The list of bio-based solutions relevant to waste management in the humanitarian context

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Document information

DELIVERABLE NUMBER	D4.1.							
DELIVERABLE NAME	The list of bio-based solutions relevant to waste management in the humanitarian context							
ANNEXES	1) Template for the collection of data on bio-based solutions. 2) The survey addressed to BIC entities (members and associate members of this consortium). 3) All bio – based solutions clustered as the "multi – purpose packaging products". 4) All bio – based solutions clustered as "packaging products for food and drinks". 5) All bio – based solutions clustered as "hygiene products". 6) All bio – based solutions clustered as "construction related products". 7) All bio – based solutions clustered as "other products potentially applicable in the context of humanitarian interventions". 8) All bio – based solutions clustered as "small – scale technologies". 9) All bio – based solutions clustered as "big scale technologies".							
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Contents

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Table of figures

List of tables

List of abbreviations

AIMPLAS	Asociación de Investigación de Materiales Plásticos y Conexas
BIC	Bio-based Industries Consortium
BSF	Black soldier flies
DRC	Democratic Republic of the Congo
HUMANITARIAN REPORT	Humanitarian sector needs assessment report
IBF	Irish Bioeconomy Foundation
ITENE	Instituto Tecnológico del Embalaje, Transporte y Logística
LCA	Life Cycle Assessment
PAH	Polish Humanitarian Action
PIN	People in Need
PRO CVIS	Fundacja Edukacji i Dialogu Społecznego PRO CIVIS
SWM	Solid waste management
UC	Universidad de Cantabria
WP	Work Package

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EXECUTIVE SUMMARY

The main purpose of Task 4.2.1. of the Bio4HUMAN Project was the identification of already existing technological solutions, or solutions in the pre – production phase, being of bio – based origin, which could respond to the needs and expectations of the humanitarian actors and the beneficiaries of humanitarian actions. The preparation of the **"List of bio – based solutions relevant to waste management in the humanitarian context"** has been preceded by the analysis of Project's deliverable D.3.3. - *"The humanitarian sector needs assessment report"* and by internal Project's analysis executed as T.4.1. - *"The theoretical and practical scope of bio-based solutions and bio-based systems to be potentially applied under the humanitarian context"*.

The humanitarian report (D3.3.) provided *inter alia* the very important information on the types of humanitarian waste and generally on waste in humanitarian settings, with organic and plastic waste definitely being the most ubiquitous. Further important insights from this report were the solid waste management challenges identified in the humanitarian context, expectations of the humanitarian sector versus bio-based solutions and the main constraints linked to the actual implementation of bio-based solutions in humanitarian settings. Of importance for further proceedings were also the guiding examples of bio-based products and bio-based technologies of potential application in the humanitarian context.

The theoretical and practical scope of bio-based solutions and bio-based systems (internal working document) set the appropriate frameworks for the actual identification (scoping activities). The broad catalogue of bio-based solutions and the most common definitions of "bio-based products" and "bio- based technologies" were of particular importance. In terms of the bio-based products the types and forms have been specified, as well as detailed characterization criteria. In terms of bio-based technologies, the ones applicable in solid waste management have been presented in a more detailed fashion. The key areas for the creation and delivery of bio-based innovations have been taken into further considerations. Already at this stage practical examples of bio-based innovative solutions of potential relevance for Bio4HUMAN were also identified.

The actual process of scoping for bio-based solutions took the form of surveying Bio-based Industries Consortium entities (members and associate members) and analyzing various data sets, incl. a) outcomes of projects financed by the CBE JU initiative, b) the lists compiled by national and international organisations advocating for the bio-based solutions, c) the patents d) the awards given to the exceptional bio-based products and technologies. Despite the faced obstacles, in particular moderate readiness by BIC entities to participate in the survey, lack of appropriate finished solutions in the CBE JU projects, difficulties in getting the lists of products awarded at trade fairs and the lower utility of "industrial designs" – 81 solutions have been scoped and presented in a more detailed form.

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After initial analysis, 32 bio-based products and technologies were selected and put up to **the internal and external consultations**. The internal observations referred mainly to the possibility of the local production (i.e. in the humanitarian destination) of the proposed products, the quality, the actual demand from the humanitarian organisations, the "end of life" scenario (in particular the feature of biodegradability), price and cost considerations, the local resources needed for the implementation of technologies and the functional and operational elements. All of these issues, joint with more general questions like "applicability, usefulness and efficacy of the products in the humanitarian context" and "transferability of the technology to humanitarian destinations / feasibility of the technological implementation and operation" have become the subject of the external consultations with representatives from national and international humanitarian organisations.

The successfully conducted internal and external consultation processes gave rise to establishing **the final list of 27 bio-based products and technologies.** The solutions on the List are divided into six clusters:

1) multi-purpose packaging products,
2) packaging products for food and drinks,
3) hygiene products,
4) construction related products,
5) other products potentially applicable in the context of humanitarian interventions,
6) small-scale technologies.

The list is comprised of solutions contributing strongly to a more circular bioeconomy and exercising features of renewability, recyclability, biodegradability, compostability and sustainability. There are bio-based solutions with proper functional properties, comparable with fossil-based counterparts. They allow for durable applications and a reduction in the use of material. A few solutions combine both the product side and the technology side, allowing for the technology/installation to be easily transferred to the destination location (for example African locations) and for the products to be prepared and delivered just on site of the humanitarian intervention. On the list there are also innovative, patented and certified products and technologies.

The presented solutions have been generally appraised by the Project's Ethics Advisory Board and Internal Ethics Officer as relevant for the context and the purposes of Bio4HUMAN during a separate working meeting. The main topics of ethical considerations are the sustainability of raw materials, environmental and waste management concerns, as well as potential impacts on ecosystems and food security. For all the subjects raised additional explanations have been provided. The issues of legal and "cultural" frameworks of using the solutions in the countries concerned and the capacity building issues will be then addressed in the next Project's next stages.

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The authors of the "List of bio-based solutions relevant to waste management in the humanitarian context", i.e. PRO CIVIS Foundation as the leading entity, joint by active collaborators – ITENE, AIMPLAS, Irish Bioeconomy Foundation, University of Cantabria and WeLOOP, are convinced that the proposed collection of products and technologies responds in the proper way to the identified solid waste management challenges in the humanitarian context. The List of solutions will serve as the rightly set and interesting case study for further Project's based LCA, S-LCA, LCC analysis, and the feasibility evaluation processes. The proposed bio-based solutions and the processes described in this deliverable shall also form one of the substantive elements when drafting the guidelines and recommendations for the envisaged key groups of stakeholders.

1. Introduction.

The general objective of the project *"Identifying bio-based solutions for waste management applicable to humanitarian sector"* (further referred to as ***"Bio4HUMAN"*** or ***"Project"***) is to assess the scope to which bio-based innovative technological solutions and bio-based systems have the potential to be applied under a humanitarian context, with the simultaneous positive effect on the environment. The assessment shall take into account performance, supply and pricing considerations when possible/available.

Being more concrete, Bio4HUMAN Consortium shall have been able to respond to the following question:

To what extent the bio-based products, bio - based systems and bio – based innovative solutions could contribute to successfully manage environmental challenges relevant to waste in humanitarian contexts?

The Scoping Exercise for the bio – based solutions has been one of the key elements of the first part of the Project. This activity was supposed *inter alia* to:

1. Deliver on the identification of existing (or being under current development) innovative technological solutions and bio-based systems, which may constitute the bio economical response to the needs and the difficulties faced by the humanitarian aid sector in the solid waste management (**"SWM"**) issues.

2. Deal with the value chains' aspects – both in the bio-based sectors and in the humanitarian aid sector; the potential influence of the aforementioned value chains on humanitarian initiatives shall also have been taken into the analysis.

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List of bio-based solutions potentially relevant to waste in humanitarian context (further referred to as ***"List of bio-based solutions"***) summarizes the first phase of the Scoping Exercise of the Project, the one relating to the identification of existing products and technologies. According to the Project's application **the purpose of this phase of the Scoping Exercise was to**:

''Identify the already existing technological solutions (or solutions being in the pre-production phase) - like for example plant carton packages, 100 % recycled paper products, compostable liners and bags, bio-based laundry detergents, hygienic products made from plant origin, plastics products for agriculture to be degradable in soils or in compost conditions, 100 % bio-based textiles – which could be marked "made by bioeconomy" and which could respond to the needs and expectations of the humanitarian actors and the beneficiaries of humanitarian actions."

The identification process of solutions consisted of a broad investigation from several different sources, seeking to obtain an inventory of available bio-based products and solutions.

This process was however preceded by two other Bio4UMAN tasks, which have set important frameworks for the search and systemization of innovative bio – based products and technologies. These two Bio4HUMAN tasks being: 1) Humanitarian sector needs assessment report, 2) The theoretical and practical scope of bio-based solutions and bio-based systems to be potentially applied under the humanitarian context.

2. Humanitarian sector needs assessment report

The first important substantive task of the Project was to define the actual and potential needs of the humanitarian sector in solid waste management and to present the current status – how the needs are being addressed. The humanitarian partners to the Project, i.e. People in Need (**"PIN"**) and Polish Humanitarian Action (**"PAH"**) prepared the **"Humanitarian sector needs assessment report"** (further referred to as the ***"Humanitarian Report"***), which in a very detailed manner dealt with solid waste management needs of the humanitarian sector, especially the ones which could potentially be addressed by bio-based solutions.[1]

The following important conclusions from the Humanitarian Report have been taken into consideration by the Bio4UMAN consortium partners, when starting on the preparation of the List of bio – based solutions:

[1] The Humanitarian Report has been prepared as part of the T.3.3. activity of the Project and is available at: https://bio4human.eu/resources/ .

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1) **The main solid waste management ("SWM") challenges identified in the humanitarian context**:
    a. lack of national policies regulating SWM and no strategic planning for SWM;
    b. lack of SWM infrastructure and services (e.g. recycling) with either non-existent or nascent official waste transformation systems;
    c. lack of coordination / linkages among SWM stakeholders (including humanitarian organisations); actors tend to work in silos, e.g. waste collectors do not create linkages with waste transformers;
    d. lack of policies as well as financial and human capacities of humanitarian organisations to implement sustainable SWM – the issue is not being treated as a priority;
    e. lack of sustainable humanitarian procurement / supply chains;
    f. the low technical capacity of all actors in SWM;
    g. general lack of quality waste data, resulting from lack of monitoring and research both on the side of governments, academia, private sector and humanitarian organisations;
    h. lack of SWM awareness & mentality – low perception of responsibility.
2) **The expectations of the humanitarian sector versus bio-based solutions,** which are generally welcomed by many in the humanitarian sector, especially if they:
    a. are sustainable,
    b. address environmental, economic, and social factors,
    c. utilize local resources,
    d. are adaptable to local conditions,
    e. have the possibility of empowering local communities,
    f. provide long-term benefits without unintended negative consequences.

Of significant importance for the scoping of bio-based solutions were also the charts from the Humanitarian Report on **the types of humanitarian waste and generally on waste in humanitarian settings.** The following classification of non – hazardous and hazardous humanitarian waste by WREC[2] has been provided in the Humanitarian Report:

[2] Coordinated by the Global Logistics Cluster, the Environmental Sustainability Team **WREC Coalition**
is a coalition of humanitarian organisations - the Danish Refugee Council (DRC), the International Federation of Red Cross and Red Crescent Societies (IFRC), Save the Children International and the World Food Programme of the United Nations – with input from all Logistics Cluster partners, other humanitarian clusters, the private sector and academic partners.

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Non-hazardous waste	Hazardous waste
Plastic waste (mostly from packaging) 1 PET (Polyethylene Terephthalate) (e.g. oil, water bottles, packing strap) 2 HDPE (High-Density Polyethylene) (e.g. milk bottle, detergent recipient, buckets, plastic pallet) 3 PVC (Polyvinyl Chloride or Vinyl) (e.g. window frames, pipes, cables) 4 LDPE (Low Density Polyethylene) (e.g. shopping bags) 5 PP (Polypropylene) (e.g. woven bags, bins, brooms, cables, plastic pallet, packing straps, bottle tops) 6 PS (Polystyrene) (e.g. cups and plates, egg cartons) and EPS (Styrofoam or extended polystyrene) (e.g. plates and cup containers, trays, packaging bubble wrap) 7 OTHER (Miscellaneous) (e.g. DVDs, computer cases, nylon, car parts) Aluminium laminate plastics (e.g. sachets) *In the absence of plastic numbers, better to check the recyclability of plastics with the local waste collectors or recycling companies.* Metal waste • Aluminium (e.g. drink cans, food cans, aluminium tray and foil) • Steel (e.g. Vehicle Spare Parts • Tin • Copper Glass waste • Bottles and jars • Auto glass • Window glass Paper& Cardboard: • Cardboard (e.g. packaging boxes, eggs tray) • Paper (e.g. office paper, paperbags, envelopes, newspaper) Organic waste • Food waste (e.g. peelings, food scraps) • Vegetation waste (e.g. branches, leaves, scrap wood) Wood • Broken pallets (wood) • Furniture • Bamboo scraps	E-waste: • IT Hardware (e.g. servers, routers, external drives, CPUs) • Telecoms equipment (e.g. deskphones, radios, mobile phones, computers, laptops, monitors, keyboards, Scanners, printers, copiers, toner cartridges) • Household/office appliances (e.g. Air conditioners, fridges, generators) • Lighting equipment (light bulbs, switches, fluorescent lamps) • Electrical and electronic equipment (e.g. cameras, smoke detectors, drills, medical devices) • Solar Photovoltaic equipment (e.g. PV panels, inverters) Batteries of different types (e.g. lithium ion, lead acid) Medical Waste: • Pharmaceutical products (e.g. expired and unused medicines and vaccines, pills, creams) • Used sharps (e.g. needles, razors, scalpels) • Infectious items (e.g. Infected with body fluids) • Etc. Fleet management waste: • Used engine oil • Oil Filters • Lubricants • Tyres Chemicals: • Solvents • Acids • Detergents • Paints • Varnishes • Inks • Glues • Non-empty packaging waste that contains hazardous substances Pesticides Asbestos

Table 1 Classification of non – hazardous and hazardous humanitarian waste by WREC

The Humanitarian Report also provided important classification on **waste in humanitarian settings** in Sub – Saharan Africa, where Bio4HUMAN has its two pilot studies (South Sudan and the Democratic Republic of Congo). In Sub-Saharan Africa, the municipal solid waste is 57 % organic, 13 % plastic, 9 % paper, 4 % metal, 4 % glass, 13 % other. Research participants of the Humanitarian Report confirmed that the most ubiquitous waste is organic and plastic.

The comparison of municipal solid waste composition in Sub-Saharan Africa and globally has been shown in the **Figure 1** below.

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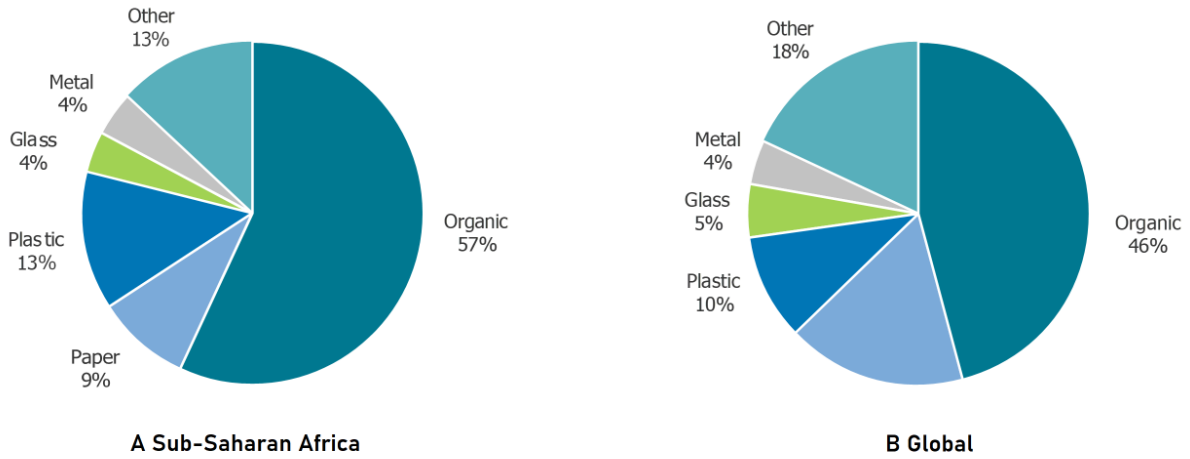

Figure 1 Municipal solid waste composition, Sub – Saharan Africa and global

Organic waste shall be understood as "*any material that comes from either a plant or an animal, and can be decomposed by microorganisms (biodegradable) into carbon dioxide, methane, and simple organic molecules, or consists of the remains, residues, or waste products of any organism*".[3] Most often, organic waste refers to waste food, but it also includes yard waste, paper, wood, some fabrics, sewage and manure. Worldwide organic waste makes up roughly three-quarters of the waste streams.[4]

As for the **plastic waste –** according to the Humanitarian Report it stems mostly from the packaging of relief items (44 %) and consists of:

- polyethylene terephthalate (PET) – used for oil/water bottles;
- high-density polyethylene (HDPE) – used in vegetable oil containers;
- polypropylene (PP) – used in woven bags for commodities such as rice and sorghum;
- paper and cardboard (43 %).

81 % of humanitarian organizations consider packaging and / or plastic as the biggest problem in terms of waste streams, followed by medical waste (in the wake of the Covid-19 pandemic).

Of high importance for the Scoping Exercise were also **the main challenges linked to potential implementation of bio-based solutions in humanitarian settings**. The following main challenges have been highlighted by Humanitarian Report:

1) Economic viability:
   - difficulty in creating sustainable business models around bio-based solutions

[3] https://www.sciencedirect.com/topics/engineering/organic-waste, accessed on February 25th, 2025.
[4] https://climate.mit.edu/explainers/organic-waste , accessed on January 14th, 2025.

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- limited markets for end products (e.g., compost, biogas) in humanitarian contexts
- competition with cheaper, non-sustainable alternatives

2) Operational challenges:
   - integrating new systems into existing waste management practices
   - ensuring consistent waste separation at source
   - managing odors and pests associated with organic waste processing

3) Knowledge gaps:
   - lack of local expertise in bio-based waste management techniques
   - limited data on long-term effectiveness of waste management practices in humanitarian contexts

4) Logistical issues:
   - difficulties in transporting necessary equipment or materials
   - challenges in establishing reliable supply chains
   - managing seasonal variations in waste composition and volume

5) Social and cultural barriers:
   - resistance to handling or separating certain types of waste
   - lack of community buy-in or participation
   - cultural taboos related to waste or waste products

6) Regulatory hurdles:
   - navigating complex or unclear regulations in host countries
   - obtaining necessary permits for waste processing activities

Having these challenges in mind the Humanitarian Report provided sets of **guiding examples of bio-based products and bio-based technologies of potential application in the humanitarian context**. These are:

1) **For the products category:**
   a. biodegradable packaging, e.g. materials from plant-based sources like corn starch or sugarcane bagasse, mycelium-based materials (fungal networks);
   b. containers made from materials like bamboo, corn starch or other plant-based sources;
   c. construction materials, e.g. mycelium composites for insulation panels, bricks, and other structural components for shelters;
   d. agriculture and food security, e.g. bio-fertilizers and soil enhancers from compost and other organic waste products;
   e. textiles and clothing, e.g. sustainable textiles from natural fibers;
   f. energy products, e.g. bioenergy such as biodigesters converting organic waste into biogas.

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2) **For the technologies category:**
    a. composting systems for organic waste, in order to reduce the volume of waste going to landfills, open dumps and / or to produce valuable fertilizer for local agriculture or reforestation efforts;
    b. anaerobic digestion of organic waste in order to produce biogas as a clean cooking fuel or for electricity generation;
    c. upcycling of organic waste into useful products like paper from agricultural residues, textiles from fruit peels, construction material from plastics;
    d. bioremediation – microorganisms or plants to break down contaminants in soil or water bodies affected by improper waste disposal.

It must be noted that all the above cited materials and information from the Humanitarian Report constituted a well-researched background for the Scoping Exercise and the preparation of the List of bio-based solutions.

3. The theoretical and practical scope of bio-based solutions and bio-based systems to be potentially applied under the humanitarian context

The second of the preparatory activities for delivering the List of bio – based solutions was the report on "**The theoretical and practical scope of bio-based solutions and bio-based systems to be potentially applied under the humanitarian context"** (further referred to as ***"Bioeconomy Report"***).[5]

The general objective of the Bio4HUMAN Consortium is to assess the scope to which bio-based innovative technological solutions and bio-based systems have the potential to be applied under the humanitarian context, with the simultaneous positive effect on the environment. However, before taking up this identification of existing (or being under current development) technological solutions and bio-based systems, which may constitute the bio economical response to the needs and the difficulties faced by the humanitarian aid sector in the solid waste management (SWM) issues, the Consortium had set **the theoretical and practical scope of bio-based solutions and bio-based systems** in the Bioeconomy Report.[6]

[5] The Bioeconomy Report has been prepared as part of the T.4.1. of the Project. The leading partner being PRO CIVIS, with active substantive contribution from ITENE, IBF and AIMPLAS.
[6] The Bioeconomy Report has been substantively prepared by analysing and studying the following groups of documents and materials: 1) the strategical, programming and legislative documents of the EU; 2) EU standards for selected bio-products; 3) reports and publications resulting from the EU funded projects on bioeconomy; 4) the national strategies on bioeconomy; 5) the recently published reports on bioeconomy; 6) the Climate and Environment Charter for Humanitarian Organisations.

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The following conclusions from the Bioeconomy Report were of essential character from the perspective of the works on compiling the List of bio-based solutions:

1) The bio-based sector produces and uses renewable biological resources and/or applies innovative biological processes and principles **to deliver bio-based solutions**. They may be understood broadly as **bio-based products, bio-based technologies, bio-based processes, bio-based systems and bio-based innovations**. It must be noted that the category of "bio – based products" comprises also "bio – based services".

2) The most common definitions of the **"bio-based products"** refer to **the composition – being wholly or partly derived from materials of biological origin**. For bio-based products it is essential to characterize the amount of biomass contained in the product. Not all bio-based products are completely made of biomass or substances exclusively derived from biomass. The European specifications for some bio-based products only require 25 % bio-based content or do not set a minimum requirement of bio-based content at all[7], meaning that even lower proportions of bio-based content are acceptable according to standards and certificates.

3) The complexity of bio-based products varies, as they may take the form of materials, intermediates, semi-finished products and **finished products**, with the latter having the key role for the Bio4HUMAN research. The most important characteristics of bio-based products include **potentially better recovery and recycling options, often low toxicity and often high biodegradability or compostability**. There are also the advantages over conventional products in the areas of more sustainable production processes, improved functionalities and innovative properties.

4) The detailed characteristics of the **"bio-based product"** shall be delivered based on the features such as **bio-based content, bio-based carbon content, type and origin of biomass, biomass sustainability and end of life options**. There are "bio-based products" demonstrating the broadness of the sector and providing concrete examples of "bio-based concepts" that have succeeded in progressing from the early ideas to a final product placed on the market. Bio-based products cover a broad range of intermediate products, product components and ready-made products, e.g. bio-based plastics, bio-lubricants, bio-

[7] https://single-market-economy.ec.europa.eu/sectors/biotechnology/bio-based-products_en#:~:text=What%20are%20bio%2Dbased%20products,bacteria%2C%20fungi%20and%20yeast

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fibres for textiles, chemical and pharmaceutical building blocks, organic acids, amino acids and enzymes. As per the nature of Bio4HUMAN – only the ready – made products could have made to the List of bio-based solutions.

5) **"The bio-based technologies"** are mainly about the transformation of conventional industries and decoupling of economic growth from environmental degradation. From the perspective of Bio4HUMAN, **the environmental biotechnology**, which can contribute to the development of more sustainable bio-based products and **the appropriate processes for the recycling of waste streams** – shall have played the most essential role.

6) **Biotechnology in solid waste management** – the process of application of science and technology to the living and non-living materials for the treatment and disposal of solid waste (and wastewater) in controlled condition without disturbing the ecosystem – needed the attention of the Project's consortium. The special interest must have been devoted to the environmental technologies aiming at fulfilling the vigorous sustainability pursuits of energy and material cycling. The important factor was also the potential successful implementation of more sustainable solid waste management practices, such as a) realization of better closed loop of materials' recycling, b) enlargement of renewable energy supplies, c) preservation of biodiversity and natural ecosystems. The technologies of interest were then **composting (incl. the rapid composting), black soldier fly biowaste processing, waste biorefineries (incl. anaerobic digestion), bioremediation, and the innovative new resource recovery technologies.**

7) The importance of the innovativeness aspect to bioeconomy and to bio-based solutions. The **"bio-based innovations"** jointly harness jointly the potential of nature's biological functions and the abilities of available technologies – for the sustainable sourcing, industrial processing and conversion of biomass into bio-based materials, products and services. **The potential use of biological waste as feedstock, along with bio-based products and biotechnology driven environmental services –** have been pointed out as the key areas for the creation and delivery of bio-based innovations.

8) The challenges of using wastes and residues as a resource, managing recycling and waste, and maintaining the value of products, materials and resources for as long as possible – could be addressed by novel and effective ideas, concepts, models, methods, products or services, i.e. **"bio-based innovative solutions"**.

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The following practical examples with of bio-based innovative solutions of potential relevance for Bio4HUMAN were already identified at the stage of the Bioeconomy Report:

a. solutions for transforming the waste and utilizing it for innovative products with high energy efficiency and low impact on the natural environment,
b. new and original applications of residues – as a standalone resources or after further processing and mixing,
c. ideas for recombining the bio-based materials and ingredients.

The Bioeconomy Report has, however, not only dealt with the theoretical frameworks of the innovative bio – based solutions, but also tried to properly place the theme of **solid waste management within the paradigms of bioeconomy and circular economy**.
The multiple definitions of **bioeconomy** highlight different substantive aspects important from the perspective of Bio4HUMAN, i.e. the potentially useful role of residues and waste, the issues of sustainability and the protection of the environment.

The following selected features of **the circular economy** concept may be also be of importance from the perspective of solid waste management in humanitarian context:

a. preventing or reduction of waste generation;
b. increasing preparation for re-use and for recycling of waste;
c. developing the waste management infrastructure;
d. minimizing the incineration of waste and avoiding / reducing of the litter;
e. increasing the durability, reparability, upgradability or reusability of products.

There are also **the common substantive areas for the paradigms of the bioeconomy and circular economy**, as the bioeconomy can contribute in several ways to the circular economy, especially **in the topics connected to waste management**. This could be achieved *inter alia* by introducing biodegradable products being returned to the organic and nutrient cycles, utilisation of organic side and waste streams, successful recycling of wood and paper and collection and recycling of bioplastics.

The circular bioeconomy paradigm is a kind of so-called twin transition, where the fossil resource is being replaced by a bio-based one as the same time as the linear economic model is being replaced by a circular one – this also **relates strongly to the waste management issues**. Namely the constituting elements of the circular bioeconomy are:

a. use of wastes and residues as a resource,
b. integrated multioutput production chains,
c. recycling and waste management,
d. circular and durable product design.

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The Bioeconomy Report provided the needed background and understanding about the role of solid waste management in the much brighter scope of bioeconomy and circular economy. The characterizations and definitions of bio-based products and bio-based technologies, as well as examples of potentially Bio4HUMAN applicable bio-based innovations, set the right framework for starting and conducting the scoping for bio-based solutions potentially relevant to waste in humanitarian context.

4. The actual process of scoping for bio-based solutions

4.1. The five Investigation Lines

According to the Bio4HUMAN application, the identification of existing and novel bio – based solutions being of potential value to the solid waste management in the humanitarian aid sector – shall have taken the following forms (further referred to as the ***"Investigation Lines"*** or ***"Investigation Line"***):

1) **The survey conducted with all the bio-based companies being members of the Bio-based Industries Consortium** – the biggest non-governmental European conglomerate of companies envisaging the transformation of bio-based feedstocks into novel sustainable products and applications through investments, innovation, and know-how. The survey shall have included questions relating to the actual product portfolio, but also to the ongoing R & D & I activities of the companies.

2) **The analysis of the bio-products and bio-services delivered through projects financed by the Circular Bio-based Europe Joint Undertaking (CBE JU)** being €2 billion partnership funding projects advancing competitive circular bio-based industries in Europe, in the topics related to bio-based products and technologies.

3) **The product information on the web pages of national and international organisations advocating for the bio – product and bio – services** (e.g., Database by the InnProBio, BioPreferred by the USDA, the Plant Based Products Council, State of Green).

4) **The awards given to the exceptional products at the biggest trade fair events relating to the bio-economic issues** (i.e., Plastics Recycling Show Europe in the Netherlands, International Trade Fair for Waste Management, Recycling, Environmental Technologies in South Korea, ECOMONDO The Green Technology Expo in Italy).

5) **The analysis of the formal applications submitted to the European Union Intellectual Property Office (industrial designs) and to the European Patents Office (patents)**.

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The execution of the five Investigation Lines proceeded in the following manner:

4.2. The survey conducted with companies from Bio- based Industries Consortium

This Investigation Line consisted of a survey to all bio-based entities that are members of the Bio-Based Industries Consortium (BIC). Already at the stage of Project's preparation, the Letter of Support was signed by Representatives of BIC.

The survey was distributed to all BIC members, but responding to the survey was entirely voluntary and as could have been foreseen not all entities answered. To increase the chances of finding relevant solutions, **ITENE[8] – being the leader of this Investigation Line** – used its internal network to distribute the survey among other organisations working in the bioeconomy sector.

Figure 2 outlines the different steps that were considered to arrive at the final selection of solutions. First, the survey was designed and refined with feedback from the Bio4HUMAN consortium partners. The survey was open and distributed to BIC entities vis BIC newsletter and in addition promoted through social media and in conferences. The responses to the survey were analysed together with PRO CIVIS[9], as the leader of the whole scoping Project's task. Additional information for these and other (non-BIC) responses was collected. The selected solutions were described in the template developed and provided by PRO CIVIS.

[8] Instituto Tecnológico del Embalaje, Transporte y Logística.
[9] Fundacja Edukacji i Dialogu Społecznego PRO CIVIS.

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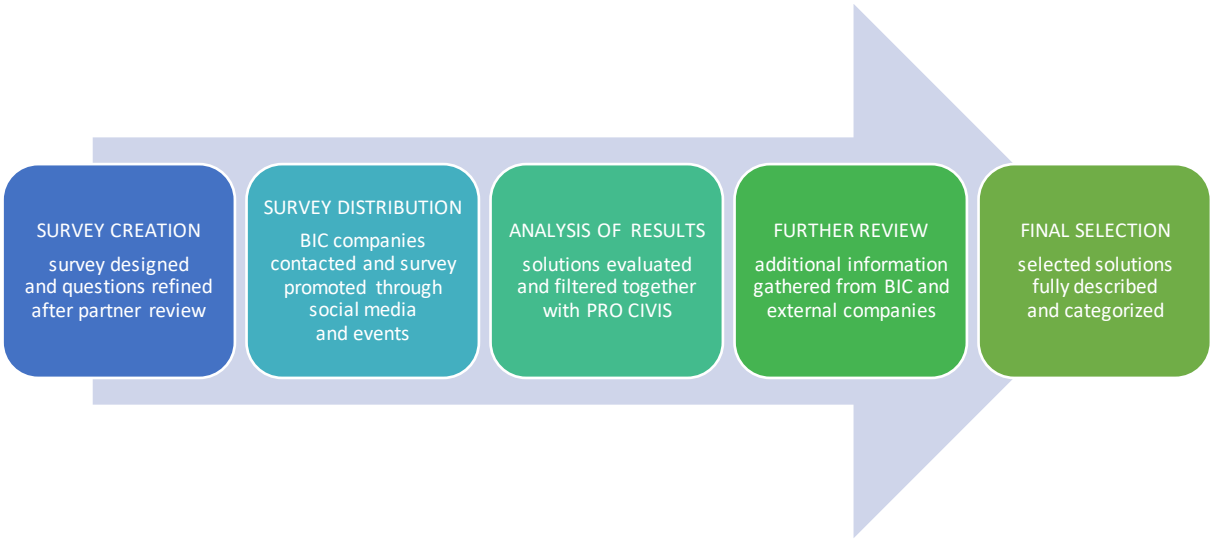

Figure 2 Steps followed to reach the final selection of solutions

PRO CIVIS provided a template for the collection of data on bio-based solutions, provided here as **Appendix 1**.[10] According to the template – the main categories of data to be collected were the following:

I. Bio-based solution category: product, service, technology.
II. Basic information – name and description of the solution (function, process description, product description, basic conditions of use), source of data.
III. Technology Readiness Level of the solution.
IV. Potential impact of climatic conditions on the features and functioning of the solution.
V. Possibility of employing the solution as an autonomous unit.
VI. Identified owner of the solution and his willingness to provide further detailed technical and technological data.
VII. 4R principle addressed by the solution (reduce, reuse, recycle, recover).
VIII. Needs of the humanitarian sector and / or of the solid waste management constraints in the humanitarian settings – addressed by identified solution.
IX. Logistic supply chains application potential – at which stage?

Based on the categories given above, ITENE formulated the questions for the survey in order to collect as much relevant information as possible without resulting in an extremely long and cumbersome questionnaire.

The first version of the questionnaire was circulated among the task partners[11] and refined according to the feedback received. The reasons for the companies' participation – as the possibility to enter the extensive

[10] The same template has been applied to all 5 investigation lines.
[11] ENSPIRE, PRO CIVIS, AIMPLAS, IBF, UC and WeLOOP.

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market of humanitarian deliveries and positive visibility – were clearly stated to motivate the companies to take part in the survey.[12] In order to simplify the task for the respondents, closed questions (yes/no or with a list of answers to be ticked) were included where possible. The context about the Project and some illustrative photos showing the variety of bio-based solutions possible have also been added to the online version in Google forms. The survey was also translated into Spanish and French[13] to maximize the number of responses. The final version of the survey constitutes **Appendix 2** to this deliverable.

With the aim of distributing the survey and reach as many BIC organizations as possible, the BIC Board Member for Human Capital & Stakeholder Relations – Mr. Nelo Emerencia has been contacted by the Project Leader Enspire. The survey was advertised in the BIC newsletter, which went out to the members and associated members of BIC on November 21, 2024. In addition, a link to the survey was published in various LinkedIn posts[14] and a QR code and flyers were created so that participating Bio4HUMAN partners could share the survey when attending relevant events – like the conference organized by "European Bioplastics", or the final event of the "PRESERVE" project.[15]

Moreover ITENE created a list of the EU projects in which they participated, in order to collect relevant partners, who could fill out the survey and propose interesting bio – based solutions (**Table 2**).

EU project	Relevant companies involved
ENZYCLE	Microbial enzymes for treatment of non-recycled plastic fractions: postconsumer PET trays and clamshell containers, PET-PE multilayer packaging and microplastics.
DEEPURPLE	Conversion of diluted mixed urban bio-wastes in sustainable materials and products in flexible purple photobiorefineries.

[12] The introduction to the survey read as follows: *"Why it´s definitely worth it to take part in the survey? Thanks to y our participation in the BIO4HUMAN survey your bio-based solutions (products, services, technologies) may get noticed by the humanitarian community! The solutions identified through the questionnaire will get a chance to appear in the Project final guidelines. Of course, such a presentation in the guidelines must get the preceding approval from your company or organisation."*

[13] The French translation provided by WeLOOP.

[14] The post was reshared by RuralBioUp Project, Catedra MARE de Economia Circular, BioeconomuVentures
and WORM project.

[15] Link to Preserve final event where Bio4human was presented:
https://www.linkedin.com/posts/bio4human_bio4human-solidwastemanagement-biobasedsolutions-activity-7274369885579673601-c7N5?utm_source=share&utm_medium=member_desktop

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PRESERVE	High performance sustainable bio-based packaging with tailored end-of-life and upcycled secondary use.
PULPACTION	Optimised moulded pulp for customised cellulose-based packaging solutions for specific food and electronic packaging applications.
NENU2PHAR	Development of viable alternatives to current petrochemical-based plastics that are sustainable and biodegradable, based on PHAs produced from algae-fed bacteria.
TERRIFIC	Flagship bio-based circular solutions for advanced packaging that deliver superior performance while improving circularity and resource efficiency throughout the supply chain.
WASTE4SOIL	Reducing the percentage of food waste in Europe by recycling food-processing residues and turning them into soil improvers to enhance soil health across Europe.
SCALIBUR	Cut urban biowaste and replace it with a new production chain of biomaterials, forming a partnership of end users to recover and transform biowaste.
SHERPACK	High-barrier, renewable, biodegradable, and recyclable flexible paper-based packaging material that can be easily heat-sealed and folded, offering improved stiffness and grip to replace plastics and aluminium.
PLASTICIRCLE	Develop and implement a holistic process to increase recycling rates of packaging waste in Europe.
CELLUWIZ	Process developments for a recyclable and compostable all-cellulose multilayer material for packaging.

Table 2 European projects in which ITENE has participated

The survey was conducted from November 27th, 2024 to January 2nd, 2025. Responses were weakly updated and shared as an Excel file in the Consortium SharePoint, in order to select the interesting solutions for further considerations. ITENE and PRO CIVIS worked together in filtering the most promising entries on a weekly basis. A total of 12 universities, 11 research and technology organizations, 21 SME's, 3 large enterprises and 3 clusters/foundations filled the survey. Some of the key figures derived from the survey are shown in graphs below (**Figure 3**).

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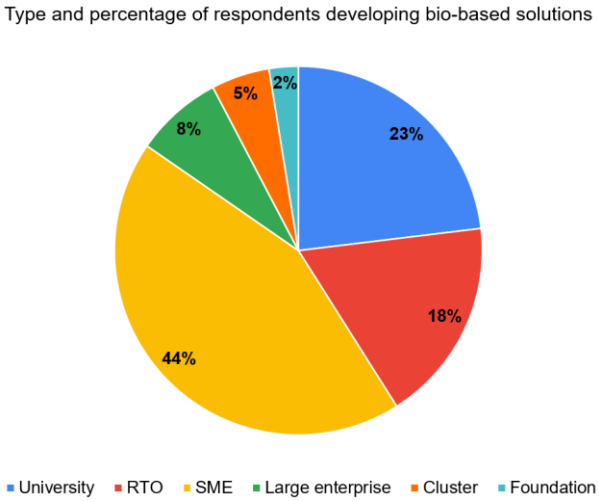
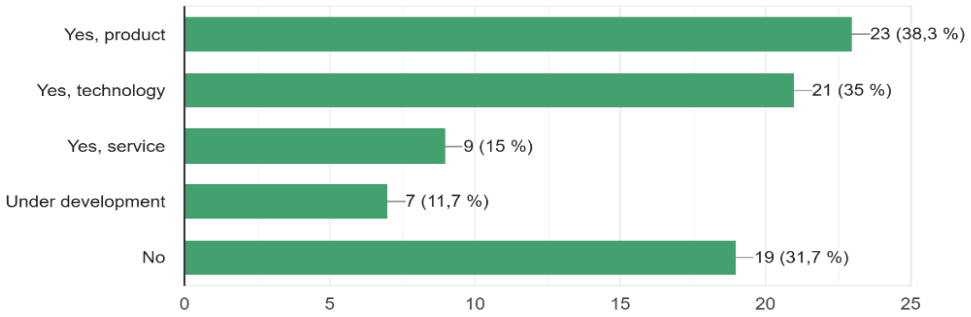


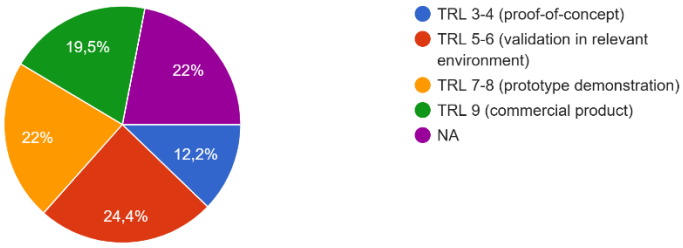
1. Has your company or organisation developed any bio-based solution (product/service or technology) of potential application in the humanita...n interventions? If not, please skip to question 19.

60 respuestas



3. What is the approximate TRL of the bio-based product?

41 respuestas



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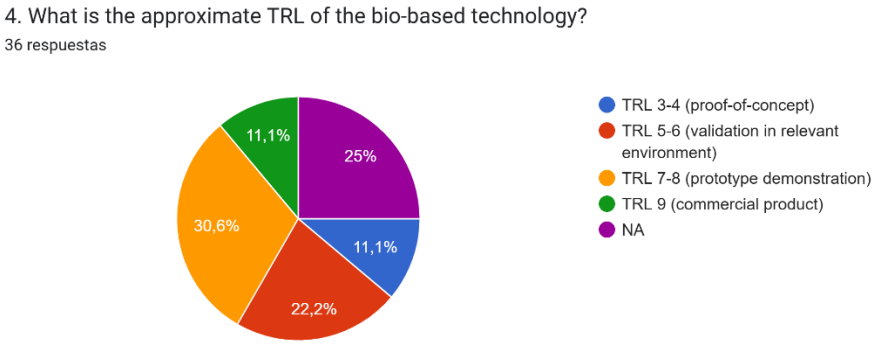

Figure 3 Key figures of the Bio4Human survey

In total 18 solutions were found to analyze in depth. 6 separate mails were sent to request further information[16]. Moreover, ITENE organized an online meeting with the Netherlands Organisation of Applied Scientific Research (TNO) and discussed internally with the project coordinators of SEALIVE. Following the feedback given by the Bio4HUMAN humanitarian organizations, ITENE worked on answering the questions and tried to expand on certain aspects as much as possible (e.g. purpose in the humanitarian context, location for production).

The shortlisted solutions are presented in the table below:

Solutions presented in investigation line 1
Research and development of packaging products made of biodegradable and biobased polymers.
New polyurethane structural materials and insulation foams from renewable sources.
AI-Core is an integrated engine designed specifically for dealing with complex science and engineering problems.
Biodegradable and compostable mulching spray.
Bioplastics for food packaging with shelf-life properties.
Plastic films from photosynthetic microorganisms.
High barrier and compostable packaging materials for food contact applications (*i.e.* packaging of dried or dehydrated foods).
Waste conversion technology: gas cracking technology and advanced thermal treatment process.
Board trays, flexible paper packaging, among other products based on cellulose.
PLA packaging solutions for food and diagnostic applications. Sustainable film concepts for medical packaging.

[16] The addresses being: Universitat Politècnica de Catalunya, Seabird, Unibo, Universita Jaume I, Latvina State Institute of Wood Chemistry, Munster Technological University.

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Enzymatic recycling technology (ENZYCLE).
Monofilament fishing nets.
Biodegradable shelter.
Black soldier fly (BSF) organic waste processing system.
Hydrothermal conversion of biogenic residues (F-CUBED).
Rigid food packaging: thermoformed tray.
Biodegradable agricultural film with improved performance.
Single use plastic cutlery.

Table 3 List of solutions resulting from Investigation Line 1.

The TRL level of the scoped solutions is generally high, what shall endorse the potential implementation in the humanitarian context.

4.3. The bio – based solutions delivered by CBE JU projects

This Investigation Line was led by **AIMPLAS**[17] and consisted of the analysis of the bio-based products and bio-based technologies delivered through projects financed by the Circular Bio-based Europe Joint Undertaking. **Figure 4** outlines the different steps that were considered in the Investigation Line to arrive at the final selection of solutions.

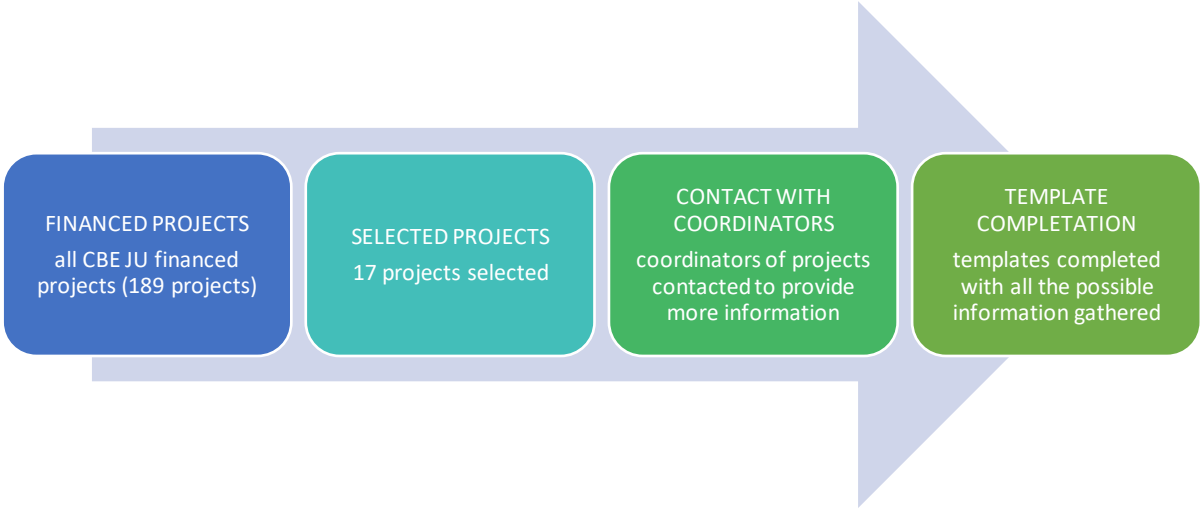

Figure 4 Steps followed to reach the final selection of solutions

First, a list of all the 189 CBE JU projects financed between 2016 and 2024 was established.[18] To select the projects that could provide good solutions for the Bio4HUMAN scope, information such as *"end date"*, *"status"*, *"summary text"* and *"feedstock origin and type"* were considered. The first selection was focused on completed projects, which had bio-based products and bio-based technologies finished.

[17] Asociación de Investigación de Materiales Plásticos y Conexas
[18] This list included also projects financed by dedicated clusters of Horizon 2020, which preceded the financing from CBE JU.

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However, after reviewing the summaries and the results of the projects completed, the solutions were not applicable to Bio4HUMAN scope, mostly due to the very technological nature of the proceedings and the outcomes – the results lacked the "applicability" feature of the finished products. Due to this, the selected solutions are from projects which have not finished yet[19], resulting in the solutions being in the state of development.

Project	Start and end date
CIRCULAR BIOCARBON	2021-2026
BioSupPack	2021-2026
ENZYCLE	2020-2024
RECOVER	2020-2024
ELLIPSE	2023-2027
BRILIAN	2023-2027
CAFIPLA	2020-2023
REDYSIGN	2023-2027
SynoProtein	2023-2028
FURIOIS	2023-2027
Bio-LUSH	2023-2027
NENU2PHAR	2020-2024
CHAMPION	2020-2024
PHENOLEXA	2021-2024
MixMatters	2023-2027
COUNTLESS	2023-2027
LUCRA	2023-2027

Table 4 Selected solutions from projects financed by CBE JU.

The 17 selected solutions were described in the template provided by PRO CIVIS. When relevant information was needed, the coordinator of the selected project was contacted in order to provide the required information. In addition PRO CIVIS checked all the solutions and gave a useful feedback which was taken into account to improve the information for each solution.

The analysis of all the projects funded by the CBE JU allowed Bio4HUMAN to gather interesting solutions from the bio-based sector. Generally the results expected from this "CBE JU marked" Investigation Line did not align with the ready solutions the Consortium was looking for, as most of the projects have not been completed yet. This meant that there were no final results that could be studied in subsequent tasks of Bio4HUMAN, especially the LCA studies. However, once the projects finish – they could present interesting solutions for the future, also considering applicability to humanitarian actions.

[19] With the convening of the CBE JU in 2021 the financed bio-related projects started to be more oriented on the direct "applicability" of the researched and developed solutions. As the projects are mostly long- term, they are still in greater extent in the execution phases.

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4.4. The products and technologies presented by organisations advocating for the bio-based solutions

According to the approved Scoping Plan the main responsible partner for this Investigation Line was **IBF**, with supporting roles of **AIMPLAS** and **ITENE** in terms of supplying websites and background information as a starting point.

At the start of the process PRO CIVIS and other partners provided the below websites to explore and constitute what bio-based products and bio-based technologies may be applicable to respond to the needs and expectations of the humanitarian actors and the beneficiaries of humanitarian actions.

- https://itemscatalogue.redcross.int/green--2.aspx
- https://www.biobasedconsultancy.com/en/database
- https://www.kompass-nachhaltigkeit.de/
- https://sustainablebiomaterials.org/
- https://biobasedcontent.eu/?page_id=152
- https://www.dincertco.de/din-certco/en/main-navigation/certificates-and-registrations/the-din-certco-database/
- https://www.storaenso.com/pl-pl/
- https://www.ecbf.vc/
- https://pbpc.com/
- https://stateofgreen.com/en/
- https://tporganics.eu/

As a result, hundreds of products were explored using the above websites. There were many duplicate types of solutions, i.e. some biodegradable food containers were very similar in design and functionality and IBF decided to choose the solutions with the best green credentials from the information provided. If this information was not provided, IBF conducted more research to find further green credentials, but this was not always possible.

During the search of the websites IBF used the following terms below:

For bio-based products within the potential humanitarian context:

- wood products
- bio – based construction materials
- hygiene products
- sanitary products
- cleaning products
- biopesticides
- natural fertilizers / bio-fertilizers / soil enhancers
- bio-based water filters / water purification
- biogas digesters

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- bio-charcoal
- biodegradable products

<u>For bio-based technologies within the potential humanitarian context:</u>

- bio-based wastes
- remediation
- upcycling of organic waste
- composting
- bioremediation
- waste biorefineries
- biorefinery processes
- biowaste processing
- waste magazines
- resource recovery technology
- conversion of wastes
- application of residues
- bio-technology in solid waste management

Once the websites were fully scoped, **IBF used the below bio-based solutions in humanitarian contexts to address solid waste management issues** to guide the search. This was done by general search of websites using the below mentioned terms and also using these terms plus the word "humanitarian" as part of the search:

- composting systems for organic wastes
- anaerobic digestion
- biodegradable packaging from plant-based sources
- bioremediation
- biopesticides and natural fertilisers
- construction material
- energy production
- water purification
- agriculture and food security
- textiles and clothing

In total IBF provided 15 solutions as part of the Investigation Line which included packaging, food, hygiene, construction solutions and bio-based technologies:

- ✓ **packaging** – two solutions including protective and insulation packaging;
- ✓ **food** – three food container solutions and biodegradable food preparation gloves;
- ✓ **hygiene** – three solutions including water wipes, incontinence pads and disposable aprons for healthcare work;
- ✓ **construction** – one insulation solution;

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- ✓ **bio – based technologies** – three solutions, including bio-flocculants, a micro AD system and water retention panels.

Once details were filled out in the templates, IBF were asked to contact with service/product providers to ascertain more information on the description of technology and TRL level (if applicable) and the description of product/service and TRL level (if applicable). Of 15 contacted providers, five responded positively and declared themselves open to further communication.

4.5. The awarded bio – based products and technologies

According to the approved Scooping Plan the main responsible partner for this Investigation Line was **PRO CIVIS**, with supporting roles of **AIMPLAS** and **ITENE**.

While executing the task PRO CIVIS contacted 8 trade fair organizers – with a request for lists of exhibited & awarded products and technologies. **The contacted trade fair organizers** were:

a. ECOMONDO – THE GREEN TECHNOLOGY EXPO, Italy
b. IFAT München - World's Leading Trade Fair for Water, Sewage, Waste and Raw Materials Management, Munich, Germany
c. RETECH International Trade Fair for Waste Management, Recycling & Environmental Technologies, South Korea
d. Environmental Protection and Waste Management Expo EKOTECH, Poland
e. Greener Manufacturing Expo, Cologne, Germany
f. ECOFIRA - Feria de la Capitalidad Verde del Medio Ambiente, Valencia, Spain
g. PRSE - Plastics Recycling Show Europe, Netherlands
h. Waste Management Europe, Bologna, Italy

The response was only received from Targi Kielce / EKOTECH, with the lists of awards for 2022, 2023, 2024 edition, but there was no suitable bio-based solutions on the list.

In connection with the above, the exhibitor catalogues for two trade fair events indicated in the project application, ECOMONDO and Plastics Recycling Show Europe were analyzed and the selected exhibitors were contacted. For the third trade fair event indicated in the application, i.e. RETECH International Trade Fair for Waste Management, Recycling & Environmental Technologies - there was no such possibility. As a substitute, the selected exhibitors of the largest environmental technology fairs, IFAT Munich, were analyzed and contacted.

For the 2024 edition of **ECOMONDO – THE GREEN TECHNOLOGY EXPO:**

- 180 exhibitors were analyzed,

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- 58 selected for direct contact,
- 52 finally contacted,
- 3 substantive responses and 1 cooperation response were received,
- three bio-based solutions have been presented to the Consortium in the form of the filled-up templates.

For the 2024 edition of **IFAT München – World's Leading Trade Fair for Water, Sewage, Waste and Raw Materials Management**, out of 3 500 exhibitors – 41 exhibitors dealing with *"biological treatment and composting"* were selected:

- all 41 exhibitors were analyzed,
- 15 were selected and contacted,
- 2 substantive responses were received,
- 2 bio-based solutions were presented to the Consortium in the form of the filled-up templates.

For the 2025 edition of **PRSE – Plastics Recycling Show Europe**:

- 48 exhibitors were analyzed,
- 20 selected for direct contact,
- 18 finally contacted,
- no substantive responses were received.

Additionally, within this Investigation Line:

1) The following awards were analyzed and taken into consideration:
   - from 2020 - 2024 events - Sustainable Packaging Summit,
   - the Renewable Materials of the Year 2019 – 2024,
   - the Bio-based Material of the Year 2019 – 2024,
   - the Tech Tour Bio-based Awards 2023,
   - the Rising Star Awards 2024.

2) The following supporting sources were activated:
   a. the list of solutions / technologies identified and / or employed by the European projects - Bio4AFRICA and DIVAGRI,
   b. selected bio-based solutions of individual companies known for outstanding bio-based record,
   c. Enspire recommended publication in Nature.

Altogether **24 bio-based solutions** from this Investigation Line were presented by PRO CIVIS to the Bio4HUMAN Consortium. The very positive role of AIMPLAS must be emphasized, as they provided the Investigation Line Leader with multiple sources of contest and competitions related to the bioeconomy and the relating awards and distinctions, which proved to be the origin of a successful scooping.

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The 24 solutions proposed by the PRO CIVIS could be catalogued as showed in the **Figure 5** below:

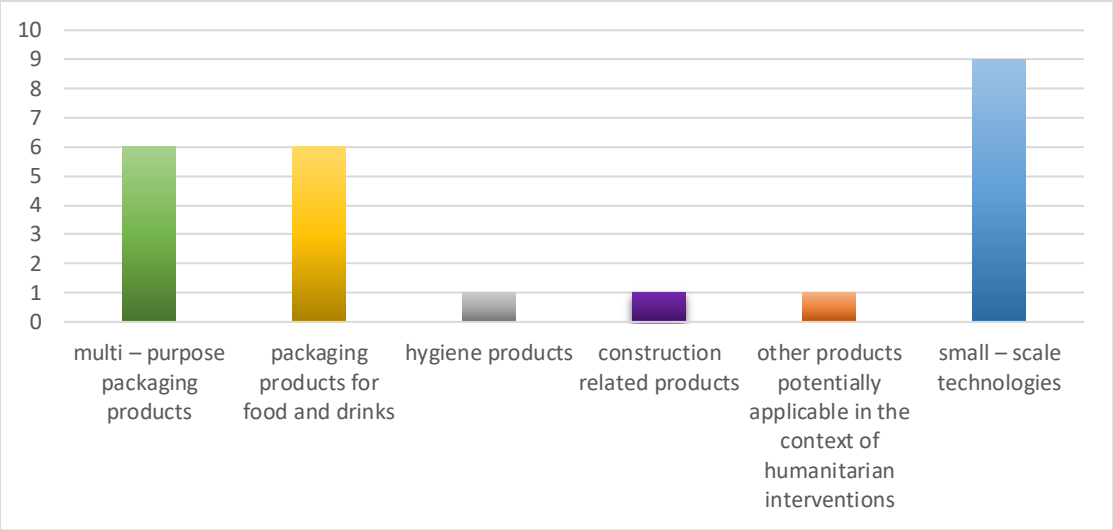

Figure 5 The types of bio – based solutions scoped by PRO CIVIS

4.6. The patents extended to the bio – based solutions

This Investigation Line consisted of the review of the formal application submitted to the European patent office, United States Patent and Trademark Office and World Intellectual Property Organization (WIPO). This review was made by the Investigation Line leader – **ITENE,** by using the **research tool Derwent Innovation**. The tool provides Internet access to more than 30 million inventions detailed in more than 65 million patent documents.

In the application and the grant agreement it was indicated that this Investigation Line should cover also the application submitted to the European Union Intellectual Property Office (*industrial designs*). However, as it was analysed and explained by ITENE experts, a design protects the appearance of either the whole product or a part of it, that results from its features, in particular, the lines, contours, colors, shape, texture and/or materials of the product itself and/or its ornamentation. The design protects only the appearance of a product, but not its function, nor its chemical, technical, or functional properties. Therefore, only the design is not of interest for Bio4HUMAN, as the Consortium is looking for bio-based materials regardless of the design.

Figure 6 outlines the different steps that were considered in order to reach the final selection of patents. First, a combination of words to look at in Derwent Innovation tool to find the desired patent applications and/or patents were decided on. Once this search was made, it went through two selections of patents by ITENE experts - to narrow the number to 12. Then

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the final selection was made by PRO CIVIS, the leaders of this WP, to narrow this number down to 6.

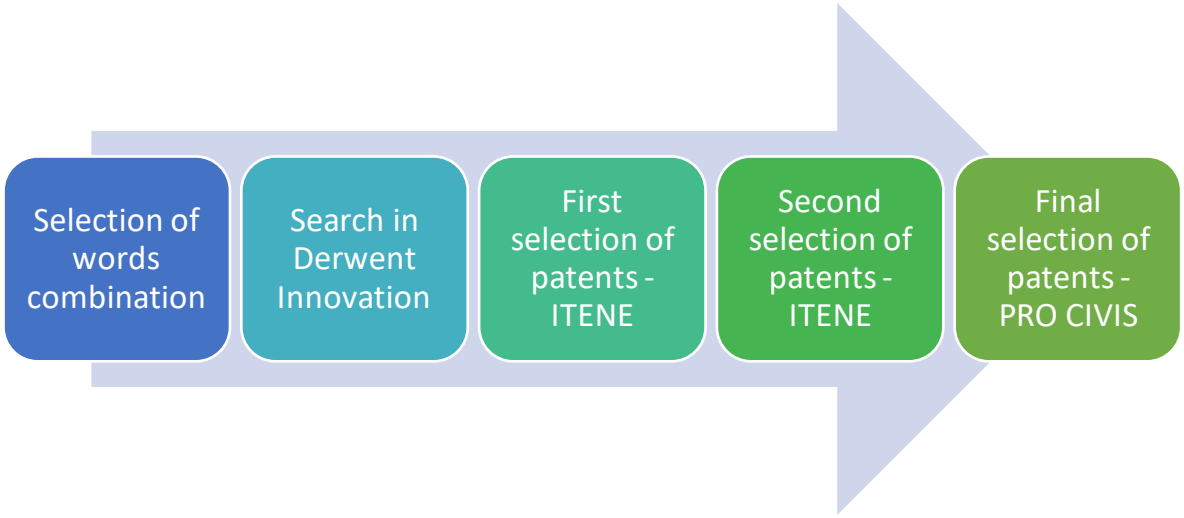

Figure 6 Steps of the methodology followed to reach the final selection of patents applicable to humanitarian context

As has already been pointed out **Derwent Innovation was the research tool that was used for the patent search.** The first step, prior to the search, was to **define the combination of words for the tool to search**. This combination of words defined by ITENE and PRO CIVIS are presented in **Table 5.** European countries, United States and WIPO have been prioritized.

	Combination of words	Number of patents found
Bio-based products/services	Bio-based bio-charcoal	2
	Bio-based biodegradable products	20
	Bio-based biopesticides	4
	Bio-based cleaning products	31
	Bio-based construction materials	23
	Bio-based fertilizers	1
	Bio-based hygiene	12
	Bio-based sanitary products	21
	TOTAL	**114**
Bio-based tehcnologies	Application of residues	50
	Bio-based composting	6
	Bio-based remediation	3
	Bio-based waste	38
	Biofuel technology	17
	Bioremediation	26
	Composting technology	23
	Recover biowaste	2
	Up-cycling organic waste	1

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	Waste biorefineries	4
	Waste conversion technology	7
	TOTAL	**177**

Table 5 Combination of words decided for the patent research within the Investigation Line No 5

Once the words were defined, the patent search using Derwent Innovation was implemented.

The number of total patent review was 291. The information obtained from Derwent Innovation was extracted to an Excel file where the following information has been included: publication number, title, abstract, publication date, dead/alive and applicant. The example of the information contained in the Excel file is included in **Figure 7**.

Derwent Innovation		Search results for:	Collections searched:					
Publication Number	**Title**	**Title - DWPI**	**Priority Date**	**Publication Date**	**Dead/Alive**	**IPC - Current - DWPI**	**Assignee/Applicant**	**PDF Copy**
US20240300712A1	Cold Chain Packaging	Packaging article used for packaging vaccine or pharmaceutical product, such as	2020-12-21 | 2021-04-14	2024-09-12	Alive	B32B002710 | B32B002718 | B32B002736 | B65D006540 | B65D006546 |	3M INNOVATIVE PROPERTIES COMPANY,St. Paul,MN,US	
US20240263029A1	THERMALLY RESISTANT AQUEOUS INKS	Method of providing packaged food product, involves printing substrate with aqueous	2021-12-17 | 2022-12-16	2024-08-08	Alive	B41M000104 | B41M000136 | B41M000700 | B65B006102 | B65D008134 |	Sun Chemical Corporation,Parsippany,NJ,US	
US20240158969A1	METHOD AND SYSTEM TO MANUFACTURE A HEMP-BASED INSULATION	Manufacturing hemp-based insulation material for installation in commercial or	2022-11-11	2024-05-16	Alive	D04H001300 | D06M001159 | E04B000174	HEMPITECTURE INC.,Ketchum,ID,US	
US20240043571A1	BIO-BASED STARCH MIXED ESTER BIODEGRADABLE AND/OR COMPOSTABLE	Bio-based starch mixed ester biodegradable composition used for forming article,	2022-07-29 | 2022-07-29 | 2022-07-29	2024-02-08	Alive	C08B003104 | C08L000306 | C08L006702 | C08L006704	EVERCORN INC.,Champaign,IL,US	

Figure 7 Information extracted from Derwent Innovation to an Excel file

In the second stage, ITENE did a first selection of the patents search, shortening the number to 50 patents: 23 for bio-based products/services and 27 for bio – based technologies.

The criteria for shortening this list were made on the basis of the applicability of the different solutions to humanitarian context. In a third stage this list was narrowed down to 15 patents and was sent to PRO CIVIS for revision. Finally, 6 solutions, due to their direct applicability level in humanitarian interventions, were requested by PRO CIVIS to be presented in the form of templates:

Name	Patent number	Public link

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Coextruded Hemp composite board	WO 2024/054266 Al	Espacenet – search results
Plant-based absorbent article	EP4142670A1	Espacenet – search results
Biodegradable containers	US009797104	Espacenet – search results
Plant for integrating biodigestion, gasification and solar technologies for recovering energy	MX2014015687	Espacenet – search results
Method of compost production	UA123639C2	Espacenet – search results
Mobile composting system for use in closed areas for treatment of waste, comprises room, which is formed in closed metal for protecting against corrosion or synthetic materials	PT104890A	Espacenet – search results

Table 6 Information on the patent numbers and the public link

4.7. The academic contribution

Additionally **three technological solutions co – developed by Universidad de Cantabria** were presented by the representatives of this University.[20] The small scale units dealing with biogas production from biowaste were scoped from the literature review, especially the assessment of the feasibility of domestic biogas digesters in African rural areas.[21]

[20] Universidad de Cantabria was not leading any of the T.4.2.1. Investigation Lines, but according to the approved Scooping Plan has had a supporting role.

[21] The following publications have been taken into account: 1) Regattieri, A.; Piana, F.; Gamberi, M.; Bortolini, M.; Ferrari, E.; Massanova, F. (2015) *Biogas production from organic waste: design and field-test of a pilot plant for developing regions*. 23rd International Conference on Production Research, ICPR 2015. 11pp. 2) Regattieri, A.; Bortolini, M.; Ferrari, E.; Gamberi, M.; Piana, F. (2018) *Biogas Micro-Production from Human Organic Waste – A research proposal*. Sustainability, 10, 330, doi: 10.3390/su10020330. 3) Nzila, C.; Dewulf, H.; Tuigong, D.; Kiriamiti, H.; Langehove, H. van. *Multi criteria sustainability assessment of biogas production in Kenya*. Applied Energy, 93 (2012) 496-506. 4) Masilela, P., & Pradhan, A. (2021). *A life cycle sustainability assessment of biomethane versus biohydrogen – For application in electricity or vehicle fuel? Case studies for African context.* Journal of Cleaner Production, 328(June 2020), 129567. https://doi.org/10.1016/j.jclepro.2021.129567. 5) Ardolino, F.; Parrillo, F.; Arena, U. (2018) *Biowaste-to-biomethane or biowaste-to-energy? An LCA study on anaerobic digestion on organic waste*. J. Cleaner Prod. 174, 462-476.

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Domestic biogas technologies and biogas production from bio-organic waste have been identified as viable solutions for solid waste management in humanitarian settings. They can be implemented in refugee camps and disaster-affected areas to convert food scraps and human/animal waste into clean cooking fuel, improving sanitation and reducing dependence on firewood.

4.8. Summary to the Bio4HUMAN scoping activities

Altogether **81 bio-based solutions** with potential application to the humanitarian interventions and potentially helping to resolve the solid waste management issues in the humanitarian contexts have been scoped and presented in the form of the filled – up templates.

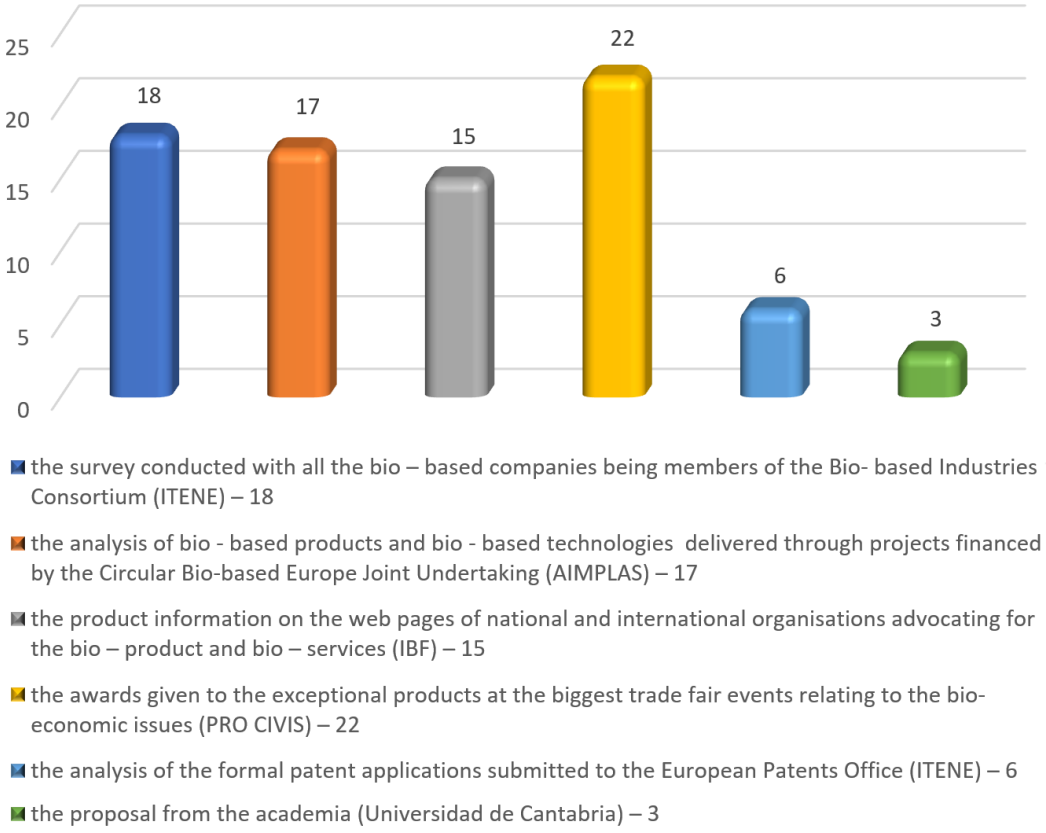

Figure 8 The division of the bio – based solutions scoped per each T.4.2.1. Investigation Line[22]

[22] It must be noted that: 1) the number of patents scoped in the Investigation Line 5 were much higher (291 after the first revision, 50 after the second revision and 15 after the third revision), but it has been jointly decided to finally present 6 patents in the form of the template; 2) within the Investigation Line 4 altogether 24 solutions have been presented in the form of the templates, but two of the solutions were identical to the ones scoped in the Investigation Lines 1 and 3 respectively and were in the presented figure assigned to these Lines.

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5. The clustering of the bio – based solutions and the initial evaluation

All **the 81 solutions** were initially analyzed by the PRO CIVIS and then clustered into seven categories based on the features of applicability and functionality. The categories are:

1) Multi-purpose packaging products,
2) Packaging products for food and drinks,
3) Hygiene products,
4) Construction related products,
5) Other products potentially applicable in the context of humanitarian interventions,
6) Small-scale technologies,
7) Big-scale technologies.

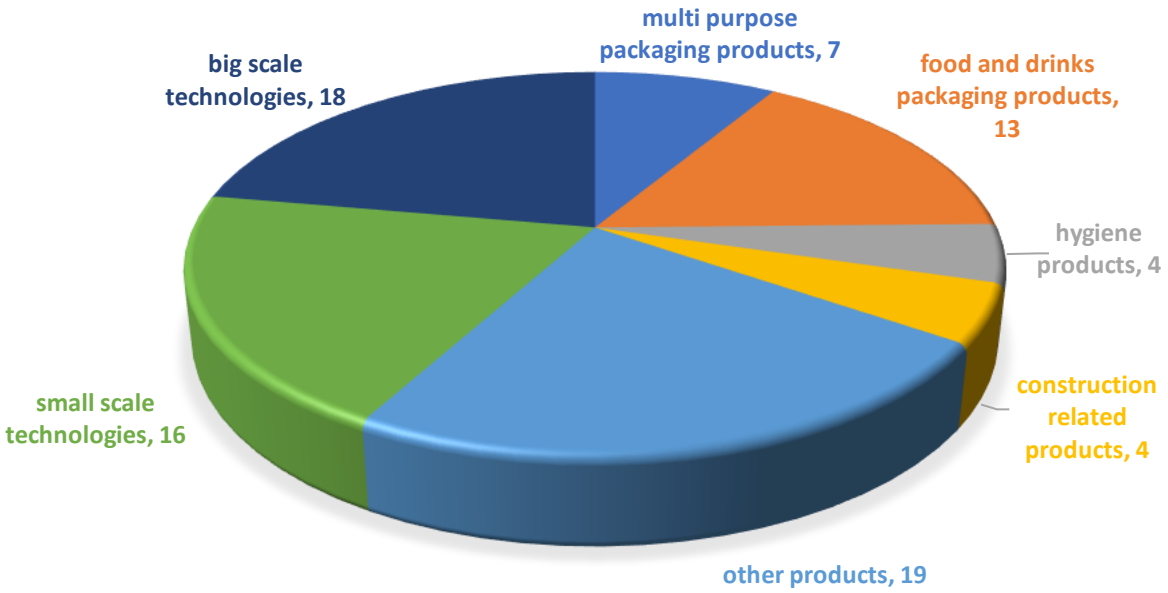

Figure 9 The clustering of the bio – based solutions

The presentation of all scoped bio-based solutions clustered into the seven categories as mentioned above – constitute **Appendices 3 to 9** of this Deliverable.[23]

[23] Cluster "multi – purpose packaging products" – **Appendix 3**.
Cluster "packaging products for food and drinks" – **Appendix 4**.
Cluster "hygiene products" – **Appendix 5**.
Cluster "construction related products" – **Appendix 6**.
Cluster "other products potentially applicable in the context of humanitarian interventions" – **Appendix 7**.
Cluster "small – scale technologies" – **Appendix 8**.
Cluster "big scale technologies" – **Appendix 9**.

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Characteristics of all the 81 scoped solutions:

There are:

1) Solutions with varying TRL, ranging from TRL 2 to TRL 9, including commercial products and technologies already on the market and in operations; the products and technologies with lower TRL are those with higher innovative, in some cases, even disruptive potential.

2) Interesting solutions combining both the product side and the technology side; they allow for the technology / installation to be easily transferred to the destination location (for example African locations) and for the products to be prepared and delivered on site of the humanitarian intervention.

3) Solutions proposed by:
   a. established larger companies,
   b. very promising start-up's, some of them already having financed their
      bio-based innovations by venture capital,
   c. European, African and Asia-based scientific and research institutions,
   d. foundations and other non-governmental organizations.

4) Solutions for which the owner expresses the explicit interest in working with the humanitarian partners and even declares further research expanding the scope of the current applicability, should the solution be widely accepted for humanitarian purposes.

5) Solutions for the development of which humanitarian partners have been already directly involved (e.g. Médecins Sans Frontières).

6) Bio-based solutions utilizing biological raw materials (for example forest based, seaweed, corn, banana), but also industrial waste, agricultural waste and residential waste.

7) Solutions contributing strongly to a more circular bioeconomy and exercising features of renewability, recyclability, biodegradability (up to 100 %), compostability (up to 100 %, incl. home compostability and industrial compostability) and sustainability (in terms of sourcing the feedstock).

8) Bio-based solutions with excellent functional properties, comparable with fossil – based solutions or even exceeding qualities; solutions

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allowing durable applications, reduction in the use of material and contribution to the reduce of energy consumption.

9) Solutions which can be delivered at the same cost level as the comparable fossil – based alternatives; but also solutions for which at the moment a key barrier is the higher cost compared to traditional products; this elevated cost is often associated with environmental, social and governance investment.

10) Solutions for which the Life Cycle Assessment has already been conducted or the owner is willing to share further data allowing the Bio4HUMAN to conduct the Project- specific, separate LCA.

11) Patented products and technologies, as well as bio – based solutions:
    a. tested as bio-based products according to the NCS 16785 standard,
    b. certified according to „OK COMPOST INDUSTRIAL“ scheme by TÜV,
    c. compostable certified according to DIN EN 13432 and Normec OWS,
    d. plastic-free certified according to Conventional Plastic Free Certification,
    e. ISO certified for sustainable building materials.

12) Solutions allowing for the local valorization of biomass and tailored to local availability of waste resources, as well as solutions already proved or under testing in African countries (Uganda, Ethiopia, Ivory Coast, Ghana, Namibia, Mozambique, South Africa, Botswana and Kenya).

13) Solutions with lower environmental impact at the end-of-life stage, successfully addressing waste disposal challenges and providing sustainable energy, potentially aligning with the needs of humanitarian actors and beneficiaries.

14) Products that can influence the whole supply chain of the humanitarian operation in terms of solid waste generated and managed; the potential positive influence expected mostly at the stages of:

    a. procurement – sourcing / purchasing of products and services,
    b. transport to the destination country,
    c. transport to the final destination,
    d. operational logistics at final destination – distribution of goods and services.

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15) Big-scale solutions incl. plants integrating the technologies of gasification and biodigestion, waste conversion, biorefinery processes and the valorisation of heterogeneous waste streams generated in significant amounts.

6. The initial List of bio-based solutions and its characteristic

After careful consideration PRO CIVIS put forward an initial List of 32 bio-based solutions, which in the best manner fulfilled the following criteria:

a) the assumed practical applicability to the humanitarian purposes,
b) the innovativeness of the presented solution,
c) the willingness of the Solution Owner to provide detailed technical and technological data, especially the one serving the further LCA purposes,
d) potential dependence on climatic conditions,
e) the scale of potential investment – in case of technologies,
f) the logistic supply chain application – in case of products,
g) the TRL level.

The preliminary List of bio-based solutions is made up of the following 32 products and technologies:

PRODUCTS

Multi-purpose packaging products

1) Packaging utilizing Notpla Seaweed / Zero Waste Paper
2) MYCO 4Pack and SafePads (material + technology)
3) PLA packaging solutions for food and diagnostic applications
4) LAM'ON – Biodegradable laminating film
5) monta biopack® – self-adhesive tape (monta Klebebandwerk)
6) Sway Polybags
7) Wood Foams utilising the Fibrease® and Papira®

Packaging products for food and drinks

8) Non-woven materials for pads, high barrier/advanced packaging materials and compostable cutlery and cups
9) NAKU PLA/rPLA Bottle/Bioplastic Bottle 250ml, 500ml and 750ml
   or alternatively
   PLA bottles for water + small water bottling unit for blowing and filling PLA bottles
10) Starch-based biopolymer active, intelligent food packaging
11) Bio Based Pouch

Hygiene products

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12) Anandi Eco+ – 100% Compostable Sanitary Pads + Aakar Mini – Factories
13) Plant-based Absorbent Article
14) NATY Compostable Wipes

Construction related products

15) KINGSPAN Bio based insulation in buildings
16) Product lines made from bioPUR
17) Coextruded Hemp Composite Board

Other products potentially applicable in the context of humanitarian interventions

18) Biodegradable shelter
19) Bio4Pack Waste Bag
20) Single use compostable HaPPE apron
21) Biodegradable containers
22) Monofilament fishing nets
23) Biodegradable and compostable mulching spray

TECHNOLOGIES

Small-scale technologies

24) Black soldier fly (BSF) opportunities
or alternatively
Small-Scale Residue Utilization Pathways (SSRUP) – Black Soldier Fly technology
25) Modular micro AD system – Qube Renewables
26) Single Stage Biogas Digester
or alternatively
Micro Biogas Digester
27) Mobile composting system for use in closed area for treatment of waste
28) Biogas production from (bio) organic waste
29) Polystyrene-consuming lesser mealworm
30) ROBONOVA® - the bioremediation technology
31) Household Composter

Big-scale technologies

32) MixMatters

As for this preliminary List of bio-based solutions it should be noted, that:

a) The Consortium did not limit itself to the quite obvious catalogue of products (like one dimensional plant based packaging items) and technologies (black soldier flies) and tried to look for **innovative solutions**, **often at the lower TRL**, some of them even controversial at first sight – for example such **"out of box"** ideas as *"starch-based biopolymer active, intelligent food packaging"* and *"polystyrene-consuming lesser mealworm"*.

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b) The Consortium tried to look at the subject of solid waste management in a humanitarian context from **a brighter horizontal perspective**, which resulted in putting innovative ideas on the List such as:

- *"biodegradable and compostable mulching spray"* – as using of the spray limits the periodic and frequent replacement of plastic films, which generates a huge amount of agricultural plastic waste;
- *"ROBONOVA® the bioremediation technology"* – as the main purpose of this technology is to limit the negative effects of soil contamination affected by improper waste disposal.

c) As the focus of the humanitarian partners in the Consortium, i.e. People in Need and Polish Humanitarian Action was on the local implementation of the scooped solution, **the catalogue of small-scale technologies** is quite extensive; in the case of technology – local implementation is possible, even advisable; in the case of products, with a few exceptions – it will be very difficult to envisage the reallocation of production.

d) The proposed set of **bio-based products** generally lacks the competitiveness factor in comparison with the fossil-based counterparts, mainly due to the price factor (with few minor exceptions); the proposed **small-scale technologies** are on the other hand configured in a way allowing for reduced investment and operational cost, making it more accessible for humanitarian destinations; the detailed price / cost considerations will however take place in the proceedings of WP5 and WP6 of the Project.

7. The internal consultation process – the workshop and the most valuable contributions

The internal consortium consultation workshop took place on January 21st, 2025 and was followed by comments of the Bio4HUMAN partners directed at the whole composition of the preliminary List of, as well as at the singular solutions.
The main contributions, which took the form of questions, remarks, comments, observations and expressed concerns, are presented below.

The category of bio-based products:

- the qualities of the proposed products, for example carrying capacity and size of the packaging products;
- the fulfillment of the standards by the proposed products;
- the willingness of the suppliers and of the end – producers to use the new types of packaging;
- the actual demand of the humanitarian organisations for the given type of product;
- the stage of the humanitarian supply chain, at which the solution could be implemented, if applicable;

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- the possibility of the local production (i.e. in the humanitarian destination) of the proposed solutions;
- the “end of life” scenario for the proposed solutions;
- price and cost considerations;
- cultural and societal acceptance by the local communities.

The category of bio-based technologies:

- the local resources needed for the implementation;
- the functional and operational elements;
- the maintenance issues;
- the high complexity of the proposed solutions
- the sustainability of the technologies in humanitarian context.

The very active role in the internal consultations of representatives from People in Need, Polish Humanitarian Action, WeLoop, ITENE and AIMPLAS shall be emphasized.

Summarizing the internal consultation it was agreed / confirmed that:

1) All the main topics raised during the internal consultation in the form of questions, remarks, comments, observations and concerns shall be reflected and highlighted in the consultation process with the external humanitarian stakeholders.
2) The description scheme for bio-based solutions to be presented to the external humanitarian actors shall include features like:
    a. “functionality”,
    b. “relief potential”,
    c. “end-of life characteristics”,
    d. “potential replicability in the destination country (human capital, raw materials)”,
    e. “the willingness of the Solution Owner to share further information”.

3) The more detailed price considerations for the solutions will be taken up in Work Packages 5 and 6 by the Life Cycle Analysis, Life Cycle Costing and the feasibility assessments.

8. The external consultation process – the workshop and the most valuable contributions

For the purpose of **external consultation with the humanitarian stakeholders the second iteration of the List of bio-based solutions was prepared**. This iteration and the proposed changes were the result of the internal consultation. The main change referred to:

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1) The strengthening of the catalogue of the small – scale technologies as they exercise the strong feature of potential local adaptability and implementation; the originally alternatively proposed *„black soldier fly"* and *"biogas digester"* technologies have been now presented as singular and independent solutions; one more *"biogas digester"* technology has been added.[24]

2) The new entries in the products' catalogue were *"NATY incontinence pads"* and *"eco-friendly insulation with natural sheep's wool"*.[25]

3) Out of two *"PLA bottle products"* the one combining the mobile production unit has been selected.

The catalogue of questions to be presented to the external humanitarian stakeholders reflected most of the observations and constraints raised during the internal consultation.

The questions for particular clusters of bio-based products and technologies referred to the following topics:

Cluster - MULTI PURPOSE PACKAGING PRODUCTS

- applicability of the product to the different stages of the humanitarian supply chains (purchasing, transport, logistics at final destination);
- usefulness of the products for primary, secondary or tertiary packaging of humanitarian deliveries;
- willingness to use the product regionally and / or internationally.

Cluster - FOOD AND DRINKS PACKAGING PRODUCTS

- applicability and efficacy of the product in the humanitarian context;
- innovativeness of the product and its potential to replace the fossil-based solutions;
- probability for the product to face cultural or societal barriers, when being implemented in the humanitarian interventions.

Cluster - HYGIENE PRODUCTS

- an interest in establishing the production locally / in the humanitarian destination;
- potential of local production to serve as development / livelihood project;

[24] At the same time *"mobile composting system for use in closed area for treatment of waste"* and *"household composter"* have been removed from the List.
[25] At the same time *"bio – based pouch"*, *"plant-based absorbent article"*, *"NATY compostable wipes"* and *"coextruded hemp composite board"* have been removed from the List.

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- the fulfilment by the product of the sustainability criteria of the humanitarian interventions, like “do not harm” and “sustainability of resources”.

Cluster - CONSTRUCTION RELATED PRODUCTS

- potential of the product of becoming an important part of humanitarian interventions in the protracted crisis / recovery phases;
- ability of the product / material to address construction needs in humanitarian settings (e.g., shelter, durability, insulation);
- the importance of the solution for the environment in the targeted areas.

Cluster – OTHER PRODUCTS POTENTIALLY APPLICABLE IN THE CONTEXT OF HUMANITARIAN INTERVENTIONS

- applicability and functionality of the product in the humanitarian context;
- possibility of the product to easily realize the envisaged “end of life” scenario in the humanitarian context;
- potential interest in establishing the production locally / in the humanitarian destination.

Cluster – SMALL SCALE TECHNOLOGIES

- applicability of the technology for humanitarian purposes;
- transferability of the technology to humanitarian destinations;
- feasibility of the technological implementation and operation;
- potential of human capital that could ensure smooth operations, if and when provided with necessary capacity building.

Cluster – BIG SCALE TECHNOLOGIES

- transferability of the technology to humanitarian destinations;
- attribute of the technology to form part of a development component to the humanitarian intervention;
- feasibility of the technological implementation and operation;
- potential of human capital that could ensure smooth operations, if and when provided with necessary capacity building.

The external consultation has taken place on February 5th, 2025. In order to ensure that the participation to this workshop consisted entirely of the targeted audience (in this case, humanitarian organisations), dissemination of this event was done by direct reach out from our humanitarian consortium members People in Need, and Polish Humanitarian Action, who sent out invitations to this workshop directly to their networks, and via their social media accounts.

Following the distributed invitations, a total of 16 humanitarian organisations registered to participate in this session:

1. *Center for Rehabilitaion and Development (Ethiopia)*

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2. *Danish Refugee Council (representatives from Georgia and Bangladesh)*
3. *Action Contre La Faim (France)*
4. *United Nations World Food Program (representative from Italy)*
5. *United States Agency for International Development (representative from Italy)*
6. *World Vision (Germany)*
7. *CTG Somalia*
8. *World Relief (representative from South Sudan)*
9. *Місцевий Розвиток Громад (Ukraine)*
10. *SOS Children Villages (representative from Somalia)*
11. *Logistics Cluster (representative from Italy)*
12. *Hulo (France)*
13. *Médecins Sans Frontières (Switzerland)*
14. *NGO EKOVITA (Macedonia)*
15. *International Committee of the Red Cross*
16. *People In Need (Czech Republic)*
17. *Polish Humanitarian Action (Poland)*

Of the 16 invited humanitarian organisations, 9 attended the external consultation on February 5th, 2025. Below is a complete list of attending organisations:

1. Action Contre La Faim (France)
2. United Nations World Food Program (representative from Italy)
3. Danish Refugee Council (representatives from Georgia and Bangladesh)
4. Logistics Cluster (representative from Italy)
5. Médecins Sans Frontières (Switzerland)
6. Hulo (France)
7. International Committee of the Red Cross (Switzerland)
8. People in Need
9. Polish Humanitarian Action

It is important to note that the Bio4HUMAN project officer, Giulio Pattanaro was in attendance at this workshop as well.

All but the following solutions have been assessed positively by representatives of the external humanitarian organisations:

- *Starch-based biopolymer active, intelligent food packaging* – scoring low in terms of applicability and efficacy in the humanitarian context and at the same time scoring high in terms of facing potentially cultural or societal barriers, when being implemented in the humanitarian intervention.

- *Polystyrene – consuming lesser mealworm* – scoring only medium in terms of applicability and transferability of the technology to humanitarian purposes and then even below medium in terms of feasibility of the technological implementation and operation.

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- *ROBONOVA® - the bioremediation technology* – scoring below medium in terms of transferability of the technology to humanitarian destinations, feasibility of the technological implementation and operation and the potential of human capital that could ensure smooth operations.

- *MixMatters* – scoring below medium in terms of attribute of the technology to form part of a development component to the humanitarian intervention and in terms of feasibility of the technological implementation and operation.

It must be emphasized that the external consultation with humanitarian stakeholders provided very valuable feedback to the solutions put forward by the Bio4HUMAN consortium. The discussion referred to the actual willingness of the humanitarian organisations to include the proposed solutions to their supply chains. The policies and market mechanisms potentially incentivizing such inclusions were also discussed.

The external consultation allowed for presenting **the final List of 27 bio-based solutions** potentially applicable to humanitarian context and helping in the process of solid waste management.

9. The bio-based solutions

9.1. Multi-purpose packaging products

1) Packaging utilizing Notpla Seaweed / Zero Waste Paper

description / functions	Remarkable zero-waste paper from a forest below the sea. **A by-product from seaweed processing**, formerly considered waste, gives Notpla Seaweed Paper its unique veining quality while closing the loop on the seaweed industry. **Notpla Seaweed Paper's full potential allows for delivering boxes of different sizes and functions.** The product is targeted at food applications; packaging of medical or sanitary products to be considered. All the seaweed Notpla uses is sourced responsibly in Europe where the paper is made too.

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end of life characteristic	Notpla Seaweed Paper is entirely natural and circular, is made to be recyclable and home compostable.
TRL	9
solution owner	Notpla Limited (United Kingdom)
reference photo of the solution	

2) MYCO 4Pack and SafePads

description / functions	MYCO 4Pack and SafePads is **a combination of protective mailers (made from natural materials) with cardboard** as an environmentally friendly option for product protection while being transported. The bio – based solution in this case is **the MYCO material and the MYCO technology.** **The material is a composite material consisting of mycelium and waste** from the woodworking or agricultural industry. There is the possibility to produce the material in less expensive way in comparison to other bio – based solutions and on the same level as plastics foams. **The technology is a simple patent of growing mushrooms on waste** and it could be easily transferred to African locations.

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end of life characteristic	Material 100% biodegradable.
TRL	9
solution owner	myco s.r.o. (Czech Republic)
reference photo of the solution	

3) Sustainable film concept for medical and food packaging

description / functions	PLA tubular film for diagnostic applications. **The optimized high-performance film represents an alternative to cellulose-based films** such as cellophane or comparable films with high water vapor permeability. The material is based on renewable raw materials with reduced CO2 footprint. Designed in particular for **demanding diagnostic flow pack applications for sterile barrier systems**, the film features good mechanical properties as well as excellent oxygen and water vapor permeability.

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	There is also similar packaging solution for food (Planova flow pack film).
end of life characteristic	The material can be composted industrially in accordance with DIN EN 13432.
TRL	9
solution owner	Südpack (Germany)
reference photo of the solution	

4) AM'ON – Biodegradable laminating film

description / functions	LAM'ON is a 100 % biodegradable laminating film for packaging. **It is derived from renewable resources like corn**. The glue layer that was developed specifically for the needs of the industry is completely toxic-free. **The product could be applied on standard laminators, is printable and water resistant** to keep the products safe without compromising on sustainability.

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	The production method is simplified in a way that saves time and money. LAM'ON offers the same results, is used on the same machines, and is offered at the same price range as the currently used laminating films.
end of life characteristic	LAM'ON film is 100 % compostable.
TRL	9
solution owner	LAM'ON OOD (Bulgaria)
reference photo of the solution	

5) Monta Biopack® – self-adhesive tape / monta Klebebandwerk

description / functions	Monta Biopack® is the certified sustainable self-adhesive tape. It is made from about 90 % renewable resources, its carrier is a bio-based PLA film that is coated with a natural

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	rubber adhesive. The tape features **strong and robust backing material, excellent immediate tack and adhesion on various surfaces, low elongation and hand tearability.** **The selected fields of the applicability:** sealing biodegradable bags, films, other sustainable packaging types; permanent closure of medium heavy to heavy cardboard boxes; suitable for manual application in various hand- and table dispensers.
end of life characteristic	The tape meets the requirements on disintegration (composting) and biodegradation.
TRL	9
solution owner	monta Klebebandwerk GmbH (Germany)
reference photo of the solution	

6) Sway Polybags

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description / functions	Sway Polybags are being made with **seaweed, plants, and compostable polymers**. The seaweed is sourced from a global network of vetted ocean farms and processors who cultivate seaweed responsibly. The main ingredient of Sway Polybag is the TPSea™ - **patented golden pellet, which can go anywhere plastic goes,** with a few big differences. **The bag is strong, versatile, heat sealable and printable**. The potential applicability of the Sway Polybag: protection in shipping transit, dust guard, personal care, home goods, fashion, accessories.
end of life characteristic	The bag is home and industrially compostable (TUV pending).
TRL	9
solution owner	Sway (USA)
reference photo of the solution	

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7) Wood Foams utilising the Fibrease® and Papira®

description / functions	Wood Foams being the forest forward innovations are the sustainable solution in **protective packaging**. Wood Foams are using two types of materials: a) Fibrease® which is **a composite material, suitable for insulation purposes** in medical shipments, life science, meal kit deliveries, transport of light and fragile goods; b) Papira® which is **designed to reduce plastics and waste in future packaging solutions**; rigid, and with excellent shock absorbing properties, it is suitable for packaging of industrial, electronic and medical equipment, as well as fragile goods.
end of life characteristic	Biodegradation and disintegration under screening home composting conditions. Recyclable.
TRL	8
solution owner	Stora Enso (Sweden, Finland)
reference photo of the solution	

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9.2. Food and drinks packaging products

8) High barrier and compostable packaging materials for food contact applications

description / functions	High barrier packaging materials for **semi-liquids, dry and dehydrated food**. The main properties of this multilayer packaging being: **a) high moisture and oxygen barrier;** **b) active properties that extend the shelf-life of products up to 24 months.** The solution is utilizing plant-based by-products and waste (industrial waste and agricultural waste) and is based on cellulose and bioplastics.
end of life characteristic	100% biodegradable in soil and home compostable
TRL	7
solution owner	ITENE - Packaging, Transport and Logistics Research Institute (Spain)
reference photo of the solution	

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9) PLA bottles for water + Small water bottling unit for blowing and filling PLA bottles

description / functions	PLA water bottles – 100 % plant-based (sugar cane) and 100 % non-GMO. **The 100 % plant-based composition refers to the whole bottle, incl. cap and label.** 350ml, 500ml and 1 liter preforms/bottles can be produced at the moment. There is a possibility to extend this to 2 liter if needed. **The bottle allows for durable applications.** There is also the possibility to provide **small production (bottling) unit on wheels** for filtering local water and where the PLA bottles can be blown, filled and capped on side.
end of life characteristic	The PLA bottles are industrial compostable. In nature/landfill the bottle takes a longer time to break down.
TRL	The bottle is at TRL 9. The bottling unit is at TRL 4.
solution owner	GS-Green Packaging B.V. (Netherlands)
reference photo of the solution	

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9.3. Hygiene products

10) Anandi 100% Compostable Sanitary Pads + Aakar Mini –Factories

description / functions	Anandi Eco+ pads is the certified 100 % compostable sanitary pad. **Jute, bagasse, banana fibre and water hyacinth are used to produce the sanitary pads** in order to utilize agricultural plant waste materials. In a compost environment, at least 90 % of the pad are biodegraded within 180 days. The pads can be disposed easily in the backyard mud pit and will **create bio-manure for agriculture**. Each Anandi Eco+ pad is manufactured in **a mini-factory with simple technology**. Operating for 8-10 hours per day, one mini factory can provide a hygienic menstrual option for 200,000 women each month. The factory model potentially to be transferrable to humanitarian destination.
end of life characteristic	Biodegradability.
TRL	9
solution owner	Aakar Innovations (India)

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reference photo of the solution	

11) NATY Incontinence Pads

description / functions	**This Incontinence Pad is compostable health and sanitation product.** Eco by NATY is the first Femcare / Inco line with only compostable **certified raw plant based materials**, including the individual wrapping and packaging. The Incontinence Pads powerfully absorb more than 10x their weight to keep feeling drier for a longer time. They offer the safest protection, against leaks, and against stuff the skin doesn't need.
end of life characteristic	Compostability.
TRL	9
solution owner	NATY (Sweden)

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reference photo of the solution	

9.4. Construction related products

12) KINGSPAN Bio based insulation in buildings

description / functions	The product range, largely made from hemp, a fast-growing bio-based material, has the Jute Blend and Pure products. The HemKor Jute Blend product, with a bio-based content of at least 80 %, combines hemp with recycled jute bags. The HemKor Pure product displays a bio-based content of over 95 %. Both **products have excellent thermal performance** and **have been tested according to the NCS 16785 standard for bio-based products.**

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	The products have been developed **to help reduce the carbon footprint of buildings.** The CO2, in the part of the hemp plant that is used as an insulation, is stored in the building in which the product is installed. Growing local hemp could be adaptable to local conditions, but the production of the insulation will require a specialised factory.
end of life characteristic	The CO2, in the part of the hemp plant that is used, is stored in the building in which the product is installed. This is only released if the product is not reused or recycled at the end of its lifespan.
TRL	9
solution owner	KINGSPAN (Ireland)
reference photo of the solution	

13) Product lines made from bioPUR

description / functions	To reduce direct and indirect CO2 emissions in buildings and homes by addressing key weaknesses in thermal insulation – two innovative product lines made from **bioPUR, which feature 65-75 % renewable content** are being presented: • KLIMA-PUR Windows: **high-performance, energy-saving windows with frames made from**

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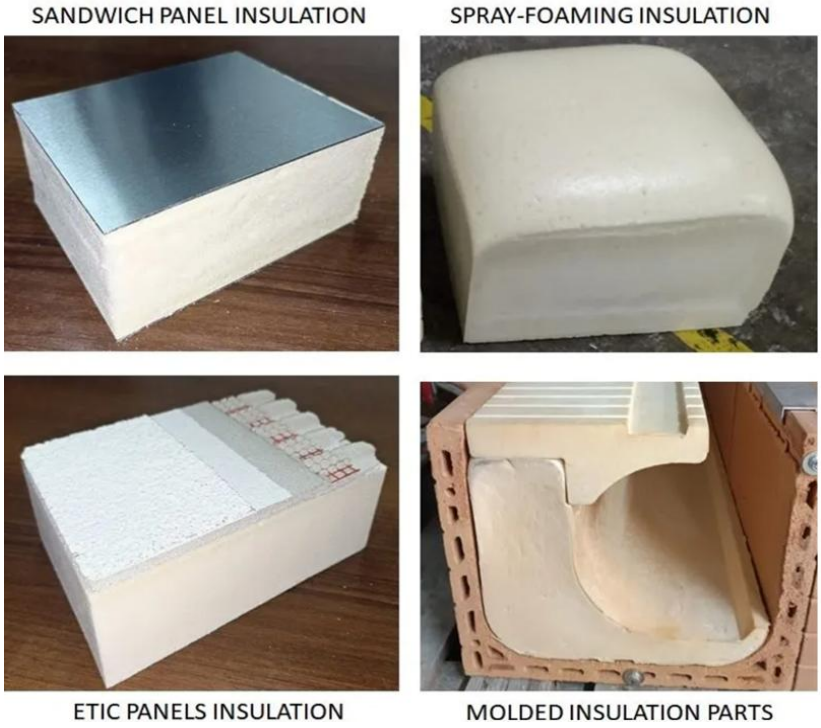
	bioPUR, offering excellent thermal and acoustic insulation; • bioPUR Foams: **a diverse range of bioPUR insulation foams for roofs, walls, and floors** that deliver outstanding thermal performance with increased sustainability compared to traditional insulation materials. PUR may be obtained from renewable raw materials (resource efficiency).
end of life characteristic	PUR is a fully recyclable material.
TRL	7 – 8
solution owner	INDRESMAT (Spain)
reference photo of the solution	

14) Eco-friendly insulation with natural sheep's wool

description / functions	The sheep wool insulating material proposed by Eco Friend Sheep is the right solution for improving energy efficiency and keeping homes and other facilities comfortable. Made with

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	100 % natural sheep wool, the insulation solution is sustainably sourced and renewable. The solution could be applied **for insulating roofs, ceilings, walls, floors, doors, windows.** **The main features of the proposed product:** • retains its high insulation performance, even when its wet • controls moisture • stabilizes heat changes • prevents mold and mildew growth • minimizes condensation • functions as an air filter trapping nitrogen oxides, sulphur dioxide and formaldehyde • is fire resistant
end of life characteristic	The proposed solution could be reused and has the features of biodegradability.
TRL	9
solution owner	S.C. ECO FRIENDSHEEP (Romania)
reference photo of the solution	

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

15) Biodegradable shelter

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description / functions	**The biodegradable shelter is envisaging the valorisation of plant-based feedstock and shall enhance the circularity of relief goods.** Currently, tent fabric is often made of PE (polyethylene) with a PVC coating. This is very difficult to recycle, as it is no longer possible to separate these materials. The presented "biodegradable shelter" solution is under development by **the following entities:** • MNEXT, • the Avans group "New Materials and Their Applications" • Médecins Sans Frontières • Wijnroemer Relief Goods. The works are carried out within the SIA-KIEM CE project. Within this project **tent fabrics consisting of fabric material that can be molecularly recycled** have been developed. **The remaining layer can be used as fertiliser**.
end of life characteristic	Recyclability.
TRL	5 – 6
solution owner	The consortium of the above named entities.
reference photo of the solution	

16) Bio4Pack Waste Bag (TIPA)

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description / functions	Bio4Pack's bags are **a responsible alternative to a disposable bag**. The bags are made from renewable resources and are available in the following sizes: 8L - 10L - 30L - 60L - 120L - 240L. TIPA compostable packaging provides currently solutions **for the food and fashion industries and is built to fit existing machinery and supply chains.** After use, the bags can be disposed of in the organic waste container together with the organic waste itself. They are designed to break down within months under compost conditions just like any organic matter; they shall disintegrate within — at most – 180 days under compost conditions.
end of life characteristic	Compostability.
TRL	9
solution owner	Bio4Pack (Germany)
reference photo of the solution	

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17) Single use compostable HaPPE apron

description / functions	Single use compostable HaPPE apron **is made from HaPPE's proprietary resin with neck loop and waist ties**. It is the sustainable personal protective equipment (PPE) product, with the usability tested by healthcare staff. The HaPPE aprons are in use in public and private healthcare providers in Ireland. The intention is **to help the healthcare industry make the shift from single use plastic consumables to medically approved compostable alternatives** in order to reach the sustainability goals. The HaPPE apron could serve as the essential personal protective equipment in humanitarian setting.
end of life characteristic	100 % compostable. Could be used in bio digester.
TRL	9
solution owner	HaPPE Earth (Ireland)
reference photo of the solution	

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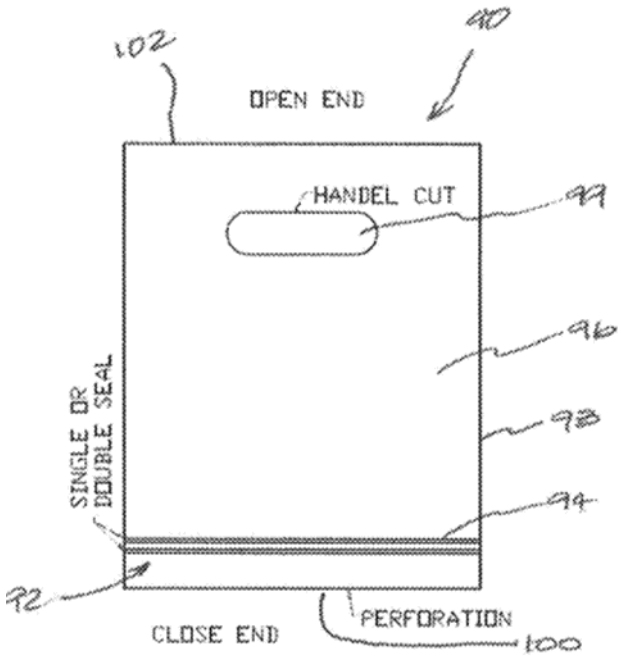
18) Biodegradable containers

description / functions	Biodegradable bags for disposing of an unwanted substance **formed from a bio-based material (maize flour) and a biodegradable plasticizer** selected from the group consisting of vegetable oil, polyesters made from glycerine, glycerine, and combinations thereof. The bags have an open end and a closed end with a sidewall extending there between. The bag includes a feature for enclosing a substance once placed into the bag. Alternatively, the feature may include an opening through a sidewall and an adhesive section. **The solution refers to biodegradability and shall allow the reduction of the usage of fossil-based materials for flexible packaging applications**, that are currently ending up incinerated or in landfills.
end of life characteristic	Biodegradability.
TRL	6
solution owner	Vijay C. Patel
reference photo of the solution	

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19) Monofilament fishing nets

description / functions	Monofilament fishing nets are utilising **biobased and biodegradable bioplastic formulations**. The product has been tested and approved by end users in regional projects and under real conditions of use. The product: a) substitutes conventional thermoplastic materials to reduce the environmental footprint b) integrates by-products for local valorization c) exercises end-of-life modulation suited to the product's use (e.g. marine biodegradation). The base component of the formulation is PLA. Producing PLA locally would require complex infrastructure and the development of a skilled workforce.
end of life characteristic	Biodegradability.
TRL	7
solution owner	SEABIRD
reference photo of the solution	

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20) Biodegradable and compostable mulching spray

description / functions	This mulching spray **prevents the growth of weeds in the soil near plants and fruits**. The bio-spray consists of an aqueous solution based on polysaccharides, obtained from renewable sources. The periodic replacement of plastic films at the end of their use generates a huge amount of agricultural plastic waste after use. This solution is sprayed onto the ground and forms a film that isolates the underlying soil preventing the birth of weeds. This film has **a duration of approx. 4-8 months**. After the cultivation period has elapsed, the treated soil is milled by motor hoe and **the film becomes a 100 % perfectly eco-compatible fertilizer.**
end of life characteristic	Fully biodegradable and compostable.
TRL	7 – 8
solution owner	Agribiom (Italy)

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reference photo of the solution	

9.6. Small – scale technologies

21) Black Soldier Fly (BSF) opportunities

description / functions	Black soldier fly **to transform local organic waste into high-protein animal feed and fertilizer**. The technology **is targeting all three organic fractions of solid waste, industrial and agri residues**. The BSF organic waste processing facility consists of waste pre-processing, biowaste treatment, separation of BSFL from the process residue, and larvae and residue refinement into products. The Project developing this BSF technology has been initiated in Uganda, Ethiopia, and Ivory Coast.

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	Benefits: • conversion of organic waste into valuable protein • BSF larvae provide essential nutrients for animals growth • BSF larvae production yields frass as an organic fertilizer (compost) for soil improvement.
TRL	9
solution owner	ACEN Foundation and EAWAG
reference photo of the solution	

22) Small-Scale Residue Utilization Pathways (SSRUP) - Black Soldier Fly technology

description / functions	This Black Soldier Fly technology was developed within the EU-funded DIVAGRI project *'Revenue diversification pathways in Africa through bio-based and circular agricultural innovations'* and **it differentiates as a type of mobile integrated biorefinery.** African countries involved are: Ghana, Namibia, Mozambique, South Africa and Botswana. The pilot study features *"dark cage"* and a *"love cage"* created for breeding and egg laying. The dark cage provided low-light conditions mimicking the flies' natural habitat, while the love

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	cage encouraged mating. Adult BSF are attracted using decomposing organic waste. The technology is designed to be **cost-effective and suitable for rural and remote areas.**
TRL	8
solution owner	The technology developed within the EU-funded DIVAGRI project.
reference photo of the solution	

23) modular micro AD system – Qube Renewables

description / functions	The dryQUBE is **an anaerobic dry digester that provides a cost-effective solution to fibrous agricultural and food waste**. The modular micro AD system is able to be **easily transported** into difficult to reach places and to be **run 'off grid'**, without the need for any supporting infrastructure. The modular dryQUBE solution is **quick to install** (2 weeks).

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	Once loaded with feedstock, the dryQUBE is irrigated with liquid digestate and begins to produce biogas. The biogas can be used for cooking, hot water, electricity generation or bioCNG vehicle fuel. After a 60–90 day retention time, the digestate can be used as fertiliser and the dryQUBE is refilled with a new batch of feedstock.
TRL	9
solution owner	QUBE Renewables (United Kingdom)
reference photo of the solution	

24) Single Stage Biogas Digester

description / functions	The proposed Biogas Digester is **a single-stage, solar-supported system**. It was developed by a team of researchers from the University of Cape Coast (UCC, Ghana) **using locally available materials like stones, wood, cement, iron rods, nails, PVC pipes, copper pipes, and their accessories**. It

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	operates **anaerobically to break down organic wastes into usable products** – methane gas, water and organic fertilizer. **Benefits:** • offers an on-site solution for managing organic waste and generating energy for farm operations; unsuitable for the management of high-risk organic waste; • supports decentralized energy production by providing sustainable energy to local communities.
TRL	9
solution owner	The technology developed within the EU-funded DIVAGRI project.
reference photo of the solution	**Country Example: University of Cape Coast, Ghana**  *Manual excavation of the digester pit* *Wood works to give the shape of the digester* *Excavated pit showing the influent and effluent chambers* *Solar thermal collector connected to the heat exchanger in the digester. Attached to the right is the solar water heater controller.*

25) Micro Biogas Digester

description / functions	Micro Biogas Digester is **a small-scale physical installation** that is fed with organic waste (food and agricultural / garden

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	waste) to generate biogas energy (for cooking and heating) and to generate fertilisers. It is a smart solution as **it utilises reliable simple technology and minimum investment.** It can be built and implemented **by any rural community**. The construction utilises easy-to-make concrete, irrigation rings, run-off pipes and a steel or fiberglass gas cap with an outpipe for gas. It has no moving parts and it can run at variable flows and temperatures. Operating costs are mainly electricity to grind waste and pump water and compress gas.
TRL	9
solution owner	The technology developed by Swedish "Suderbyn Ecovillage" and its NGO RELEARN.
reference photo of the solution	

26) Domestic biogas technologies

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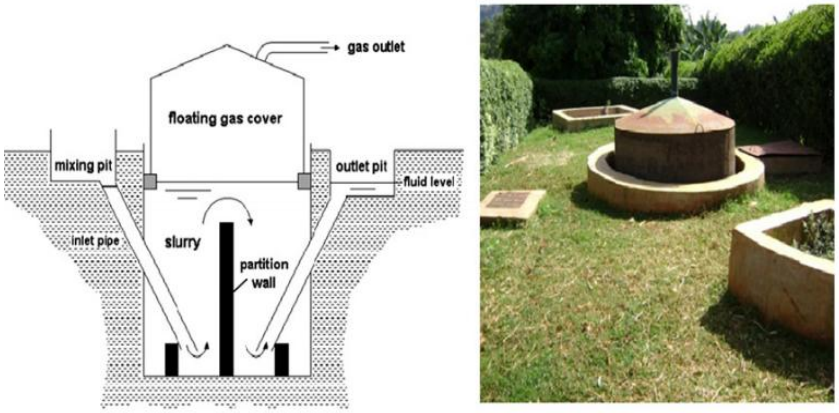
description / functions	There are **three possible biogas plant designs**: 1) floating – drum 2) fixed dome 3) tubular type The designs have been validated for the data inventory through construction, use and disposal phases. The technologies are able to utilize **fibrous and non-fibrous feedstock**, including animal excrements and or vegetable waste. The small-scale tubular design **may offer the possibility of recycling plastic waste**. The digesters were located in southern, eastern and western regions of Kenya. The functional units have been operating continuously for 340 days / year for 20 years. The installation and maintenance are easy to execute.
TRL	9
solution owner	The technology has been developed by the Kenyan Ministry of Energy.
reference photo of the solution	 **Fig. 1.** Floating drum biogas digester: (a) general scheme and (b) typical plant in Kenya [30].

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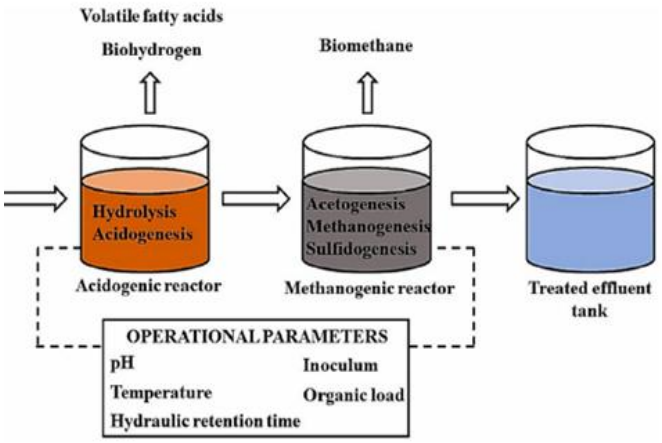
27) Biogas production from (bio) organic waste

description / functions	The biogas upgrading consists of **an anaerobic digestion reactor followed by a cogeneration unit**. The effect of the final product is **the production of biogas from the organic fraction of rural or urban solid waste** and the reduction of the dependence of fossil fuel for cooking, lighting and electricity generation. Such biogas digesters have been applicable in different scales in different regions. The case study used as reference allude to 4-8 m^3 household digesters in rural region of Ethiopia and a larger municipal digesters to produce electricity for vehicle fuel. The optimal scale size goes **from domestic households (as in Ethiopia) to small rural or urban communities**.
TRL	5 – 7
solution owner	University of Cantabria (Spain) as the entity proposing the solution
reference photo of the solution	

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10. The ethics considerations

Bio4HUMAN acknowledged the general ethics issues related to Human, Personal Data, Non-EU countries and Environment, Health & Safety / Security.[26]

During the consultation of the List of Bio – based solutions with the Project's Ethics Advisory Board and Internal Ethics Officer, which has taken place on February 20th, 2025, the following issues have been raised and discussed with Project's representatives[27]:

1) Sustainability of Raw Materials. It has been observed that some of the proposed solutions rely on plant – based materials such as seaweed ("Packaging utilizing Notpla Seaweed"), corn ("LAM`ON – Biodegradable laminating film"), hemp ("Bio based insulation in buildings KINGSPAN") and agricultural by-products. The ethical concern of overharvesting seaweed and disrupting marine ecosystems by large scale seaweed farming has been explicitly expressed:

In this regard it has been explained that:

All of the seaweed that Notpla uses is sourced responsibly in Europe. The Notpla Seaweed Paper is a by-product from Notpla's own extraction seaweed processing, formerly considered waste. Also in the case of the second seaweed-based product on the List, i.e. Sway Polybags – it has been observed that the seaweed is sourced from a global network of vetted ocean farms and processors who cultivate seaweed responsibly.

As both companies (Notpla and Sway) have been partially financed by rounds of venture capitals, it shall be assumed that the question of sustainability of raw materials have been in those cases pre-assessed positively.

Moreover, the case of potential influence on marine ecosystems will be further checked at the stage of delivering the Project's specific LCA for the bio-based products (WP 5 of Bio4HUMAN). This will be done by utilising "ImpactWorld+" tool, which includes new impact categories such as plastic physical effects on biota, fisheries impact, marine and terrestrial ecotoxicity, and photochemical ozone formation (ecosystem quality).

[26] These general ethics issues were identified in the Ethics Summary Report already during the Grant Agreement preparation.
[27] During the meeting with the Ethics Experts – Bio4HUMAN was represented by ENSPIRE (as the Leader of the Project) and by PRO CIVIS (as the Leader of the scoping exercise and the whole WP4).

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2) Potential impact on ecosystems and food security by using food crops for bio-based products (e.g. corn for laminating films and PLA bottles) and by growing bio-feedstock on arable land, what may potentially compete with food production.

In this regard it has been explained that:

In case of laminating films there is no intention of relocating the production to the Democratic Republic of Congo or to South Sudan, which makes difficult establishing a direct link to food safety in those regions.
PLA bottles could be theoretically produced at the site of the humanitarian intervention, also thanks to the small production unit on wheels, being part of the proposed bio-based solution. As for the moment the solution owner declares the production of PLA bottles in Thailand from sugar cane. In the near future, there will also be PLA made from sugar beet. The consequential aspects on ecosystems and food security from moving the production of bottles to the Democratic Republic of Congo or to South Sudan could be further considered in Project's dedicated social-LCA (WP 6 of Bio4HUMAN).

3) Waste management concerns understood mainly as the feasibility of compostability and / or biodegradability claims. This concern has been raised in particular versus Anandi Sanitary Pads, shall women lack access to proper composting facilities or in case of pads ending up in regular trash.

In this regard it has been explained that:

The solution owner claims that the pads are compostable since they are capable of disintegrating into natural elements in a compost environment. This usually occurs within 90-180 days depending on varying environmental factors. The Anandi Sanitary Pad is disposed off by burying it in a pit and waiting for the compounds to decompose naturally. Due to the natural raw materials used to make the pad, this process is safe, easy and quick. Additionally, the materials used to produce the Anandi Sanitary Pad ensure that no toxicity is left in the soil.

In a compost environment, at least 90 % of the pad are biodegraded within 180 days. Under other conditions in nature it takes longer, respectively. The pads can be disposed easily in the backyard mud pit of any rural household to avoid polluting the environment and create bio-manure for agriculture. Anandi Sanitary Pads do not use any harmful chemicals and convert into manure post disposal, which can be further utilised. This way, the pads contribute to environmental protection and increased resource reuse.

It must be further stressed that the Anandi Sanitary Pad has been highlighted as the finalist of the innovation award 'Bio-based Material of the Year 2019' organised by the Collaborating Centre on Sustainable Consumption and

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Production think tank. This fact shall endorse the compostability references presented by the solution owner.

As for the general compostability and / or biodegradability references of catalogued bio-based solutions, it must be further observed that they originate from well – established companies or already acknowledged start-ups. In many cases the products received innovation accolades at the international competitions dedicated to bio-based products / technologies.

The challenges of industrial composting will also be considered in the LCA (WP 5 of Bio4HUMAN). If a specific "end of life" treatment is absent in the case studies, it will be assessed as a standard "end of life" scenario. Given the likely lower toxicity of the products, its impact at this stage may be less significant.

4) Environmental concerns understood mainly as the additional requirements for significant amounts for energy and water at the production stages. This concern has been mainly raised versus wood foams and bio-based insulation, which may require intensive processing, affecting their overall carbon footprint.
In this regard it has been explained that:

These aspects will be included in the LCA (WP 5 of Bio4HUMAN). It is important to note that bio-based products store biogenic carbon, which is accounted for as a negative value (benefit) in the results. This biogenic carbon is re-emitted into the atmosphere at the "end of life" stage. While energy and raw materials are required for the production of bio-based products, just as for non-bio-based products—the overall climate change impact is most of the time more favourable.

5) Food safety concerns, in particular health risks for farmers and consumers from using Black Soldier Fly larvae as animal feed. The need for alignment with food safety laws has been expressed.

In this regard it has been explained that:

Both proposed Black Soldier Fly technologies have been developed and co – financed by international projects.

The first one within the scope of the Prevent Waste Alliance initiative, with the participation of ACEN Foundation, Trinomics, Eclose, EAWAG, Climate and Clean Air Coalition (CCAC). The technology has been deployed in three African countries: Uganda, Ethiopia and Ivory Coast.

The second one within the EU-funded DIVAGRI project (2021-2025), "Revenue diversification pathways in Africa through bio-based and circular agricultural innovations". This project seeks to provide African subsistence and

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smallholder farmers with tools to sustainably improve farm productivity, profitability and resilience through improved management of farming resources, output diversification and creation of high-value circular bio-products. African countries involved are: Ghana, Namibia, Mozambique, South Africa and Botswana.

It must be reasonably assumed that the international organisations co-financing and co-executing these projects have taken into considerations food safety laws and potential health risks for farmers and consumers.

Food safety will also become a relevant topic in social-LCA (WP 6 of Bio4HUMAN).

During the consultation of the List of Bio – based solutions with the Ethics Board of the Bio4HUMAN also some general observations have been raised by the Ethics Experts:

The solutions have been praised as relevant for the context and the purposes of the Project.

At the same time the legal and "cultural" framework of using these solutions in the countries concerned was pointed out. The solutions will be further checked to ensure that they indeed can be used in an efficient way and that they will not be "blocked" by any legal or cultural aspects. In that sense, the usability of these solutions needs to be checked and see how and if these solutions can practically be deployed in the context of each country.

Another aspect of the forthcoming analysis will be formed by capacity building issues for the use of these products. This could include the ethics aspects of human participation, use of personal data and steps leading to avoid the misuse of products.

Furthermore it will be assured that the potential technological transfers do not eliminate the local production. The level to which local farmers may be influenced by the introduction of the bio-based products / technologies will also be established.

There are also formal issues like legal approvals for imports of bio-based solutions and approvals for the usage of local resources.

In this regard it has been explained that:

Social impacts of the proposed bio-based solutions, including positive and negative impacts, will be evaluated following the UN Guidelines for social-LCA (WP 6 of Bio4HUMAN). Different actors and themes will be analysed, incl. local community, value chain actors, consumers, society and children. S-LCA is a methodology providing valuable information on social conditions of the

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production and consumption of products in a transparent, science-based manner. The main impact categories being human rights, working conditions, health and safety, governance and social-economic repercussions.

The legal and policy frameworks for the implementation of bio – based solutions will then be delivered within the scope of the governance aspects analysis.

11. Conclusions and further project's proceedings with the List

I.

As it was stated in the Humanitarian Report, **the most ubiquitous waste in the humanitarian settings** in Sub – Saharan Africa, where Bio4HUMAN has its two pilots studies, is **organic and plastic**. The Project's scoping activities and the List of bio-based solutions responded to this waste management challenges by identifying and presenting:

a) **Products replacing the plastic packaging / fossil-based materials for flexible packaging applications** (plastic foams, laminating plastic films, plastic – based tapes, plastic bags, plastic bottles).

b) **Products replacing other materials and humanitarian aid items utilizing plastics** (hygienic items made from synthetic polymers, sleek foils utilized in insulation materials, polyethylene tents, plastic – originated aprons, fishing nets made of thermoplastic materials).

c) **Products eliminating the need for plastic – based solutions** like plastic films utilized in agriculture to prevent the growth of weeds in the soil near plants and fruits.

d) **Products** which could be applied to different stages of the humanitarian supply and **that could eliminate plastics at later stages of supply chains**, i.e. transport to and storage at the final destination, distribution of goods and services.

e) Technologies allowing for transformation of local organic waste (solid waste, industrial and agri – residues, food, garden waste) into:

- high-protein animal feed,
- organic fertilizers,
- water,
- biogas.

II.

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The catalogues of scoped and presented bio-based solutions are far-reaching and diverse.

The List of bio-based solutions include products: a) utilising renewable raw materials, b) combining bio-based feedstock and waste, c) utilizing bio-plastics, d) combining bio-based feedstock with recycled materials, e) utilizing polysaccharides obtained from renewable sources. Most of the products are compostable and / or biodegradable.

On the technology side there are solutions: a) able to utilize fibrous and non-fibrous feedstock, including vegetable waste and animal excrements, b) offering the possibility of recycling plastic waste. The technologies are mostly suitable for rural and remote areas, with some of them adaptable also to the needs of urban communities.

It must be noted that also interesting bigger scale technologies able to deal with waste (organic, plastics) have been scoped, to name just "MixMatters"[28], "Lucra"[29] , "Recover"[30]. Due to the higher level of needed investment and / or pre-industrial scale they did not make it to the List of bio -based solutions.

III.

After having identified the bio-based products and the bio-based technologies of potential value to the humanitarian interventions, the following steps will be employed during the course of the Project:

1) **Life Cycle Assessment methodology** will be applied in WP5 in order to examine the potential of the proposed solutions with regard to actually reducing the environmental impact; for some of the selected bio-based solutions, Safe and Sustainable by Design (SSbD) analysis will be used.

2) **Social impacts of the proposed bio – based solutions**, including positive and negative impacts, will be evaluated in WP6 following the UN Guidelines for social-LCA (checking of the proposed solutions against the sustainable development principles); different actors and themes will be analysed, in particular local community, value chain actors, consumers, society, and future generations.
3) **Life Cycle Costing analysis** for the proposed bio – based solutions will be executed in WP6, taking into account factors such as a) costs relating to development and production of the proposed solutions b) costs of use, such as consumption of energy and other resources c)

[28] https://mixmatters.eu/
[29] https://lucra-project.eu/
[30] https://recover-bbi.eu/

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maintenance costs d) end of life costs, such as collection and recycling costs.

4) **The governance aspects** like legal and policy frameworks governing solid waste management in the humanitarian sector and the institutional capacity of the different stakeholders involved in the solid waste management system will be further taken into consideration in the WP6; this including also the identification of the governance opportunities that may arise from the implementation of the proposed bio-based solutions.

5) To strengthen the future efficient deployment of solutions and their optimization to consider the local conditions – **the applicability of identified solutions in a specific geographical area**, i.e. South Sudan and the Democratic Republic of Congo (DRC) will be tested.

While executing the next stages of the Project (points 1 – 5 above) it is important to have in mind the ethical considerations raised by the Ethics Board and summarized in chapter 10. They will be properly addressed whenever possible / advisable.

IV.

The selection of bio-based solutions presented in this document is the important stage for delivering by the end of the Project around 10 bio-based solutions properly assessed, evaluated and recommended by the Bio4HUMAN for the market uptake.

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