workers' rights, social protections, and overall compliance with labour laws. Table 14 outlines the meaning of each WGI dimension and clarifies its relevance for assessing working conditions, thereby determining whether these indicators can be appropriately integrated alongside Social LCA.

Table 14 Relevance of World Governance Indicators (WGI) for assessing working conditions

WGI Dimension	Meaning	Link to Working Conditions (S-LCA)	Social Relevance
Rule of Law	Respect for laws and contract enforcement	Ensures legal protection of workers, safety compliance, and fair pay	High
Voice and Accountability	Freedom of association, expression	Supports unions, collective bargaining, and fair salary negotiation	High
Government Effectiveness	Quality of public services & policy implementation	Enables enforcement of labour standards, health & safety, and social security	High
Control of Corruption	Use of public power for private gain	Prevents unfair labour enforcement, secures access to social benefits	High
Regulatory Quality	Soundness of policy and regulation	Affects the clarity of labour laws and formal employment quality	Moderate
Political Stability	Absence of conflict or violence	Allows continuity of inspections, benefits, and safe workplaces	Moderate

The following table shows the country represented by each solution provider.

Table 15 Bio-based solution providers and corresponding production countries

Solution	Production Country
PLA Oil and water container (item)	USA
Compostable pouch for RUTF (item)	China
Disposable bag from renewable resources (item)	USA
Compostable disposable pads (item)	India
Biodegradable mosquito nets (item)	France
Biodegradable laminating film (item)	Bulgaria
Bio-based adhesive tape (item)	Germany
Biobased polyurethane (item)	Spain

Hemp-based insulation (item)	Ireland
Sheep wool insulation (item)	Romania
Mycelium-based packaging (item)	Czech Republic
Black Soldier Fly (technology)	Local (DRC or SSD)
Anaerobic digestion (technology)	Local (DRC or SSD)

F. Social Impact Assessment and Interpretation

In this section, the results of the scored questions from the previous step are presented, compared, and discussed.

1. Humanitarian Organisation social impact

Figure 6 gives the results from the literature review and the slightly adjusted scores by the PIN/PAH partners. References used for the scoring can be found in Annexe IX.D.

The analysis shows that the HOs perform consistently across social themes and adhere to core humanitarian standards, while operating within the structural constraints typical of emergency contexts. It translates the reasonable implications of HOs in the DRC and SSD, with thoughts on how their actions will affect the local population. However, efforts still need to be made to establish a feedback mechanism from the population regarding their actions and access to immaterial resources.

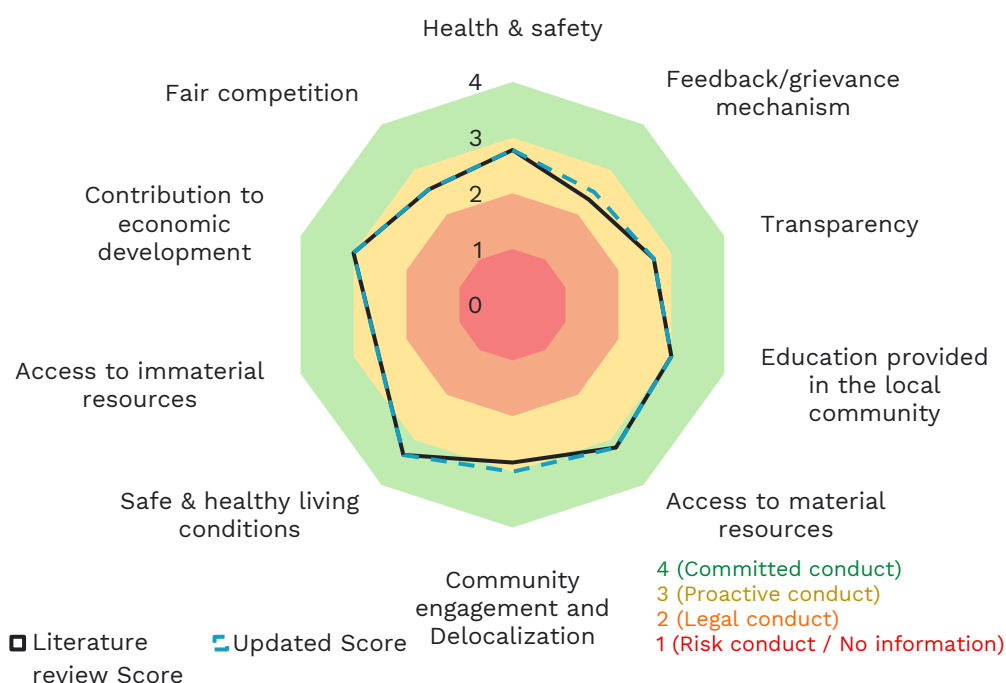


Figure 6 Social theme scores for humanitarian organisations (literature review in black and partner adjustment in blue)

To go into further details, across individual themes, several strengths and predictable limitations emerge. From the literature review, for the *Beneficiaries'* social themes, *Health and safety* procedures are strongest in food assistance, where compliance with standards is mandatory. WASH items occasionally require certified suppliers, while NFI quality is monitored mainly through Post-Distribution Monitoring. *Feedback and grievance mechanisms* are broadly established and multisectoral, though their effectiveness varies in terms of uptake and follow-up. *Transparency* remains uneven: programme-level data is available, but product-level disclosure is constrained by supply chain realities and limited NGO control beyond specification-setting within procurement processes. Contributions to *children's education* occur mainly through school feeding, WASH-in-schools, and material support, but are not systematically integrated across all missions. For *local communities*, support for *access to material resources* is evident in the construction and rehabilitation of water points, sanitation facilities, storage structures, and temporary shelters, though levels of investment vary by context. *Community engagement* is a notable strength, particularly in WASH programmes that rely on participatory governance and community-led processes. *Safe and healthy living conditions* are consistently improved through food, WASH, and NFI interventions, though impacts differ by sector. *Contributions to immaterial resources* are more indirect and emerge primarily through empowerment activities such as committee involvement, cash-for-work programmes, and volunteer engagement. Then, regarding *economic development of the society*, the organisation contributes through nationalised staffing structures, collaboration with NGOs, and cash-based assistance that stimulates local markets. Finally, *fair competition between supply chain actors* is supported by documented and standardised procurement processes, with stricter procedures applied to higher-value purchases. While procurement modalities differ by sector and context, mechanisms to ensure fairness and address supplier disputes are in place.

Partners reported that most NGOs already maintain formal *feedback and grievance mechanisms*, such as dedicated communication channels, PDM or other, which apply across sectors including food, WASH, and NFI distributions. Although WASH committees are common, their function is primarily operational rather than serving as formal accountability structures. Consequently, the effectiveness of feedback management depends largely on the robustness of organisation-wide systems rather than on community committees alone. On the other hand, NGOs and the humanitarian aid sector operate within a broader support system. All communities already have their own feedback mechanisms, both formal and informal structured within their government set up history, which may include reporting concerns to community leaders. The main role of NGOs is to link their official feedback mechanism with already existing feedback pathways in the community. Partners also highlighted systemic limitations influencing product quality, *transparency*, and responsiveness. These include strict price ceilings, limited availability at local markets, and the widespread absence of laboratory testing capacity in field contexts. As a result, organisations often rely on supplier labels and pre-defined pipeline items over which they have little influence. *Community engagement* is

strongest in WASH programming—particularly where infrastructure is handed over to local structures—while sectors such as food and NFIs integrate participation in more targeted and episodic ways. Humanitarian organisations were also described as contributing indirectly to *local economic development* through nationalised staffing and procurement practices, even though economic outcomes fall primarily within development mandates. Increased reliance on cash-based assistance is reshaping sector practices and reducing dependence on physical kits.

2. Solution providers' country-specific social impacts

As mentioned in Annexe V.B, because SPs' websites did not provide information about the working conditions of the employees producing the solution, the scoring for the “Employees/Workers” was assessed by solution production countries rather than by companies.

To score the working conditions themes, government sites were used as references with L&E Global reports on countries on the website and additional supporting websites detailed in Annexe IX.F. The results are shown in the following diagram. It shows that the best-performing countries are European, especially Spain, Germany, and France. Some countries may have strong features but perform poorly in specific categories, such as India, the USA, China, Ireland, and Eastern European countries. In contrast, the DRC and SSD have generally poor working conditions. Producing in these countries could result in a lower social impact if the manufacturing company does not have measures to improve working conditions.

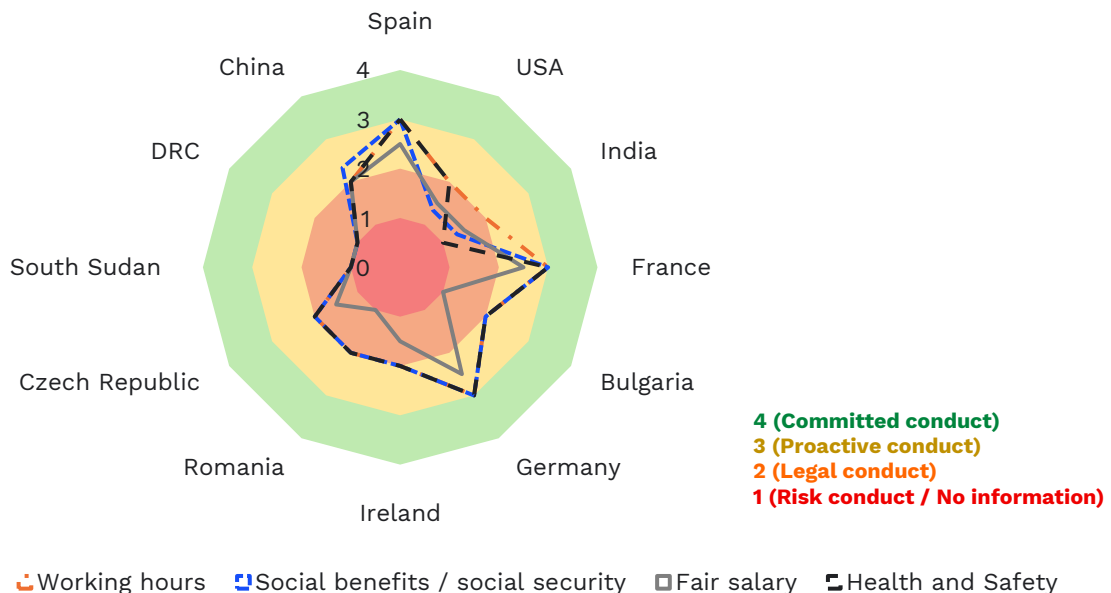


Figure 7 Workers/Employees stakeholder scores for solution production countries

The results in Figure 7 were compared to World Governance Indicators (WGI) from the World Bank. The WGI scores for the countries studied are presented below. For better comparison, another graph with a scaled 1-4 scoring is also provided.

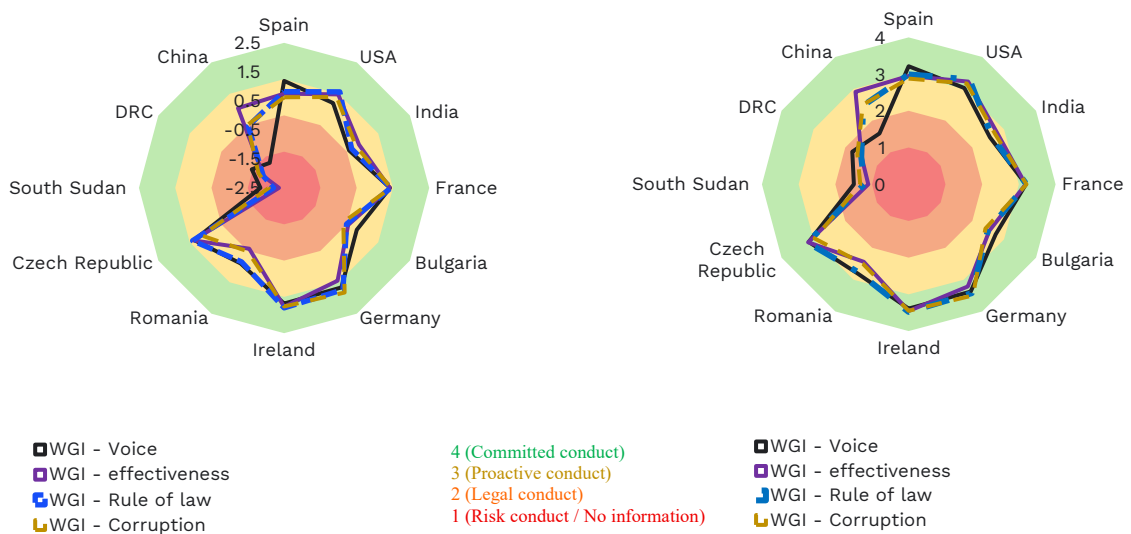


Figure 8 World Governance Indicators (WGI) for solution production countries

The comparison between S-LCA working condition scores and World Governance Indicators (WGI) shows a generally strong coherence across the analysed countries. In most cases, countries with higher WGI values – especially for Government Effectiveness, Rule of Law, Regulatory Quality, and Control of Corruption – also achieve higher S-LCA scores, reflecting better enforcement of working hours, social protection systems, and occupational health and safety standards.

Overall, the WGI offer a complementary perspective to S-LCA results, helping to explain why certain countries perform better or worse in areas such as fair salary, health and safety, or social benefits. High WGI scores generally align with structured and transparent labour governance, as observed in Germany or Ireland. In contrast, lower scores, such as in China or India, often reflect enforcement gaps, high prevalence of informal labour, and limited worker empowerment. In fragile governance contexts such as SSD and the DRC, low WGI scores align closely with systemic social risks identified by S-LCA. For many countries analysed, there is a clear match between S-LCA and WGI results; however, the WGI tend to assign relatively higher scores to countries such as the USA, Ireland, and the Czech Republic compared to their S-LCA working condition outcomes, highlighting that strong governance indicators do not always translate into uniformly high working-condition performance at an operational level.

3. Solution providers' company-specific social impacts

The following graphs present the results for the solution items and technologies. For each solution, individual scores were averaged to provide an overall performance profile. Because the solutions differ in function and intended use, direct comparison

between them is not appropriate; therefore, an aggregated overview offers the most meaningful representation of the findings.

Notably, the compostable disposable pads achieved the highest social performance among all assessed items, as the company producing them communicates about their social actions, unlike the other solution items. The scores are based on a literature review, and it is essential to remember that low scores on other social themes indicate that little to no information about the companies' actions was found on their websites or communication channels and are therefore considered risky conduct. Scores on Employees/Workers' social themes are from the results of the previous section.

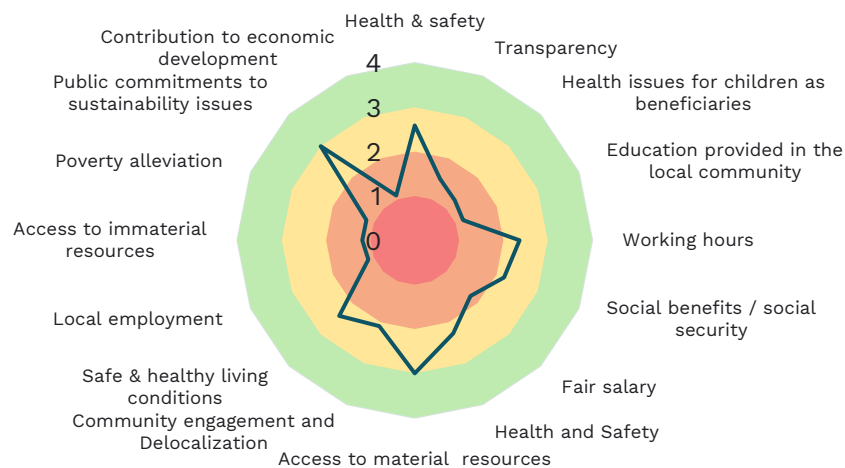


Figure 9 Social performance results for bio-based solution items

The results indicate that most companies primarily communicate on social actions related to access to material resources, public commitments to sustainability, and community engagement, including aspects linked to delocalisation. These outcomes are unsurprising, as the perceived benefits of biobased items are primarily associated with their environmental performance; consequently, companies tend to emphasise environmental sustainability, with social aspects presented as secondary or supportive narratives.

In contrast, limited communication or documented actions were identified regarding local employment creation, transparency, access to immaterial resources, poverty alleviation, and contributions to economic development. This pattern suggests that producers of biobased item solutions generally prioritise communicating environmental initiatives over social performance, resulting in a less comprehensive representation of their social impacts.

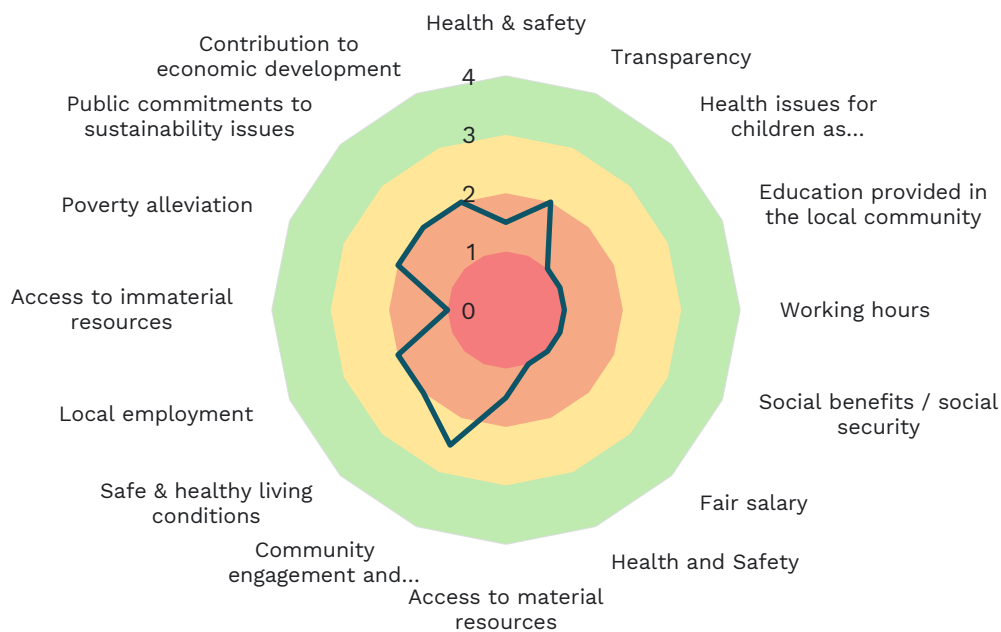


Figure 10 Social performance results for technology-based solutions

For the technology solutions, the assumed implementation contexts were the DRC and SS. As a result, several social themes (such as working hours, social benefits, and related labour conditions) received low scores, reflecting national-level indicators rather than company-specific practices. In reality, the actual social performance will depend heavily on each company’s implementation strategy and operational model. Among the assessed technologies, anaerobic digestion (biogas) demonstrated stronger performance compared to the baseline alternatives. However, when combined with the Black Soldier Fly technology, the overall results remain low. This is mainly due to the limited publicly available information on the latter, which led to the application of a conservative scoring approach, assigning the lowest value where evidence was insufficient. It is important to emphasise that these results are based solely on information available through company websites and similar sources. If further data becomes available (such as through interviews or technical consultations), the scoring can be revised to more accurately reflect the potential social benefits of implementing these technologies.

G. Social Insights for Humanitarian Operations and Solution Providers

This section presents the strengths and limitation identified in the social assessments for HOs and SPs.

Humanitarian Organisations (HOs)

Strengths:

- Widespread use of established humanitarian standards and accountability mechanisms.

- Strong health and safety procedures, particularly in food assistance programmes.
- Post-Distribution Monitoring (PDM) is commonly used to monitor quality and beneficiary satisfaction.
- Consistent performance across core social themes, including health and safety, access to essential resources, and community engagement.
- Community engagement is a strong feature of WASH programs.
- Feedback and grievance mechanisms are generally in place.
- Access to material resources (although limited) is supported through infrastructure development (water points, sanitation facilities, shelters).
- Improvements in safe and healthy living conditions observed across food, WASH, and NFI interventions.
- Contributions to children's education through school feeding, WASH-in-schools, and material support.
- Indirect contribution to local economic development through national staffing, local procurement, and cash-based assistance.
- Documented and standardised procurement procedures support fair competition.

Gaps and limitations:

- The lack of integration of waste management and end-of-life responsibility within traditional humanitarian mandates represents a significant gap, particularly given the strong influence humanitarian organisations have in these areas. Long-term social outcomes are difficult to integrate due to short operational timeframes.
- Product-level transparency remains limited due to supply chain constraints and reduced control over item specifications.
- Effectiveness of feedback and grievance mechanisms varies, particularly regarding follow-up and corrective actions.
- Transparency on product composition and potential toxic substances is uneven.
- Children's education and well-being are not systematically integrated across all sectors.
- Access to the offer of immaterial resources (e.g. education) is uneven and often indirect.
- Structural constraints such as limited funding and emergency conditions restrict social performance improvements.

Solution Providers (SPs)

Strengths:

- Strong communication on the environmental benefits of bio-based and technology-based solutions.

- Some companies demonstrate social engagement, resulting in higher social performance scores.
- European production countries generally show better working conditions.
- Training and capacity-building elements improve the social performance of technology-based solutions.
- Certain technologies (e.g. anaerobic digestion) show more substantial overall social potential.
- Use of governance indicators helps contextualise labour and social conditions.

Gaps and limitations:

- Social themes related to employees/workers are weakly documented at the company level.
- Social performance is often assessed conservatively due to a lack of transparency.
- Limited publicly available information on social practices, particularly on working conditions.
- Local employment creation is rarely documented.
- Contributions to poverty alleviation and economic development are insufficiently described.
- Access to immaterial resources (education, funds, mental health support) is rarely addressed.
- Child-specific safety and well-being considerations are not consistently documented.
- Social performance is strongly affected by country-level governance conditions.
- Weak governance contexts increase social risks when company-level safeguards are not documented.
- Limited use of direct engagement or interviews constitutes a gap affecting the accuracy of company-specific assessments.

Cross-cutting (HOs & SPs)

Strengths:

- Social Life Cycle Assessment provides a structured framework to identify social risks and opportunities.
- Governance indicators align well with observed social performance patterns.
- The assessment highlights key social themes relevant to humanitarian contexts.

Gaps and limitations:

- Limited direct stakeholder engagement restricts qualitative insights.
- Environmentally sustainable solutions do not automatically guarantee social benefits.

- The limited incorporation of social criteria alongside environmental assessment highlights a critical gap in current approaches.
- Data gaps limit the precision of social performance assessment, and social assessment methodological developments in the humanitarian aid sector are needed.

VII. SSbD framework

This section provides an overview of the sustainability assessment performed through environmental, social and economic LCA in [D5.1](#), [D5.2](#), [D5.3](#) and the present document. In the following section, the importance to consider safety requirements as a criterion for bio-based solutions selection is underlined.

A. SSbD

The Safe and Sustainable by Design (SSbD) framework⁴³ for chemicals and materials was developed by the JRC in 2022, as for the scientific basis for the European Commission Recommendation of 2022. In 2025, this framework is being reviewed to support a more resilient, competitive and innovative based, future proof industrial ecosystems.

The SSbD framework serves as an approach for supporting decision-making to guide innovation towards safe and sustainable chemicals and materials life cycles. The definition of the system under study includes the chemical/material under assessment, and the targeted life cycle, including relevant processes and products. The system should always cover the three elements that are needed to define the boundaries for the assessment: chemical/material, process(es), and product. Depending on the innovation under study, the SSbD system can be simplified, intermediate or full.

Safety and sustainability assessments are the methods for characterization of the systemic environmental and toxicological impacts of processes, products, and their associated chemical releases. The two approaches should be developed separately to produce a robust, reliable, and adequate assessment, including:

- Intrinsic physical and (physico-)chemical properties.
- Safety assessment.
- Sustainability assessment.

Intrinsic physical and (physico-) chemical properties.

As a common ground for safety and sustainability assessment, it covers the collection of physical and chemical characteristics of chemicals and materials. These properties determine how chemicals and materials behave under different

⁴³ Bracalente, G.; Abbate, E., Garmendia Aguirre, I. (2025). Safe and Sustainable by Design Chemicals and Materials. Revised framework (2025). Draft for consultation.

conditions and how they interact with one another. These properties are influenced by molecular structure, substance composition, physical dimensions, and other properties.

Safety assessment

Safety assessment quantifies both the potential of exposure and the hazard associated with a specific chemical or material in specific scenarios, thereby generating an absolute estimate of risk and reporting results relative to maximum threshold levels, where available. This point covers the analysis of the intrinsic properties of the chemical/material to understand its hazards profile in combination with the exposure (human health and environment), aspects throughout the life cycle, including the production, manufacturing process, other downstream processes (including End-of-Life), and final application and use of the product, which the chemical/material is part of. The processes are also evaluated in the safety assessment from a broader perspective, including, where relevant, assessment of alternative production processes.

Sustainability assessment

Environmental sustainability assessment evaluates environmental impacts along the entire chemical/material life cycle using Life Cycle Assessment (LCA), assessing several impact categories such as climate change and resource use, for, among others, the production, downstream processes, and final application and use of the chemical/material.

Socio-economic sustainability assessment describes how to assess aspects related to social fairness (e.g. working conditions and human rights) and competitiveness (e.g. vulnerabilities in the supply chain, skills shortages, and Life Cycle Costing). The assessment includes both social risk assessment, the identification of Critical Raw Materials, and the assessment of societal costs throughout the life cycle of a chemical or a material.

B. B4H project and SSbD

Within the Bio4Human (B4H) project, sustainability assessment was conducted in WP5 (LCA of innovative bio-based solutions) and WP6 (socio-economic and governance aspects evaluation, replication tool). The environmental findings are detailed in D.5.3, while the socio-economic results are presented in D.6.1 (this deliverable).

Life Cycle Assessment (LCA) contributions to SSbD – D5.3

To perform the LCA, a Life Cycle Inventory (LCI) was first developed. The LCI serves as the data foundation for integrating Safe-and-Sustainable-by-Design (SSbD) principles throughout a product's life cycle. By providing a detailed breakdown of all inputs (raw materials, energy, and chemicals) and outputs (emissions and waste), the LCI supports safety and sustainability considerations in several key ways:

Early Hazard Identification: The LCI enables systematic screening of chemical substances. By cross-referencing the inventory with safety databases (such as REACH), potential hazards - including toxicity, persistence, and bioaccumulation - can be identified before a solution is scaled or replicated.

Quantifying Environmental Trade-offs: Beyond safety, the LCI provides the necessary data to assess the "Sustainability" pillar of SSbD. It enables the calculation of environmental footprints (e.g., carbon and water footprints), ensuring that a "safer" chemical alternative does not inadvertently lead to higher energy consumption or greater environmental impacts elsewhere in the life cycle.

Supporting Evidence-Based Selection: In the context of the Bio4Human project, where existing market solutions are evaluated, the LCI acts as a decision-support tool. It provides a transparent comparison of bio-based alternatives, ensuring that the final selection is based on a balanced assessment of both high technical performance and low environmental and health risks.

By bridging the gap between technical data sheets and impact assessment, the LCI ensures that safety is not a post-hoc check, but a core component of the sustainability evaluation within the B4H framework. Nevertheless, in practice, much of this safety information was confidential and difficult to obtain. Furthermore, assessing the replicability of the solutions across the selected geographical sites proved challenging due to the complexity of local working conditions.

Social and Economic contributions to SSbD – D6.1

The socio-economic and governance results detailed in D6.1 provide the necessary context to fulfill the broader sustainability of pillars of the SSbD framework. While environmental safety is technical, true sustainability requires that bio-based solutions are also socially acceptable and economically viable within their target markets. The findings from this report contribute to SSbD in the following way:

Social Acceptance and Human Wellbeing: By evaluating governance and social aspects, the project identifies potential barriers to the adoption of bio-based solutions. This ensures that a "safe" product also aligns with local community needs and ethical standards, a core requirement for long-term social sustainability.

Economic Viability and Market Readiness: Economic analysis helps determine whether the identified safer alternatives are cost competitive. This prevents "burden shifting" where a product is environmentally superior but economically inaccessible for the intended geographical sites.

Contextualizing Working Conditions: The socio-economic evaluation complements the hazard assessment by providing a reality check on local working conditions. This enables a more nuanced SSbD approach, in which safety measures are tailored to each site's actual capacity and governance structures.

By integrating these results, the Bio4Human project ensures that the transition to bio-based solutions is not only chemically safe but also socially just and economically resilient.

Data Gaps and Limitations

A transparent acknowledgement of data limitations is essential to strengthen the validity of the SSbD framework within the B4H context. The primary challenge encountered was the asymmetry of the information:

- Confidentiality barriers
- Geographical granularity
- Primary data scarcity

Confidentiality barriers. The ‘black box’ (incomplete LCI) around specific chemical formulations limit the ability to perform a full toxicological screening.

Geographical granularity. While global databases provide average values, they often fail to capture the specificities of local waste management and labour conditions in humanitarian contexts, leading to uncertainties in the final impact results.

Primary data scarcity. The lack of high-quality data from the entire value chain remains a significant hurdle for bio-based solutions, which are often less documented than their fossil-based counterparts.

Analysis of Trade-offs

In pursuing SSbD objectives, several trade-offs were identified where full optimization was not possible.

- Safety vs market readiness. Selecting existing market solutions (rather than developing new ones) meant that while the products were ready for immediate deployment, they could not be "designed from scratch" to eliminate all inherent hazards.
- Environmental performance vs local replicability. Some bio-based solutions with superior environmental profiles (e.g. low carbon footprint) require a more sophisticated recycling infrastructure. In many target regions, this infrastructure is absent, forcing a trade-off between the product’s theoretical sustainability and its actual end-of-life impact in local settings.
- Cost vs toxicity. Transitioning to "safer" chemicals sometimes involves higher costs, which directly conflict with the strict budget constraints of humanitarian operations.

Recommendations for future implementation at the HO level

Based on the lessons learned from B4H, the following steps are recommended for HO to improve SSbD adoption.

- HOs should include REACH compliance and detailed Safety Data Sheet (SDS) requirements as criteria in tendering processes to overcome current data gaps.
- Sustainability should not be assessed in a stand-alone assessment; the HOs must evaluate products based on the local capacity (waste treatment, energy mix) of the deployment site rather than relying on generic environmental claims.
- Encourage the creation of open-access databases for bio-based materials within the humanitarian sector to reduce the burden of individual LCAs and improve transparency.
Start by selecting the "safest available" options (as done in B4H) while gradually moving toward co-designing solutions with manufacturers to address the "Safe-by-Design" pillar at the source.

C. S-LCA conclusions

The Social Life Cycle Assessment was conducted to complement the environmental Life Cycle Assessment developed within the Bio4HUMAN project by analysing the social and socio-economic implications of selected bio-based solutions in humanitarian contexts. Following the UNEP S-LCA Guidelines, the assessment combines stakeholder surveys to identify social themes and stakeholders relevant for the humanitarian context, literature review, publicly available company information, and country-level indicators to provide a structured and realistic appraisal of social performance across the life cycle.

The results indicate that HOs generally perform consistently across most relevant social themes, particularly regarding access to essential resources, community engagement, health and safety, and fair competition in procurement. These findings reflect the widespread adoption of humanitarian standards and accountability mechanisms, such as post-distribution monitoring and feedback systems. However, structural constraints inherent to emergency settings—including funding limitations, short operational timeframes, and limited control over supply chains—continue to restrict transparency at the product level and the systematic integration of longer-term social outcomes.

For solution providers, the assessment highlights a significant gap in social communication. While the environmental benefits of bio-based solutions are frequently emphasised, limited publicly available information exists on social performance, particularly regarding working conditions, local employment, economic development, and access to immaterial resources. As a result, several social themes were assessed conservatively, reflecting data availability rather than confirmed negative impacts. It is important to note that more direct engagement with solution providers could have led to different results by revealing practices not captured through public sources.

A key limitation of this study is the absence of direct interviews with either humanitarian organisations or solution providers. Although some humanitarian organisations reviewed and provided feedback on the literature review, time and

access constraints prevented in-depth qualitative engagement. This limitation affects the granularity of the assessment and reinforces the need for cautious interpretation of results, particularly for solution providers.

To address data gaps related to Employees/Workers, the study used a country-level assessment approach grounded in international labour standards and governance indicators. The observed alignment between working condition scores and governance indicators confirms the relevance of this proxy method, while also illustrating its limitations in capturing operational-level variability, especially in fragile and conflict-affected contexts.

Overall, the findings confirm that bio-based solutions can contribute positively to humanitarian objectives, particularly from an environmental perspective, but that social benefits are neither automatic nor guaranteed. Social performance depends strongly on transparency, governance context, procurement strategies, and implementation choices. Strengthening dialogue with solution providers and humanitarian organisations, alongside improved disclosure of social practices, would significantly enhance future assessments and support more balanced and responsible decision-making in humanitarian innovation.

D. LCC Conclusions

The LCC assessment provides a comparative cost perspective for selected bio-based solutions and packaging substitutions in humanitarian kits, using the best available data within the operational constraints of humanitarian settings.

A key output of this work is the Excel-based LCC tool provided alongside the report, which operationalises the calculations and enables users to test alternative scenarios by adjusting kit configurations and key parameters (transport, storage, and prices). This improves transparency and reproducibility and supports practical decision-making within humanitarian organisations.

Across the assessed kits, replacing conventional packaging with bio-based packaging generally leads to only small changes in total kit cost. This is because packaging represents a relatively small share of overall kit costs, while total costs are mainly driven by key kit components. In the WASH kit, the most significant cost contributors are soap, the water container, and the torch. In the NFI kit, costs are dominated by the tent, followed by kitchen sets and sleeping mats. For the Food kit, wheat, pulses, and rice account for the largest share of total cost, while in the Agriculture kit, the main cost drivers are spools of twine, filament (in South Sudan only), and vegetable seeds. As a result, changes in packaging prices have a limited influence on total kit cost. These findings indicate that, where bio-based packaging delivers a clear environmental benefit compared to the reference scenario, its adoption can be considered a relevant and low-risk option from a cost perspective and could therefore be encouraged in humanitarian operations.

Finally, despite unavoidable limitations (restricted time horizon, incomplete EoL information, partial reliance on market price ranges), the study demonstrates that LCC can effectively support humanitarian procurement and programme design when used as a transparent decision-support tool, especially when combined with environmental and social assessments. Future iterations can substantially strengthen robustness by expanding scenario/sensitivity testing, adding qualitative EoL notes, and improving harmonised primary data collection on logistics, storage, and procurement practices.

Taken together, the LCC and S-LCA results highlight that the adoption of bio-based solutions in humanitarian contexts cannot be assessed on cost or social performance alone. While the LCC shows that bio-based packaging generally has a limited impact on total kit costs - making it a feasible option from an economic perspective - the S-LCA demonstrates that social outcomes depend strongly on governance, transparency, and implementation choices. Integrating economic and social considerations alongside environmental performance therefore supports more balanced, context-sensitive, and responsible decision-making in humanitarian innovation.

VIII. Global conclusion

Across the assessed bio-based solutions, environmental benefits are highly context-dependent and cannot be generalised. While certain applications such as mosquito nets, oil containers, and small packaging demonstrate clear LCA advantages, others may result in increased impacts, particularly where higher material demand is required. End-of-life conditions emerge as a decisive factor, often outweighing material choice itself. From a broader sustainability perspective, bio-based solutions tend to improve social outcomes when local value chains are enabled but may introduce trade-offs related to land and resource use. Economically, slightly higher upfront costs can be a barrier, but these can be offset in specific cases through reuse or reduced waste management burdens. Finally, governance considerations (particularly on infrastructure availability, procurement frameworks, and operational constraints) are critical determinants of real-world feasibility. Overall, the results highlight that the transition toward bio-based solutions in humanitarian contexts requires a system-level approach integrating environmental performance, socio-economic conditions, and implementation capacity. The following Table 16 summarises, solution by solution, the advantages and drawbacks of each of these indicators.

These conclusions should be interpreted in light of data limitations, particularly regarding supplier-level social information, actual end-of-life practices, and the evolving governance frameworks in the DRC and South Sudan.

A. Feasibility

The integrated assessment shows that feasibility is primarily determined by the alignment between solution requirements and local operational conditions, rather

than by environmental performance alone. In the contexts of the DRC and South Sudan, key constraints relate to the absence of waste segregation systems, limited composting and recycling infrastructure, weak regulatory enforcement, and, critically, the lack of functional end-of-life pathways, meaning that bio-based materials cannot be processed as intended and may not deliver their expected environmental benefits in practice.

Several concrete trade-offs were identified. Bio-based solutions with strong environmental performance, as indicated by life cycle assessment results (e.g. lower carbon footprint or improved material circularity), often rely on end-of-life conditions that are not present in the target contexts, such as separate collection or composting systems, limiting their real-world benefits. Similarly, while several solutions show to be technically feasible, their scalability cannot yet be assessed in practice, as most have not been piloted in the target contexts. To date, only a limited number of solutions, such as biogas and black soldier fly (BSF) systems, have been tested at pilot level in the DRC and South Sudan. Economic and operational trade-offs are also critical. While indicative estimates suggest that cost differences at kit level are relatively limited, given that packaging represents a small share of total kit costs, this conclusion should be interpreted with caution due to limited price transparency and reliance on partial market data. It must be acknowledged though that this finding applies primarily to packaging-related solutions, which represent only a subset of the assessed bio-based options, while the majority of solutions (e.g. biogas, BSF, and other system-level interventions) have fundamentally different cost structures. In addition, some safer or more sustainable options are associated with higher costs or lower market readiness, reflecting a trade-off between immediate deployability and optimal design,

Social feasibility is equally critical, as several solutions depend on user acceptance, behavioural change, and context-specific conditions such as access to water, privacy, or established practices. These aspects were assessed in detail in the D6.2 Community Engagement Report and represent key constraints on uptake, even where environmental and technical performance is favourable.

Overall, feasibility is therefore context-dependent and conditional: solutions are only viable where minimum requirements related to infrastructure, governance, cost, and user practices are met.

B. Replicability

From a replicability perspective, the assessed solutions can therefore be divided into different levels of readiness. Low-complexity substitutions, such as bio-based adhesive tape and small packaging items, appear most suitable for near-term replication because they have limited cost impact and can be integrated into existing procurement systems with minimal governance constraints. However, their adoption still depends on validation of performance and suitability under field conditions. Other solutions, such as biodegradable single-use sanitary pads, PLA oil containers, and PLA mosquito nets, are conditionally replicable, provided that

performance, user acceptance, procurement requirements, and end-of-life conditions are addressed, particularly in contexts where waste management systems and appropriate disposal pathways remain limited. From a feasibility and scalability perspective, local production would be an important consideration, but it must be assessed alongside the availability of raw materials in sufficient quantities, potential competition for feedstocks used in PLA production, and implications for food security. Cost remains a critical determinant for attracting private sector engagement and broader stakeholder buy-in. This consideration is particularly acute for biodegradable single-use sanitary pads, which cannot be reused and therefore represent a recurring expense. Without sustained affordability and reliable supply, women could be left without a viable solution after only one or two menstrual cycles, depending on the quantity distributed or purchased. As such, any assessment of these products must balance environmental benefits with economic viability, continuity of access, and long-term user reliance.

Bio-waste treatment solutions, including anaerobic digestion and BSF, have strong system-level potential but require infrastructure, coordination, investment, technical capacity, and institutional support. This makes them appropriate for controlled pilots ahead of broader scale-up with the risk of remaining confined to pilot applications where enabling systems are not yet in place.

Overall, the most replicable solutions are not necessarily those with the strongest environmental benefits in isolation, but those that achieve a workable balance between environmental performance, affordability, social value, governance feasibility, and operational practicality. Replication should therefore be selective and conditional, based on the specific humanitarian context and the availability of enabling conditions such as procurement acceptance, waste-management infrastructure, community engagement, local implementation capacity, and viable market and supply systems.

C. Determinants of Scalable Implementation

The integrated assessment confirms that all assessed bio-based solutions have potential value for humanitarian contexts, but their recommended implementation pathways differ. Their feasibility and replicability depend on how environmental performance, cost, social acceptance, governance readiness, and operational conditions interact in practice. Some solutions appear most suitable for near-term replication, as they can be integrated into existing procurement systems with limited need for piloting, although basic performance validation and testing under field conditions remain necessary. Others are better introduced through targeted pilots, context-specific deployment, or further technical optimisation before broader scale-up, with the recognition that without adequate enabling conditions, such solutions may remain confined to pilot applications with the recognition that without adequate enabling conditions, such solutions may remain confined to pilot applications, particularly for solutions that have not yet been tested in the target contexts. To date, only a limited number of solutions, such as biogas and black soldier fly (BSF) systems, have been piloted in the DRC and South Sudan.

The analysis also highlights several trade-offs that should guide implementation. Environmental benefits are strongest when appropriate end-of-life conditions are available, especially for compostable or biodegradable materials. Social benefits are strongest when solutions respond directly to beneficiary needs and do not create additional burdens, for example in relation to washing, privacy, usability, workload, or health protection. Economic feasibility depends not only on unit cost, but also on whether a solution affects total kit costs, waste-management burdens, logistics, value creation, or long-term use. Governance feasibility depends on procurement acceptance, quality validation, local authority engagement, and the availability of waste-management systems.

Therefore, replication should not be understood as automatic duplication across contexts. Instead, each solution should be replicated through the pathway that best matches its maturity, operational requirements, and enabling conditions. Table 17 summarises these differentiated implementation pathways and the conditions under which each solution can be most effectively scaled.

Table 16 Overview of bio-based solutions performance, based on environmental, social, economic and governance assessments

Solution	LCA (D5.3)	Social LCA (D6.1)	LCC (D6.1)	Governance (D6.1)
Monofilaments fishing nets/ Mosquito net (PLA)	~26% lower impacts vs polyester; benefits driven by lower fossil use and improved EoL (industrial composting)	Positive if performance maintained; strong health dependency (malaria protection)	Slightly higher cost; acceptable if durability equivalent	Requires strict validation (health standards); moderate deployment complexity
	Recommended for targeted scale-up following field validation and performance testing. Replicability is likely to be strong provided that durability, safety, and malaria protection standards can be fully demonstrated and accepted by humanitarian procurement and health actors, and that sufficient funding is available alongside reliable supply chains to support sustained adoption without reverting to conventional products.			
PLA bottle for oil	~29% lower impacts; production dominates impacts; strong EoL benefits (industrial composting)	Potential local production benefits; limited social risks	Higher cost; partial offset via waste reduction	Scalable if supply chains exist; dependent on composting availability

	Recommended for targeted integration into humanitarian supply chains, particularly in food assistance programmes where liquid commodities (e.g. oil) are distributed. Replicability is likely to be strongest where reliable supply chains are in place and where humanitarian actors can integrate PLA containers into procurement frameworks, ensure logistics compatibility (transport, storage, handling), and align with realistic end-of-life options (e.g. controlled disposal, composting where available, or waste management partnerships), provided that compliance with relevant food safety standards, material regulations, and procurement requirements can be ensured, and that sufficient funding is available to support adoption and avoid reversion to conventional packaging.			
PLA bottle for water	~80% higher impacts due to higher material mass; EoL better but insufficient to compensate (industrial composting)	Neutral to positive; no major direct social impact	Higher cost due to material inefficiency	Not suitable at current maturity; technical limitation (strength/volume)
	Recommended for targeted integration into humanitarian supply chains, with differentiation by application, alongside further technical optimisation. Larger-volume PLA containers are more relevant for WASH applications, where water storage and distribution rely on container-based systems, while smaller-volume PLA bottles are better suited for specific liquid products within the health sector, where supply chains are more controlled and quality requirements are higher. Replicability is likely to be strongest where humanitarian actors can integrate these solutions into existing procurement frameworks, ensure logistics compatibility and product durability for their intended use, and align with realistic end-of-life options, provided that compliance with relevant health, safety, and material standards can be ensured, and that sufficient funding and reliable supply chains support sustained adoption.			
Sanitary pads – reusable	Improved performance (~-27%); minimal EoL impacts (open burning)	Strong positive (dignity, waste reduction) but context-dependent (water, privacy)	Higher upfront, lower long-term cost	High dependency on context (WASH conditions); behavioural adoption needed
	Recommended for stable or protracted settings with adequate WASH conditions. Replication is strongest where users have access to water, privacy, washing facilities, and where community engagement supports acceptance.			

Sanitary pads – biodegradable single-use	Slightly higher impacts (+9%) due to biomass production, but significantly lower EoL impacts (home composting)	Positive: reduced environmental and health risks linked to waste accumulation; maintains usability in emergency contexts (no washing required)	Higher unit cost; no reuse savings but potential waste management cost reduction	Highly relevant in low-infrastructure contexts; performance depends on actual EoL conditions
Recommended for emergency and low-WASH contexts. Replication is relevant where reusable options are less feasible, provided disposal practices and waste-management implications are considered				
Adhesive tape (bio-based)	~-8% lower impacts; reduced EoL burden (home composting)	Minor indirect benefits (less pollution)	Slightly higher cost, negligible at system level	Easy implementation; low risk
Recommended for near-term procurement substitution after field testing. High replicability due to low implementation complexity, limited cost impact, and easy integration into existing logistics and procurement systems.				
Packaging – small items (mycelium protective material, biodegradable laminating film)	Environmental benefits when replacing short-life plastics; strong reduction in plastic leakage and EoL impacts (industrial composting)	Positive indirect effects (reduced pollution)	Slightly higher cost but low share of total kit (2–5%)	Very easy to implement
Recommended for near-term substitution, after field testing, where end-of-life assumptions are realistic. Replicability is high because cost impact is limited and operational changes are minimal, especially for short-life packaging.				
Packaging – large volume (disposable bags from renewable sources)	Often worse due to increased material demand (multiple units needed); EoL by industrial composting	Neutral	Higher costs due to current lower mechanical efficiency	Not recommended unless material performance improves
Recommended with performance improvement and careful application. Replication should prioritise cases where material efficiency, mechanical strength, and packaging functionality can match operational needs without increasing material demand.				

Biowaste treatment (AD, composting, BSF)	Strong system-level benefits (avoided impacts, reduced open dumping/burning)	High positive impact (jobs, sanitation, local value)	High investment, long-term savings	High complexity; requires infrastructure and coordination
Recommended for piloting and progressive scale-up. Strong replicability potential at system level, but implementation requires waste segregation, infrastructure, technical capacity, coordination with authorities, and demand for outputs such as compost, frass, larvae, or energy.				

A final decision making chapter: For humanitarian actors, the results provide a prioritisation basis for selecting bio-based solutions according to operational context: low-complexity substitutions can be integrated through procurement, user-sensitive items should be accompanied by community engagement and behavior change programming, and system-level waste-treatment solutions should be introduced through pilots and partnerships with local authorities and service providers.

IX. Annexes

A. LCC tool and Kits Cost Details

The LCC tool is provided as an Annex in an .xlsx file format.

Table 18 WASH kit cost comparison

WASH	Reference Products	Biobased items	Biobased items + Bio Packaging
SSD			
Items Purchase cost	36.65	39.73 (+8.4%)	39.73 (+8.4%)
Packaging purchase cost	10.45	10.45	13.81 (+32.1%)
Life Cycle Costing	47.10	50.18 (+6.5%)	53.54 (+13.7%)
DRC			
Items Purchase cost	46.05	50.23 (+9.07%)	50.23 (+9.07%)
Packaging purchase cost	10.45	10.45	13.81 (+32.1%)
Life Cycle Costing	56.50	60.68 (+7.4%)	64.04 (+13.4%)

Table 19 NFI kit cost comparison

NFI	Reference Products	Biobased	Biobased + Bio Packaging
SSD			

Items Purchase cost	565.34	565.8	565.8
Packaging purchase cost	12.66	12.66	15.94 (+25%)
Life Cycle Costing	578	578	581.74 (-1.5%)
DRC			
Items Purchase cost	583.34	568.8 (-2.5%)	568.8 (-2.5%)
Packaging purchase cost	12.66	12.66	15.94 (+25%)
Life Cycle Costing	596	581.46	584.74 (+0.5%)

Table 20 Food kit cost comparison

Food	Reference Products	Biobased	Biobased + Bio Packaging
SSD			
Items Purchase cost	213.47	213.47	213.4673
Packaging purchase cost	23.59	28.73 (+21.77%)	253.3138 (+973.92%)
Life Cycle Costing	237.06	242.19 (+2.17%)	466.7812 (+96.91%)
DRC			
Items Purchase cost	92.02733	92.02733	92.02733
Packaging purchase cost	23.591	28.72629 (+21.77%)	253.3138 (+973.92%)
Life Cycle Costing	115.6183	120.7536 (+4.44%)	345.3412 (+198.66%)

Table 21 Agriculture kit cost comparison

Agriculture kit	Reference Products	Biobased	Biobased + Bio Packaging
SSD			
Items Purchase cost	190.78	190.78 (+0.00%)	190.78 (+0.00%)
Packaging purchase cost	4.54	4.54 (+0.00%)	13.71 (+201.98%)
Life Cycle Costing	195.30	195.30 (+0.00%)	204.47 (+4.70%)
DRC			
Items Purchase cost	35.50728	35.50728 (+0.00%)	35.50728 (+0.00%)
Packaging purchase cost	4.540893	13.71534 (+201.98%)	13.71534 (+201.98%)
Life Cycle Costing	40.04817	49.22262 (+22.90%)	49.22262 (+22.90%)

B. Survey Questions and Participants

Table 22 Survey Questions

Question	Sub-parts / Options
Please indicate the organisation to which you are affiliated	—
Please indicate your position's title	—
Please indicate the scope of activities of your organisation	—
Please specify the activities/areas of expertise relevant to humanitarian aid	Producers/providers of bio-based solutions; Producers/providers of other solutions; Transport & logistics (upstream); Humanitarian organisations / NGOs; Organisations/individuals representing beneficiaries; Supporting activities (policy makers, academia); Waste collection & transport; Waste treatment as compost; Waste treatment as recycling; Re-use of packaging; Waste treatment as incineration (without energy recovery); Waste treatment as incineration (with energy recovery); Other
Please indicate where your solutions/activities are manufactured/located	—
Which regions are targeted by your main activities?	South Sudan; Democratic Republic Congo; Africa (excl. South Sudan, DRC, MENA); MENA; Asia (excl. Middle East); North America; South America; Europe; Oceania; Global; Additional details
Choose only one region of concern	Region restated
Evaluate influence of stakeholder categories	Employees/Workers; Local Communities; Supply Chain Actors; Beneficiaries; Society; Children; Other
Evaluate relevance of sub-categories for Employees/Workers	Freedom of association & collective bargaining; Child labour; Fair salary; Working hours; Forced labour; Equal opportunities/discrimination; Health and safety; Social benefits/social security; Employment relationship; Sexual harassment; Smallholders/farmers; Other
Evaluate relevance of sub-categories for Local Communities	Access to material resources; Access to immaterial resources; Delocalisation & migration; Cultural heritage; Safe & healthy living conditions; Respect of Indigenous rights; Community engagement; Local employment; Secure living conditions; Other
Evaluate relevance of sub-categories for Supply Chain Actors	Fair competition; Promoting social responsibility; Supplier relationships; Respect of intellectual property rights; Wealth distribution; Other

Question	Sub-parts / Options
Evaluate relevance of sub-categories for Beneficiaries	Health & safety; Feedback/grievance mechanism; Beneficiaries' privacy; Transparency; End-of-life responsibility; Other
Evaluate relevance of sub-categories for Society	Public commitments to sustainability; Contribution to economic development; Prevention & mitigation of armed conflicts; Technology development; Corruption; Ethical treatment of animals; Poverty alleviation; Other
Evaluate relevance of sub-categories for Children	Education provided in local community; Health issues for children; Marketing practices affecting children; Other
Are you aware of any critical social hotspots or issues?	Open-ended response
Would you like us to contact you? (Email)	Open-ended response
Please rate the difficulty of this survey	Very easy, Easy, Medium, Difficult, Very Difficult

Table 23 List of survey participants

Organisation	Participants no.
People In Need (PIN)	6
PRO CIVIS	2
Universidad de Cantabria	1
AIMPLAS	1
Polish Humanitarian Action (PAH)	1
ITENE	1
Full Development Agency Group	1
Caritas développement Goma	1
Laboratoire d'Analyse Environnementales	1
Réseau des Organisations des jeunes engage dans le changement climatique, Conservation de la biodiversité, zones humides et forêts	1
Solidarités International	1

C. Comments of survey respondents on other social categories

Additional comments from partners highlight critical **social dimensions that extend beyond** the immediate scope of material selection or kit design but are highly relevant for decision-makers working on humanitarian strategies, sustainability agendas, and long-term resilience planning. They are not going to be assessed in the study but are mentioned for further social assessment in the humanitarian sector.

a) *Child Welfare as a Critical Humanitarian Priority*

Partners noted the situation of orphaned children in the Great Lakes region as a “ticking time bomb,” signalling a severe and often under-recognised crisis. Large numbers of children lack access to basic education, family care, and psychosocial support. This challenge extends beyond the responsibility of any single programme and illustrates:

- Systemic social protection gaps that humanitarian interventions alone cannot resolve.
- The need for stronger links between protection, education, and social welfare programming.
- A long-term societal risk, as children without adequate support are increasingly vulnerable to exploitation, recruitment by armed groups, and intergenerational poverty.

b) *Chronic Underfunding as a Structural Constraint on Sustainability*

Chronic underfunding was repeatedly highlighted as a major constraint shaping the effectiveness and sustainability of humanitarian interventions. The implications of insufficient funding extend to:

- The quality and durability of items procured and distributed.
- The frequency and consistency of distributions.
- The capacity to invest in environmentally responsible or innovative materials.
- The ability to evaluate, validate, or adapt innovative solutions in the field.

c) *The Double-Edged Social Impact of Humanitarian Aid in the DRC*

Feedback regarding the DRC illustrates the complex social effects of humanitarian aid. Partners highlighted notable positive impacts, including:

- Improved access to healthcare services.
- Increased school attendance.
- Enhanced food security.

However, several unintended negative effects were also identified:

- Increased dependency among beneficiaries.
- Potential security risks when aid attracts armed actors.
- Risks of corruption or mismanagement within distribution chains.

These dynamics reflect well-documented humanitarian dilemmas, where essential assistance can inadvertently reinforce harmful patterns or exacerbate existing tensions.

d) *Behavioural, Cultural, and Economic Barriers to Adopting Bio-Based Solutions*

Partners also highlighted significant behavioural and socio-economic factors that may affect the uptake of bio-based materials. These include resistance to behavioural change, extreme poverty, and limited technical capacity to use or

maintain new products. Without appropriate support, even environmentally preferable solutions may face low acceptance or limited usability.

Additionally, the widespread perception that humanitarian aid should be free may hinder the adoption of solutions that require labour inputs, maintenance, or cost-sharing, posing challenges for future scalability or transition to market-based models.

D. References used for HOs social theme assessment

This annex lists non-exhaustive reference documents used to assess the HOs social themes related to the management of product quality, accountability, transparency, community engagement, and socio-economic impacts in humanitarian operations.

A. Product Quality, Safety, and Technical Specifications

- World Food Programme (WFP). *Food Safety and Quality Overview*.
<https://www.wfp.org/food-safety-and-quality>
- International Organization for Standardization (ISO). *ISO 22000 – Food Safety Management Systems*.
<https://www.iso.org/iso-22000-food-safety-management.html>
- UNICEF Supply Division. *General Procurement Guidelines and Cold Chain Equipment Catalogue* (illustrative product labelling and specification requirements).
<https://www.unicef.org/supply/documents/general-procurement-guidelines-cold-chain-equipment>
- UNHCR. *Environmentally Friendly Product Specifications – Plastic Tarpaulin with Logo*.
<https://www.unhcr.org/sites/default/files/2024-05/environmentally-friendly-product-specifications-plastic-tarpaulin-with-logo.pdf>
- ICRC / IFRC / UNHCR. *Eco-design Tarpaulin and Infrastructure Procurement Project (2021–2023)*.
<https://logcluster.org/en/document/icrcifrcunhcr-eco-design-tarpaulin-project-2021-2023>

B. Post-Distribution Monitoring (PDM) and Quality Follow-up

- World Food Programme (WFP). *Post-Distribution Monitoring (PDM) Guidance and Practice Examples*.
<https://www.calpnetwork.org/wp-content/uploads/2023/08/WFP-0000152015.pdf>
- UNHCR. *Non-Food Items (NFI) PDM Example*.
<https://data.unhcr.org/fr/documents/download/64564>
- CALP Network. *Cash and Voucher Assistance – PDM Examples and Corrective Actions*.
<https://www.calpnetwork.org/wp-content/uploads/2023/08/WFP-0000152015.pdf>
- Cash Hub. *Cash-for-Work and Livelihood Support – PDM Guidance*.
<https://cash-hub.org/wp-content/uploads/sites/3/2025/02/BN-Cash-Support-Programme-PDM-v2.pdf>

C. Accountability, Feedback, and Transparency

- Core Humanitarian Standard (CHS). *Core Humanitarian Standard on Quality and Accountability*.
<https://www.corehumanitarianstandard.org/>
- CHS Alliance. *CHS Guidance Notes and Indicators* (feedback, accountability, and learning).
<https://www.chsalliance.org/get-support/resource/chs-guidance-notes-and-indicators/>
- International Aid Transparency Initiative (IATI). *Aid Transparency Standard and Platform*.
<https://iatistandard.org/>

D. Education, WASH, and Living Conditions

- World Food Programme (WFP). *School Feeding and School Meals Programmes Overview*.
<https://www.wfp.org/school-meals>
- Sphere Association. *Sphere Handbook – Humanitarian Charter and Minimum Standards* (WASH, education, shelter, and infrastructure).
<https://www.spherehandbook.org/>

E. Livelihoods, Economic Development, and Psychosocial Support

- World Food Programme (WFP). *Livelihoods and Cash-Based Assistance – Programme and PDM Examples*.
<https://www.calpnetwork.org/wp-content/uploads/2023/08/WFP-0000152015.pdf>
- Inter-Agency Standing Committee (IASC) / World Health Organization (WHO). *Mental Health and Psychosocial Support (MHPSS) Guidelines and Interventions*.
<https://www.who.int/our-work/health-emergencies/knowledge-hub/mental-health-psychosocial-support-%28mhpss%29/mhpss-interventions>

E. S-LCA Scoring of Humanitarian Organisations Activities

Table 24 Detailed Scoring of HO S-LCA questions (yellow: beneficiaries, blue: children, red: local communities, purple: society, green: supply chain actors)

Social theme	Questions	Food / Agri	NFI	WASH	Global score	Average
Health & safety	Are data about defects (number, quality) assessed?	3	2	2	2,33	2,78
	Are suppliers obliged to use labels to justify quality?	4	2	3	3,00	
	Is there a Quality and/or Product Safety Management System?	4	2	3	3,00	
Feedback/grievance mechanism	Is there a mechanism for customers to provide feedback?	3	2	3	2,67	2,33
	Are there management measures to improve feedback mechanisms?	2	2	2	2,00	
Transparency	How would you qualify the transparency regarding the content of products, regarding substances that might produce a toxic impact?	3	2	3	2,67	2,67
Education provided in the local community	Are there any policies to support local education for children?	3	3	3	3,00	3,00
Access to material resources	Does the organisation provide material resources to the communities?	3	3	4	3,33	3,17
	Does the organisation provide infrastructure (school, hospital)?	3	2	4	3,00	
Community engagement and Delocalisation	Does any project have impacts on community engagement?	3	3	3	3,00	2,83
	Does any project have impacts on helping NGO or local projects?	3	2	3	2,67	
Safe & healthy living conditions	How would you qualify the effort of the sector to improve the safe and healthy living conditions?	3	3	4	3,33	3,33
Access to immaterial resources	Are there any community education initiatives within the company?	3	2	3	2,67	2,56

	Does the organisation collect funds and distribute it?	3			3,00	
	Does the organisation organise or support mental health programs?	2			2,00	
Contribution to economic development	Do any projects contribute to the economic development of countries? By creating jobs, doing trainings?	3			3,00	3,00
Fair competition	Is the procedure for selecting suppliers well-documented, transparent and harmonised?	4	2	3	3,00	2,56
	Are there any price agreements in the sector regarding the selection of suppliers?	3	2	2	2,33	
	Are there any current claims from suppliers regarding unfair competition?	3	2	2	2,33	

F. References used for SPs social theme assessment

The following non-exhaustive references were used to assess SP social themes, combining international labour standards, country-specific legal frameworks, governance indicators, and publicly available company information.

- International Labour Organization (ILO). *International labour standards and country labour profiles* (consolidated reference for working hours, wages, social protection, collective bargaining, and occupational health and safety). <https://www.ilo.org/global/standards/lang--en/index.htm>
- World Bank. *Worldwide Governance Indicators (WGI)*. <https://www.worldbank.org/en/publication/worldwide-governance-indicators>
- International Employment Law Firm Alliance (L&E Global). *Comparative employment and labour law frameworks*. <https://leglobal.org/>
- U.S. Department of Labor. *Labour standards and working conditions*. <https://www.dol.gov/>
- India Briefing. *Labour law, human resources and payroll – India*. <https://www.india-briefing.com/doing-business-guide/india/human-resources-and-payroll/labor-law>
- Global Legal Insights. *Employment and labour laws and regulations – Bulgaria*. <https://www.globallegalinsights.com/practice-areas/employment-and-labour-laws-and-regulations/bulgaria/>
- Ravio. *German employment and labour laws – overview*. <https://ravio.com/blog/german-employment-and-labour-laws-a-comprehensive-guide>
- ITUC. *Global Rights Index – South Sudan*. <https://labourrightsindex.org/lri-2024-documents/south-sudan.pdf>
- Lloyds Bank Trade. *Working conditions – Democratic Republic of the Congo*. <https://www.lloydsbanktrade.com/en/market-potential/democratic-republic-of-congo/work-conditions>
- International Labour Organization (ILO). *Country labour profile – Democratic Republic of the Congo (2024)*. <https://eplex.ilo.org/en/country-detail/?code=COD&yr=2024>
- GS Companies — <https://www.gs-companies.com/>
- Value Packaging — <https://www.valuepackaging.cn/>
- Sway — <https://swaythefuture.com/>
- Aakar Innovations — <https://aakarinnovations.com/>
- Seabird — <https://www.seabird.fr/>
- Lam-On — <https://www.lam-on.com/>
- Monta — <https://monta.de/fr>
- Indresmat — <https://www.indresmat.com/>
- Kingspan — <https://www.kingspan.com/fr/fr/>
- EcoFriend Sheep — <https://ecofriendsheep.eu/>
- Myco — <https://www.myco.cz/en/>