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D5.2: Report on Inclusive and sustainable bio-based business models for rural Africa

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Executive summary

This report constitutes Deliverable **D5.2** Report on the '<u>Inclusive and sustainable bio-based business models for rural Africa</u>', which has been the result of **Task 5.2** of the BIO4AFRICA H2020 project. The deliverable aims at <u>co-designing</u> the inclusive and sustainable business models for the bio-based technologies transferred and adapted to each pilot case <u>of the project bio-based products</u> in Uganda, Ghana, Cote D'Ivoire**,** and Senegal.

Under the BIO4AFRICA project, Work Package 5 concerns the development and assessment of circular, replicable and sustainable business models and has a goal to thoroughly assess their potential along with their investment requirements, to use the insights uncovered, and to provide hands-on business support (awareness-raising, business training, mentoring, access to finance support), as well as the circular practice guides for rural entrepreneurs to uptake the business models for the novel products.

This document is structured as follows:

1. **<u>Section 1 (Introduction)</u>**: Outlines the background of the Bio4Afrca project and bio-based products developed in each of the project focal countries.
2. **<u>Section 2 (Methodology):</u>** Outlines the methodology undertaken to accomplish Task 5.2, thus the value proposition and business models for the bio-based products in each of the Bio4Africa focal countries, namely Uganda, Ghana, Cote D'Ivoire and Senegal.
3. **<u>Sections 3 (Results):</u>** Presents the product-specific value propositions and sustainable business models for the bio-based business models.
4. **<u>Section 4 (Conclusion):</u>** presents the conclusion, way forward and recommendations for Task 5.2.

Some of the bio-based products are at different stages of development, namely prototyping, proof of concept, efficacy trials, pre-market entry assessment, and early adoption stages. In this regard, the assumptions that define the main elements of the value propositions and sustainable business models are based on the perception, planning and market intelligence data and the general knowledge and feedback provided by product value chain actors and stakeholders regarding the bio-based products.

It is anticipated that during early adoption and commercialization phases that will encompass efficacy trials, piloting and market entry stages will definitely provide valuable information/data and insights that will be used to revise or update the presented routes of value proposition and business models. This report will fuel the elaboration, improvement and validation of sustainable business models that will be informed by the data or evidence from real-life testing for the bio-based products/ technologies transferred and adapted to each pilot case under Task 5.3.

All the Bio4Africa bio-based products and technologies constitute novel business solutions with outputs that the local populations are not familiar with due to their innovative character, yet they help address major local challenges. The context for the Bio4Africa bio-based products in each of the focal countries for which the value proposition and sustainable business models are developed is presented below:

1.1 The case of the Bio4Africa bio-based products in Cote d'Ivoire

Cote D' Ivoire is one of the rapidly- growing countries in Africa, with an average growth rate of over 7% from 2012 to 2020. Agriculture plays a leading role in the national economy, being the engine of economic growth, accounting for 16% of the national Gross Domestic Product (GDP) and employing two-thirds of the population. BIO4AFRICA focuses on the use of agricultural byproducts of main productive crops that have a strong export character as well. Livestock rearing plays a key role in the economics of Cote D' Ivoire as meat consumption, particularly chicken meat, is increasing fast. Additionally, 35% of the rural population in Cote D' Ivoire struggles to access clean water.

BIO4AFRICA technologies and outputs to be tested in Cote D'Ivoire fit the local context and needs of local farmers, processors and population in terms of improving soil fertility, giving access to low-cost animal feed throughout the year and improving drinking water safety. Additionally, they provide the opportunity to exploit agricultural waste streams that, in most cases, remain unvalorized with economic and environmental benefits. Inadequate and expensive logistics infrastructures and possible resistance to the adoption of the proposed solutions by the local communities/ population should be considered important threats to be taken into account for the business rollout of the project solutions in the country (Table 1). Table 1 presents the bio-based products and technologies developed and piloted in Cote d'Ivoire.

Table 1: The bio-based products and technologies developed and piloted for Cote d'Ivoire

Bio-based Products	Market	Feedstocks	Technology
Biochar powder for additive in water filtration systems	Water purification market Agricultural market	Cassava peelings, rice husk, small branches, thinning woods, and/or residues of wood processing	Pyrolysis
Biochar powder for soil amendment	Agricultural market		Pyrolysis
Raw biomass pellets for animal feed (poultry, guinea fowl, pigs)	Livestock market	Rubber seed, cashew nuts, soybeans, rubber seed	Pelletizing
Bio-composites for composite panels	Construction industry	Bioplastics, vegetable fibres (roast tree fibre, cocoa pods)	Bio-composites production process
Bioplastics for the packaging industry	Packaging industry Agricultural market	Cashew apple juice	Bioplastics production process

1.2 The case of the Bio4Africa bio-based products in Senegal

Over 95% of Senegalese agricultural land is worked by very small-scale family-based farms engaged in subsistence agriculture. Despite agriculture's importance in the national economy, the sector is negatively impacted by land access problems, irregular rainfalls, poor soils and deterioration of forests and water resources (in quality and quantity). BIO4AFRICA focuses on agricultural byproducts stemming from the main productive crops (rice, ground nuts, cashew nuts, millet etc.) and with low competition for other uses. Regarding domestic energy use, there is overwhelming reliance on traditional cooking fuels such as firewood and charcoal, which has led to adverse health, social and ecological impacts. The building sub-sector in Senegal is growing by 3.9% per year, propelled by e.conomic growth and rapid urbanization.

BIO4AFRICA proposed outputs in the Senegalese case study answer to the vital need to improve soil fertility and, subsequently, crop yields through easy-to-access and cheap soil amendment material (biochar) to get access to a low-cost and environmentally and socially friendly alternative cooking fuel (biochar). At the same time, bio-composites and biochar as an additive to the biogas digesters provide an excellent opportunity for new, innovative business activities in sectors with low to non-existent competition. As in other BIO4AFRICA focus countries, though, attention should be paid to providing adequate awareness raising, capacity building, and training activities to the local population so as to enhance the adoption of the newly introduced technologies and also to ensure after-sales service and support. In response, the following bio-based products and technologies are developed under the Bio4Africa project for Senegal (Table 2). Table 2 presents the novel bio-based technologies and products developed and piloted in Senegal.

Table 2: The novel bio-based products developed and piloted for Senegal

Bio-based Products	Market	Biomass and Feedstocks	Type of Technology
Biochar powder for additive in biogas production systems	Agricultural sector	Peanut shells, cashew nut shells, millet stalks, rice husk	Pyrolysis
Biochar powder for soil amendment	Agricultural sector		Pyrolysis
Biochar briquettes and powder for solid fuel	Agricultural sector		Pyrolysis, briquetting
Biochar briquettes/powder for solid fuel and soil amendment	Agricultural sector	Typha, mahogany fruits	HTC, briquetting
Raw biomass briquettes for solid fuel	Agricultural sector	Peanut shells, cashew shells, millet stems	Densification
Bio-composites for composite panels	Agricultural sector	Lignocellulosic fibres coming from agri-food & waste streams	Bio-composites production process

1.3 The case of the Bio4Africa bio-based products in Uganda

Despite the pandemic's impacts, Uganda is expected to face one of the highest economic growth rates in 2021, at 6.3%, in comparison with other African countries. Livestock is a very important factor for many families in the country in order to optimize income, improve social status and contribute to food security. The agricultural production mix of Uganda includes an assortment of crops mainly for home consumption, though exports have increased by 20% between 2018 and 2019. BIO4AFRICA technologies to be tested in Uganda with low capital and operating costs and with low complexity, and focus on selected local forage species, based on the indigenous knowledge of local farmers and communities, providing high availability of animal feed alternatives during all seasons with increased nutrient concentration for several animal species. The main weaknesses that have to be faced for paving out the road to business exploitation of BIO4AFRICA outputs in Uganda are the need to build capacity on proposed technologies uses, to educate the farmers in order to enhance adoption and combat competition with established trade networks, as far as the bio-fertilizers and soil amendments are concerned in Uganda (Table 3). Table 3 presents the novel bio-based technologies and products developed and piloted in Uganda.

Table 3: The novel bio-based products developed and piloted for Uganda

Bio-based Products	Market	Biomass and Feedstocks	Type of Technology
Press cake as animal feed for ruminants	Agricultural sector	Forage species	Green biorefinery
Protein concentrates on being used as animal feed for pigs' whey feed pigs	Agricultural sector	Forage species	Green biorefinery
Protein concentrates - as feed for poultry	Agricultural sector	Forage species	Green biorefinery

Biochar to be used - as a soil amendment	Agricultural sector	Manure, struvite	HTC
Biomass briquettes used as animal feed	Agricultural sector	Biomass species	Briquetting

1.4 The case of the Bio4Africa bio-based products in Ghana

Livestock includes ruminants (sheep, goats), pigs, poultry and other species (snails, rabbits), and it is a promising sub-sector for the increase in the future in Ghana. The same promising pattern is highlighted in the marine fisheries sub-sector following the increasing consumption trends, but the introduction of aquaculture is immature at the moment, developing a dubious investment field for potential stakeholders. The Ghanaian market regarding the need for animal feed and soil amendments is expanding since the real growth rate of agriculture as a whole is increasing. Nevertheless, Ghana faces a variety of coordination problems among farmers, processors, and industrial end-users. This is not the only problem between the value chain links, but local policy implications with potential stakeholders hinder the development of value chains in the country. BIO4AFRICA outputs in Ghana could provide significant benefits to local communities and farmers, with major strengths their low-cost, infrastructure, adaptability to local conditions, robustness and low complexity. Their use would provide an opportunity to diversify farmers' income, take advantage of local feedstocks and create new job opportunities, and access to the information, communication and education on the introduced technologies are ensured, and after-sales support is guaranteed (Table 4). Table 4 presents the novel bio-based technologies and products developed and piloted in Uganda.

Table 4: The novel bio-based products developed and piloted for Ghana

Bio-based Products	Market	Biomass and Feedstocks	Type of Technology
Press cake to be used as animal feed for ruminants	Agricultural sector	Local forage species	Green biorefinery
Protein concentrates used as feed for pigs Whey to be used as animal feed for piglets	Agricultural sector	Local forage species	Green biorefinery
Protein concentrates pellets to be used as animal feed for aquaculture	Agricultural sector	Local forage species	Green biorefinery, pelletizing
Biochar as semi-charcoal dust to be used as a soil amendment	Agricultural sector	Rice husk, groundnut husk, corn cobs, maize stalks	Pyrolysis

1. INTRODUCTION

1.1 Background

Food security and climate change are two major development challenges of our time. In Africa, the food system is off track, and the climate is changing profoundly. By 2020, over 35% of the population in Africa faced hunger—more than double the proportion of hungry people in any other region— and about 282 million of Africa's population are undernourished[1]. Yet by 2050, Africa will have more than two billion people to feed whilst coping with adverse environmental, climate and health changes, including severe dry spells, droughts, floods, and food-energy poverty, among others[2]. Therefore, it is now vital to ensure food security in Africa, and the bioeconomy is set to play a starring role. African agri-food systems can contribute to the continent's food and nutrition security by alleviating poverty and securing food supplies while fostering inclusive, sustainable rural development.

Besides food security, poverty and climate change, other cross-cutting challenges are scarcity of natural resources and sole dependency on environmentally polluting, non-renewable fossil resources like charcoal, kerosene, and coal for energy. Yet the nature of the bioeconomy in Africa presents an exclusive opportunity to address the aforesaid inter-connected development challenges. It is against this background that the new BIO4AFRICA project sets off to support the deployment of the bioeconomy in rural Africa through the development of bio-based solutions and value chains with a circular approach to drive the cascading use of local resources and diversify the income of farmers. The BIO4AFRICA is deploying agricultural waste to diversify the income of farmers in Africa by integrating waste into a novel circular bioeconomy and transforming it into high-value products like animal feeds, fertilizer, pollutant absorbents, cooking fuel etc.

1.2 Description of the Bio4Africa project in Africa

The BIO4AFRICA is a 4-year, EU-funded project supported under the prestigious European H2020 Research Innovation Action program. The project is coordinated by the biomass, wood, energy, and products (BioWooEB) research unit at CIRAD, the French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions. The BIO4AFRICA project has 13 African partners (in Senegal, Cote d'Ivoire, Ghana, Uganda and Kenya); and 12 European partners (in France, Greece, Ireland, Spain, and England). The partners are committed to delivering contextually-relevant bioeconomy solutions to increase the incomes, food and nutritional security of farmers whilst propelling agro-industrialization and green growth in Africa

Bio4Africa will contribute to Africa's food and nutritional security, combatting poverty while driving inclusive and sustainable rural development. In other words, the project will support the deployment of the bioeconomy in rural Africa via the development of bio-based solutions and value chains with a circular

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[1] Holger K., Jenaneshobha S., Braimohpaavo E., Paavo E., Elisteelliot W. Mghenyi. 2022. Adapting Africa's food system to climate change is an imperative; it's time for action. Published on Africa Can End Poverty. https://blogs.worldbank.org/africacan/adapting-africas-food-system-climate-change-imperative-its-time-action

[2] Charles Onyutha., 2021. African food insecurity in a changing climate: The roles of science and policy. Food and Energy Security. https://onlinelibrary.wiley.com/doi/10.1002/fes3.160

approach to drive the cascading use of local resources and diversify the income of farmers. The project focus is to transfer simple, small-scale, and robust bio-based techs adapted to all the biomass needs and contexts, including green biorefinery, pyrolysis, hydrothermal carbonization, briquetting, pelletizing, bio-composites, bioplastics production. In doing so, the new Bio4Africa project will empower farmers to sustainably produce a wide variety of higher value and marketable bio-based products and energy, including animal feed, fertilizers, pollutant absorbents, construction materials, packaging, solid fuel for cooking, and ingredients for biogas production, significantly improving the environmental, economic and social performance of their forage agri-food systems.

To this end, Bio4Africa has set up four pilot cases with eight testing sites in Uganda, Ghana, Senegal and Cote d'Ivoire, reaching out to and offering more than 300 farmers and farmer groups, including small-scale or subsistence dairies and resource-constrained farmers, women farmer groups and transhumant pastoralists, the opportunity to test them in real production conditions. In total, seven transformation processes are implemented in four pilot zones in Côte d'Ivoire, Ghana, Uganda and Senegal, namely i) pyrolysis, ii) green biorefinery, iii) hydrothermal carbonization, iv) briquetting, v) granulation, vi) biocomposites, and vii) bioplastics.

1.3 Pyrolysis for the production of biochar as a soil amendment product

1.3.1 Production of biochar as a biofertilizer and soil amendment product in Ghana

The raw biomass materials for pyrolysis are crop residues such as groundnut husk, rice husk, and corn coms. The new unique pyrolysis to convert biomass and other Agricultural crop residues into biochar to be used for soil amendment trials. The modern Brazilin Klin and a locally fabricated metal Klin (Figure 1) are employed to produce quality biochar. The equipment design includes combustion chambers with a furnace for efficient thermal decomposition of biomass at elevated temperatures (Pyrolysis). The production capacity of the Klin equipment ranges from 60 to 350 Kg. The technology is environmentally friendly, with novel combustion chambers and furnaces designed to control the emission of thermally decomposed gases. Figure 1 presents the Brazilian Kiln employed in the production of biochar under the Bio4Africa project in Ghana.

Figure 1: Photos of the Brazilian Kiln employed to produce high-quality biochar in Ghana

Progress and application: Biochar produced reduces the pollution of the environment as most crop residue is burnt. It also reduces farmers' cost of production (soil nutrient amendment), used as an essential ingredient in fish feed formulation and water purification. To date, biochar is produced on a small scale, and the products are undergoing laboratory analysis and field-based efficacy trials as a biofertilizer and soil amendment product.

1.3.2 Production of biochar as a soil amendment product in Senegal

The raw biomass materials for pyrolysis are crop residues, namely Peanut shells, cashew nut shells, millet stalks and rice husks. The modified pyrolysis converts the biomass agricultural crop residues into biochar as the biofertilizer and soil amendment product (Figure 2). Figure 2 presents photos of the modified pyrolysis reactors employed in the production of biochar in Senegal.

Figure 2: Photos of the modified pyrolysis reactor used to produce high quality biochar in Senegal

1.3.3 Production of biochar as a soil amendment product in Cote d'Ivoire

The raw biomass materials for pyrolysis are crop residues such as groundnut husk, rice husk, and corn coms. The pyrolysis process in Côte d'Ivoire utilizes raw biomass materials involving crop-based residues as the input feedstock, primary cassava shells, cashew shells or millet and corn stalks. These raw materials are subjected to low-temperature pyrolysis, thus combustion without oxygen under the high internal temperatures of 450-600°C, from which quality charcoal or biochar products are formed. The pyrolysis technology produces biochar, which is used as a biofertilizer for soil amendment (Figure 3). Figure 3 shows the schematic representation of the pyrolysis process for the production of biochar and the importance of biochar as a biofertilizer and soil amendment product in Cote d'Ivoire.

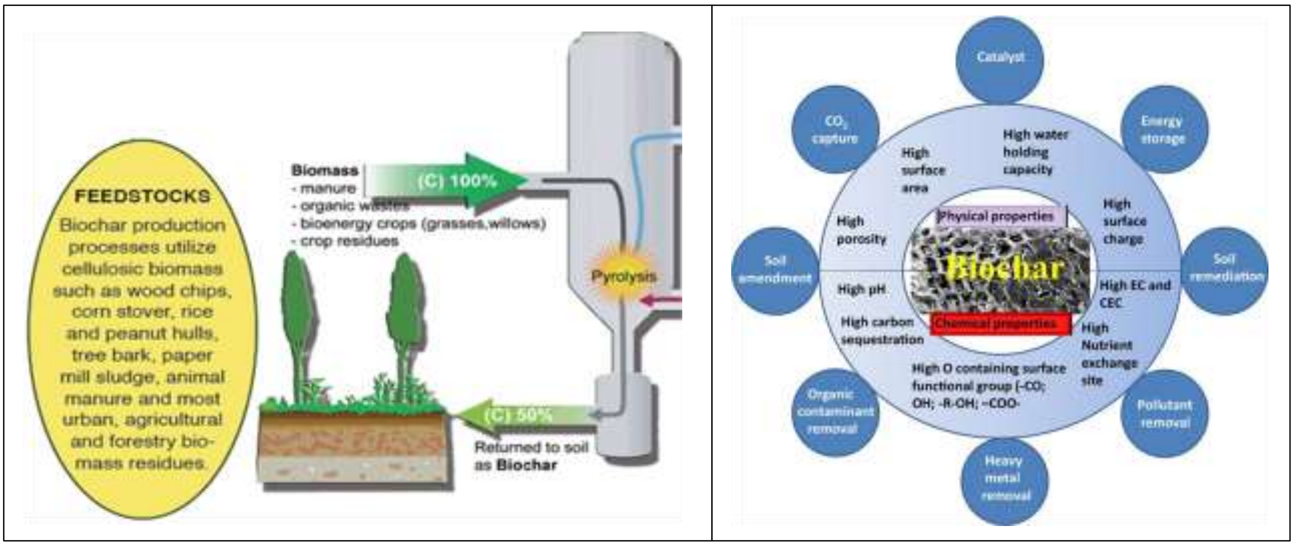

Figure 3: Schematic representation of the pyrolysis process for biochar production and the importance of biochar as a bio-fertilizer and soil amendment product in Cote d'Ivoire.

Progress for efficacy trials: In order to amend agricultural soils with biochar, soils are collected from different agroecosystems across Cote d'Ivoire. A traditional furnace for pyrolysis was constructed to produce biochar. The efficacy of the different Biochar products is assessed using varied quantities of biochar application under controlled greenhouse conditions, using tomatoes and maize as model crops. To assess the efficacy of biochar as a biofertilizer and soil amendment product, the different agro-morphological parameters of the model plants are being collected over varied growth intervals. For the first time, pyrolysis technology is introduced in Cote d'Ivoire and also provides exclusive opportunities for soil nourishment. The biochar shall also be extended to the cocoa fields to boost their productivity and yields[3].

1.4 Pyrolysis for the production of biochar as a solid biofuel product

In Senegal, a community-level pyrolysis system was adopted and is being piloted to produce biochar powder from both dry and wet agricultural biomass and byproducts. The raw biomass materials are crop residues such as peanut shells, cashew shells, millet and corn stalks and rice husks. Therefore, various crop residues are processed (crushed and mixed) into distinct feedstock blends and put in the pyrolysis reactors. They are subjected to varied pyrolysis operating parameters that are defined and tested depending on the quantity and quality of feedstock blends, as well as the intended use of biochar produced, including soil amendment, additives in the biogas production systems and solid fuel (Figure 4). Figure 4 shows photos of the community-level pyrolysis for the production of biochar and a briquetting line for biochar briquettes to be used as solid fuel in Senegal.

Figure 4: Photos of the biochar production system: a) community-level pyrolysis, b) a briquette line, and c) local biomass mixing device piloted in Senegal

Biomass and biochar briquettes will be produced in the Bio4Africa pilot case in Senegal to be used as solid fuel. The compaction of the biomass through briquetting improves its combustion properties and makes transport, distribution and storage easier and more cost-effective (Figure 4a-c). The briquettes produced are perfect substitutes for coal, charcoal and firewood for domestic cooking or for industrial uses like fuel in electric power generation and fuel for heat and steam production in industrial boilers.

[3] https://www.facebook.com/groups/208781026394227/posts/1020769581862030/

Any necessary pre-treatment steps required (thus, torrefaction and pressing) for the raw biomass or crop residues as input feedstock is assessed and optimized during the pilot phase implementation. The pyrolysis technology is complemented with a briquette line (Figure 4b), which is also adapted to the local needs in order to deliver quality biochar briquettes as solid fuel products. During biochar production as the cooking fuel briquettes, the Hydrothermal Carbonization Technology (HTC) batch operation scale unit is developed and operated using locally-sourced wet feedstocks such as Typha and mahogany fruits. In addition, the new densification process is employed to produce high-quality bio-briquettes from raw biomass derived from the agricultural waste streams like peanut shells, cashew shells, and millet stems (Figure 5). Figure 5 presents the photos of the HTC device and the biochar briquettes produced during the pilot phases in Senegal.

Figure 5: Photos of the new HTC device and high-quality biochar briquettes produced in Senegal

The biochar briquettes are to be used as novel solid cooking fuel in the target farming communities replacing traditional fuels like charcoal and firewood, thereby protecting the forests against massive deforestation and ecological deterioration.

1.5 Pyrolysis for recycling agro-waste into biomass pellets as bio-feeds for livestock

Biomass pellets are produced, and the novel animal feeds are in both the Cote D'Ivoire and Senegal at the pilot sites under the Bio4Africa project. The bio-feeds from agricultural biomass such as rubber seed and cashew nuts shall serve as feed rations or supplement for poultry, guinea fowl, sheep and pig feed diets. Both the pyrolysis and pelletisation process (Figure 6); allow agro-waste recycling and better conservation of feed resources whilst reducing feed wastage by animals, thereby improving their digestibility and zootechnical performance. Correspondingly, as the quantity (or volumes) of biomass are significantly reduced, transport and storage costs and requirements are decreased (Figure 6).

Figure 6: Pyrolysis and pelletisation process for the production of biomass feed pellets in Senegal

The parameters influencing the manufacture of the feed pellets are moisture content and physio-chemical composition of the feedstocks produced, including nutritional profile, pressure and temperature are being evaluated and optimized in the Bio4Africa pilot case in Senegal (Figure 6).

1.6 Pyrolysis for the production of biochar powder as an additive in biogas production

The high-quality biochar briquettes (Figure 7) are crushed into biochar powder. The powder is put in the biogas digestors and, thus, used as an additive in biogas production systems. In the digester, the biochar powder act as a catalyst for anaerobic digestion and as a filter for biogas pollutants, primarily the hydrogen sulfide (H_2S) in the bioreactors or biogas digesters (Figure 7). Figure 6 presents the photos of the pilot biogas digestors, the biochar powder (as the additive product), the resultant clean biogas produced at the Bio4Africa project pilot facility in Senegal, as well as a schematic representation of the biogas production systems and biogas applications.

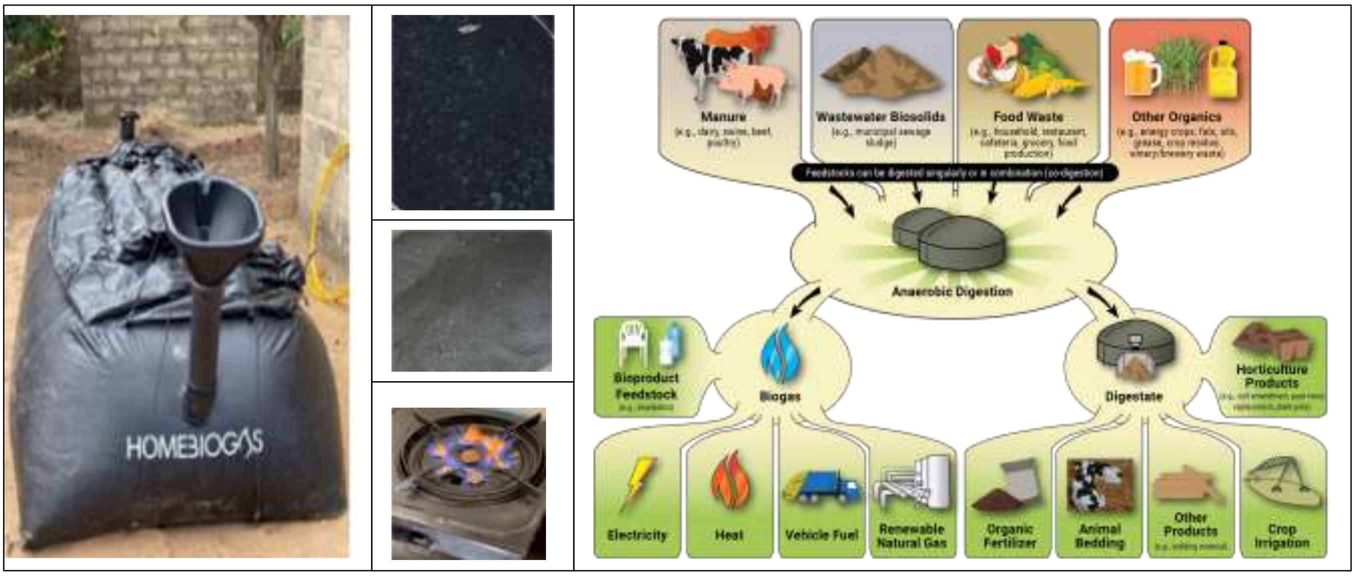

Figure 7: Photos of the biogas digestors, the biochar powder (as the additive product), the resultant clean biogas, biogas production and application systems at the Bio4Africa pilot facility in Senegal.

However, this application is still at an early stage of development, and the definition of specifications on biochar properties seems crucial because mechanisms involving biochar in anaerobic digestion are yet to be studied. The benefits of the bio-digester are multiple, including i) the provision of clean biogas – as renewable energy for lighting and cooking functions and ii) the compost manure for organic horticulture and other climate-smart farming systems, among others (Figure 7).

Progress for the efficacy trials: the biochar is undergoing screening tests and calorimetric evaluation at the laboratory scale with distinct feedstock and biochar product profiles. Anaerobic digestion tests involving biochar powder as an additive inside the reactor to catalyze biogas production and filtration of biogas pollutants are also ongoing. Some of the biophysical and chemical parameters that are studied include biogas output quantity and quality, internal air temperatures, microbial diversity evolution, reactor alkalinity, pH, and volatile fatty acid concentration, among others. These studies are based on the hypothesis that biochar could increase the kinetics of biogas production, as well as the biogas yield based on the assertion of Scarlat and Kougias[4].

1.7 Pyrolysis for the production of biochar powder as a medium for water filtration

Under this Bio4Africa Task T5.2, AFAAS developed a sustainable business model for biochar as a medium for water filtration. The raw biomass materials for the pyrolysis are biomass residues of energy crops (Figure 8), including rice husk, empty cocoa shells, palm seed fibres, palm roundups, wood processing residues, cashew nuts, cassava skin, and straw, among others. In Côte d'Ivoire, the pyrolysis process for the production of high-quality biochar for water filtration purposes utilizes the raw biomass materials from the crop-based residues as the feedstock, preferably cassava shells, cashew shells or millet and corn stalks. The community-level pyrolysis system and a traditional pyrolysis oven were adapted and tested to produce biochar powder from major agricultural residues or byproducts. The Biomass raw materials are subjected to low-temperature pyrolysis, thus combustion without oxygen under the high internal temperatures of 450-600^{o}C, from which quality charcoal or biochar products are produced. The pyrolysis technology produces biochar, which is used as a medium for water filtration and treatment purposes (Figure 8).

Use of Biochar as the pollutants adsorbent in water filtration systems: regarding the use of biochar as a pollutants adsorbent, a strong evidence base suggests that biochar has an excellent capacity to remove the broad spectrum of contaminants from aqueous systems, including toxic inorganics (e.g., uranium, fluoride, arsenic), radionuclides, synthetic, and organics, pesticides and pharmaceuticals, and pathogenic organisms (Figure 8). Figure 7 presents the water filtration process using the INP-HB device and system installed at the Bio4Africa project sites in Kahankro village, Cote d'Ivoire.

[4] Scarlat and Kougias (2018). Water- Energy- Food- Ecosystem Nexus in Western Africa: Small-scale sustainable solutions and energy from agricultural organic waste. Ispra, European Commission, 2018, JRC111857.

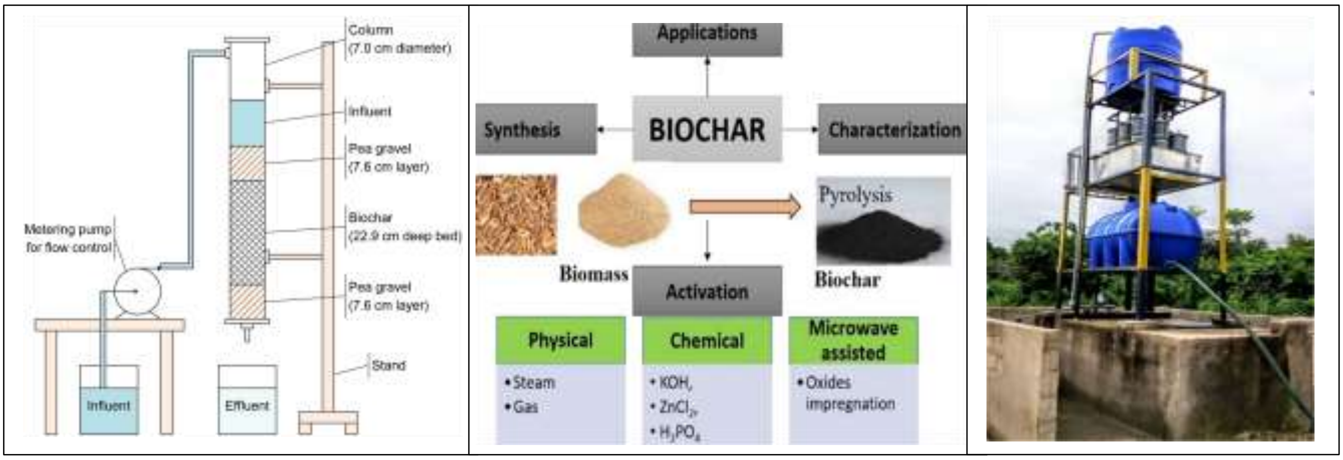

Figure 8: Schematic representation of the water filtration process using the novel INP-HB device and system installed at the Bio4Africa project sites in Kahankro village, Cote d'Ivoire

The potential of using high-quality biochar as an adsorbent in water filters for the removal of multi-contaminants in drinking water, with several advantages over other low-cost methods (thus, sand filtration, boiling, chlorination, etc.). However, the link remains not fully elucidated between materials used, process conditions and performances that are dependent on the pollutants to be removed and the water matrix. Bio4Africa project will explore factors such as biochar porosity, size of pores, the role of functional groups present on the surface and material acidity to advance these biochar applications.

Progress for the efficacy trials: For the biochar-based water filtration trials, biochar from the pilot furnace by pyrolysis has been used to design and construct the water filtration device now operational. Trials are currently in the progress of calibrating the novel INP-HB device and system (Figure 8). After obtaining biochar, efficacy tests to evaluate the physical and chemical parameters of the water after the treatment with varied quantities of biochar are ongoing.

1.8 A green biorefinery for the production of press cakes as ruminant feeds (e.g., cattle)

In Ghana and Uganda, Bio4Africa targets the pilot technologies for processing forage species and various types of agri-food waste streams to produce green biorefinery streams and biochar. In this case, the small-scale green biorefinery for the production of; i) livestock feeds (press cake and whey) and ii) feed with protein concentrates to supplement the fish feeds. The novel green biorefinery is the new technology that is used for the processing of biomass and leguminous crops into bio-based livestock feed products, namely the press cake and whey, as well as protein feed concentrates as supplements for the fish feed formulation. The raw key materials are the leguminous crop residues, namely cowpea leaves, pigeon bean leaves, soybean leaves, *mucuna prurient*, Itch grass, goat weed, and related green leaves (Figure 9). Figure 9 shows the major steps in feed processing using the small-scale green biorefinery process.

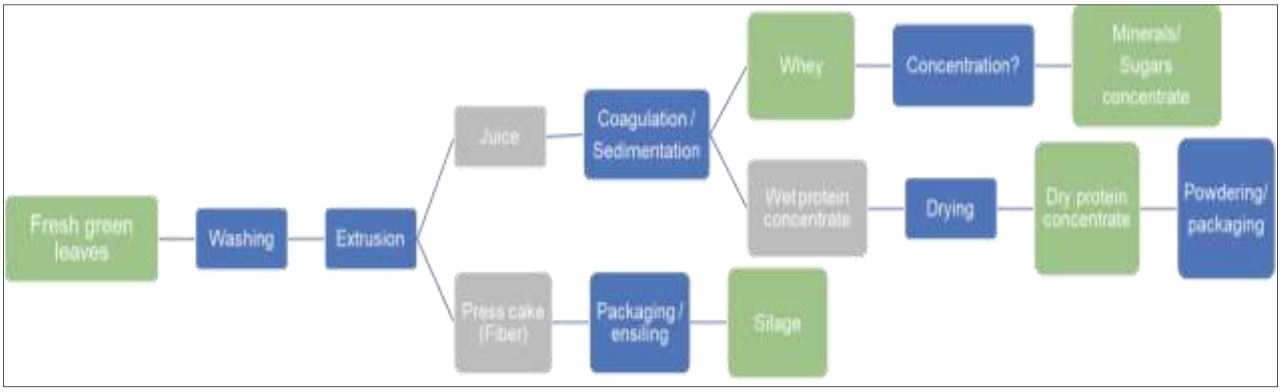

Figure 9: Schematic representation of the small-scale green biorefinery process for Ghana

The new green biorefinery is customized and adapted to process local types of biomasses, and the biorefining process is continuously optimized to maximize the extractable protein per unit whilst minimizing the energy requirements (Figure 9). Also, diverse types of grass-based biomass are used as the feedstock input/ forage species, namely *Andropogon gayanus, Pennisetum Purpureum,* and *Leucaena Leucocephala*. Moreover, the inputs are tested in order to produce feeds from readily available agricultural byproducts like cassava peelings, rice husks and forest-based byproducts. The feedstock blends and pyrolysis operating parameters are defined and/ or tested, depending on the availability of the feedstocks, like crop residues from legumes, cereals, tubers, fruits, and vegetables such as cowpea, groundnuts, soybeans, maize, millet, sorghum, wheat, yam, cassava, sweet potatoes, cabbage, lettuce and spinach. Moreover, to diminish the energy needs of the new green biorefinery facility, gas released during the pyrolysis process is burned in the combustion chamber; to produce the heat required for biorefinery, combining the relevant technologies.

1.9 A green biorefinery for the production of protein concentrate as aquaculture feeds

Quantities of the protein concentrate are pelletized to be used as the aquaculture feed for the target local communities that breed fish (thus, Tilapia and catfish). Besides the pig and piglet feed trials, the novel protein concentrate is also undergoing evaluation for use as an aquaculture feed using Nile Tilapia (*Oreochromis niloticus*) species and catfish as the specimens. The experimental parameters are feeds used, fish species used, water quality (thus the acidity, alkalinity, salinity, water temperature, and the rate of water circulation), the system of fish production, feeding schedules, and the number of fish used in a trial. The trials use growth rate analysis to measure fish growth rate in relation to weight, duration of maturity, and the health of fish species used, while feed analysis assess the nutritional value of the Nile tilapia and catfish production.

1.10 A green biorefinery for the production of whey as monogastric feeds (e.g., pigs)

The green biorefinery produces three types of animal feed products, namely (i) fibre/protein grass press cake as ruminants feed, (ii) protein concentrate as monogastric feed, and (iii) protein whey as monogastric feed. Protein concentrate and whey are transported to the pilot pig farms to be used as animal feed, substituting soya, and mostly imported. The protein concentrate and press cake are dried protein concentrate that is easily stored and transported to the farm sited (Figure 10). Figure 10 presents field-based photos of the green biorefinery and the novel feed products produced, including the whey for monogastric feeds.

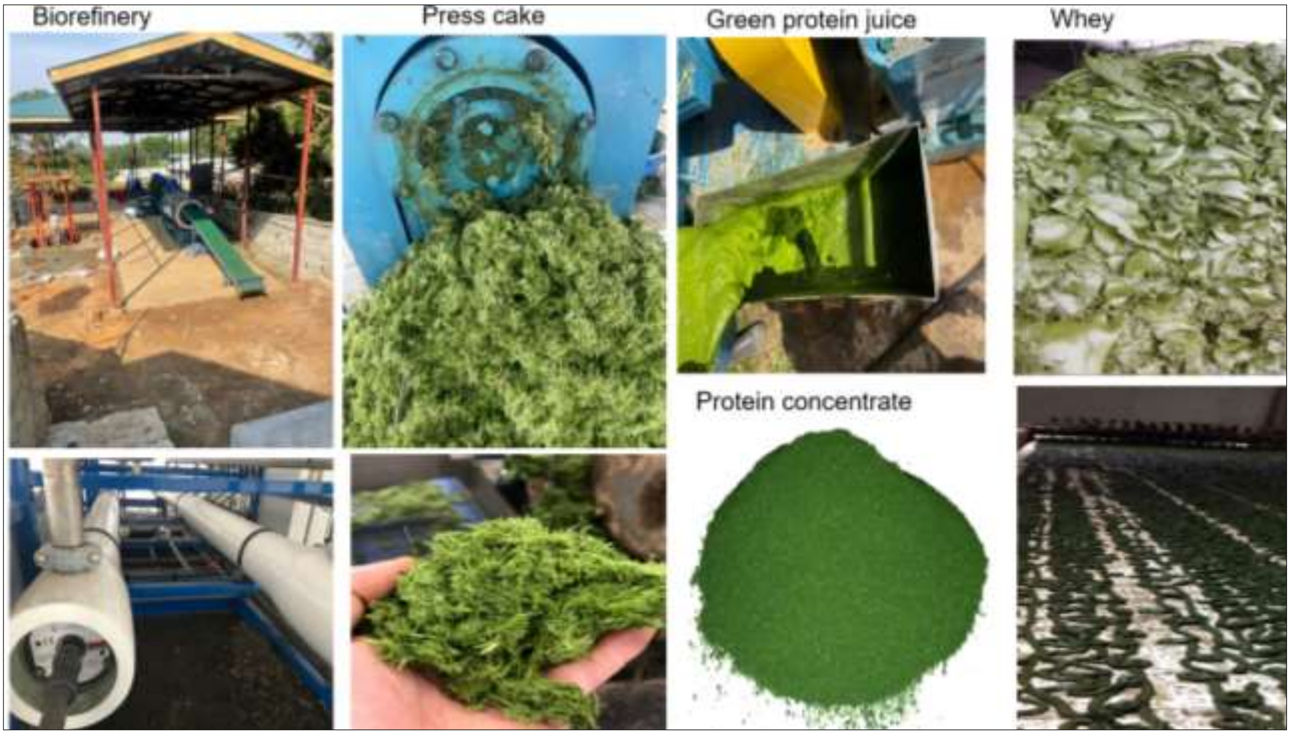

Figure 10: Photos of the novel feed types produced using green biorefinery in Ghana

These feeds are envisaged to increase feed supply and availability throughout the year, even in remote locations with less favourable growing conditions. With these feeds (Figure 10), the farmers have the capacity to engage in zero-grazing dairy framing systems both in the urban and peri-urban area's farmers. This is because local dairy production is compromised by a shortage of quality feed resources; there is a shortage of dairy cattle feed, especially in the dry season. Efficacy trials for nutrient profiling and feeding performance of the animal feed, primarily the fibre or protein grass press cake, protein concentrate, and protein whey, are ongoing.

1.11 Densification and Pelletisation Milling for the Production of Fish Feed Pellets

A pelletization mill is employed to process crop biomass and residues into fish feed pellets (Figure 11). The fish feed pellets size range from 1-12 mm and are produced using the modern diesel engine (100 -150 kg, LM-60) pelletization mill, which is also operated using a 2-3 phase hydro-electric power supply. Figure 1 presents the densification process and pelletisation mill machinery used in the processing of crop biomass residues into the novel fish feed pellets in Ghana.

Figure 11: Photos of the densification process and pelletization machinery of bio-feed fish pellets in Ghana.

The raw materials for making fish feed pellets are poured into the stirring compartment of the pelletisation machinery (Figure 12). Water is added in suitable proportions into the machinery before the feeding motor, and the main motor is started by rotating the driving wheel. In the process, the raw materials are then stirred well, mixed and poured into the extruder system due to the effect of the protective cover. The electric cutting motor is started to drive and rotate rolling rollers, thus achieving the object of the extruded materials. In the end, the fish feed pellet particles are produced from the extruded hole, squeezed and cut out of the material under the effect of rotation of the blade, and finally, slipped out through the discharge port (Figure 5). Figure 5 presents photos of the fish feed pellets and different classes of the fish feed pellets produced.

Figure 12: Photos of the fish feed pelletization machine and different classes of the fish feed pellets

The fish feed produced from the pelletization machine through densification and pelletisation milling processes can be floated on water for 13 hours without pollution effects. The pelletization device produces fish feed pellets with different diameters and shapes (Figure 12). The main objectives are to i) Produce and supply quality sheep feed pellets based on local tanning plants for the control of gastrointestinal parasites; ii) demonstrate the efficiency and effectiveness of the feed pellets through assessing their efficacy, as well as the socio-economic benefits to producers and farmers.

1.12 Production of bio-composite from bioplastic and composites from coconut fibre and palm tree branch fibre

1.12.1 Production of bio composite from bioplastic in Senegal

The Bio-composites are used as construction materials (Figure 13). Bioplastics and vegetable fibres (thus, the roast tree fibre, cocoa pods), and other lignocellulosic fibrous agricultural waste are mixed with binding agents (e.g., resin), and the hot-pressed to produce bio-composites in the form of panels. The resultant fibrous panels are lightweight with several potential non-structural load-bearing indoor applications, including false ceilings, furniture, interior walls, and insulation, among others (Figure 13).

Figure 13: Photos of the bio-composites and their application in the construction of structures

With the view of transforming agricultural waste into the value-added bio-products for re-use, suitable processes are being developed to produce bio-composites. Local fibrous and dry agricultural waste, such as primary wooden biomass (thus, the small branches, thinning woods and residues of wood processing), and secondary biomass (thus, fibre crop residues like straw, rice, palms etc.), as well as Typha, are mixed with resin or other binding agents and hot-pressed to produce the high-quality bio-composites in the form of panels.

1.12.2 Production of biocomposite from bioplastic in Cote d'Ivoire

Bioplastics are produced from molasses and juice of cashew apples (Figure 14). Figure 14 presents the sample photos of the fresh and dried cashew apples and molasses as primary raw materials used in the production of bioplastics under the Bio4Africa project.

Figure 14: Sample photos of the fresh and dried cashew apples and molasses for making bioplastics

Field trials using the cashew apple and juice-molasses mixtures producing the varying composition for the production of bioplastics are ongoing. Preliminary results show the presence of molasses that inhibits the growth of microorganisms, which could amplify the production of bioplastics.

In addition, two plant fibres for coconut and rônier branches are collected and used as raw materials in the production of bioplastics. The coconut and rônier plant fibres are selected since they are available, under-utilised and are also considered agricultural waste in the project host communities. During the efficacy trials, lignocellulosic characterization of different fibres from the plants is assessed. In this regard, the preliminary results show that the plant fibres with high cellulose profiles (greater than 50%) but with relatively low hemicellulose and lignin content, such as coconut and rônier, make their fibres good candidates for the production of bio-composites.

Initially, bioplastics are processed from plant-based raw materials such as cashew apple juice molasses, coconut and rônier branches using Polyhydroxyalkanoates (PHAs) under a microbiological fermentation process[5]. PHAs are naturally occurring biodegradable polymers. PHAs are synthesized and stored as water-insoluble inclusions in the cytoplasm of some bacteria and are used as carbon and energy reserve materials for biochemical and physical processes. Under the Bio4Africa project, the PHA produced by the INP-HB system in Cote d'Ivoire (Figure 15) is also employed in water filtration. Figure 15 presents the INP-HB system used in the production of the PHA and sample photos for the biocomposite materials produced.

Figure 15: Photos of the INP-HB system installed and the biocomposite products to be produced

These PHAs produced from the INP-HB system are harvested and then processed (isolated, dried and crushed into powder form. The powdered PHA is used to formulate or design, and produce the biocomposite materials (Figure 15).

[5] Keshavarz, T. and Roy, I., 2010. Polyhydroxyalkanoates: bioplastics with a green agenda. Current opinion in microbiology, 13(3), pp.321-326.

2. Methodology

2.1 Literature review and desktop research

AFAAS conducted a detailed desktop literature review and analysis of the Bio4Africa project tasks and outputs but with special attention and emphasis put on Tasks 1, 2 and 5. In doing so, peculiar elements, including activities and salient bottlenecks along the bioeconomy commodity value chains that could inform the process of co-designing of sustainable business model, were identified. During the literature review and desk research, data from project reports and secondary data resources related to the value propositions and business models were analyzed and collected. The data type and quality dimensions of completeness, consistency and external comparisons were correlated with preliminary data obtained during Task 5.2 of the Bio4Africa project.

The rural developing world faces a significant challenge in achieving the dual objectives of economic growth and decarbonization[6]. The traditional economics and linear business models driven by a "take-make-dispose" philosophy are unable to manage the demand and supply balance in the consumption of natural resources[7]. This imbalance compromises the sustainability of enterprises and rural economies in general, with a knock-on effect on global supply chains, leading to socio-economic and environmental risks and volatility. Realizing the increasing scarcity of natural resources coupled with the challenges of climate change vagaries, the traditional business model is giving way to the circular bioeconomy model, which is more eco-friendly and is also sustainable. The circular bioeconomy model focuses on careful alignment and management of resource flows across the value chain by integrating reverse logistics, design innovation, collaborative ecosystem, and business model innovation[8]. Under the Bio4Africa project, Task 5.2 examines how the circular bioeconomy model, namely the 'Triple Layered Business Model Canvas (TLBMC)', could be deployed in the rural farming communities to actualize contextually-relevant sustainable business models that are based on reducing, re-use, and recycle paradigms of the natural resources.

The aim of designing and use of the TLBMC as a new reference tool and framework of the circular bioeconomy is to support farming communities in figuring out suitable courses of action to promote the use and adoption of bio-based products[9]. The TLBMC, therefore, presents all-inclusive results that fully illustrate sustainable value propositions and considers all three main pillars of sustainability, namely the environment, economy, and society [10]. In other words, the TLBMC tool is a modern tool in agri-food industries that fosters the SMEs to capture value from sustainable business models whilst producing in a more economically and responsibly

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[6] Li, C. and Shen, B., 2019. Accelerating renewable energy electrification and rural economic development with an innovative business model: A case study in China. Energy Policy, 127, pp.280-286.

[7] Goyal, S., Esposito, M. and Kapoor, A., 2018. Circular economy business models in developing economies: lessons from India on reduce, recycle, and reuse paradigms. Thunderbird International Business Review, 60(5), pp.729-740.

[8] Nosratabadi, S., Mosavi, A., Shamshirband, S., Zavadskas, E.K., Rakotonirainy, A. and Chau, K.W., 2019. Sustainable business models: A review. Sustainability, 11(6), p.1663.

[9] Basile, V., 2021. The triple layered business model canvas in smart agriculture: the case of Evja startup. *Piccola Impresa/Small Business*, (2).

[10] García-Muiña, F.E., Medina-Salgado, M.S., Ferrari, A.M. and Cucchi, M., 2020. Sustainability transition in industry 4.0 and smart manufacturing with the triple-layered business model canvas. Sustainability, 12(6), p.2364.

way. In a holistic vision, the TLBMC tools involve the customers, suppliers, employees, and communities, as well as shareholders, for the products.

Upon desktop review of the Bio4Africa Tasks 1-5, AFAAS reviewed and analyzed publicly available secondary literature and data resources on bioeconomy to inform the co-designing of the value propositions and co-creation of sustainable business models. The foremost secondary literature resources were past bioeconomy projects[11], as well as peer-reviewed journal papers[12]. AFAAS leveraged the secondary data from Bio4Africa Task 5.2 to design the 'Concept Note', which informed the co-designing of value propositions and business models for the bio-based products.

2.2 Co-designing value propositions for the bio-based products

2.2.1 The rationale for the co-design value proposition workshops

Task 5.2: Inclusive and sustainable bio-based business models for rural Africa were informed by the value proposition workshops with the institutions and stakeholders for the bio-based products in host countries. The value proposition workshops were based on the premise that the novel bio-based products developed under the BIO4AFRICA project have achieved the 'Proof of Concept', and the products have matured to a 'Minimum Viable Product (MVP)' level with working prototypes. They are ready to be tested out in the field, including efficacy trials and market studies, to inform strategies for commercialization stages, starting with the early adoption, market entry and penetration. To support these commercialization stages, the early and lean validation of the value proposition for each novel bio-based product is a prerequisite for developing sustainable business models as the frontline tool for the commercialization of the product. Therefore, the multi-stakeholder workshop was organized to design a contextually relevant, unique, effective and market-centred value proposition for each of the piloted bio-based products in Ghana, Cote d'Ivoire, and Senegal.

The value proposition workshops looked into stakeholders and actors at the different nodes of the value chains for the bio-based products ranging from input-output suppliers, traders, customers and farmers (Annex 3); who were invited to discuss the bottlenecks, barriers to market entry and critical success factors for scaling commercial production and trade of the new bio-based products. The stakeholders were from the local public and private entities, including; i) District local government (DLG), ii) Agricultural extension and advisory agencies, iii) Officials from agriculture and other line ministries, administration and legislative bodies; iv) Civil Society Organisations (CSOs), v) the Non-Governmental Organizations (NGOs), vi) local traders and consumers associations, vii) Academic institutions (Universities and colleges); viii) National Research Agricultural Research Organisation (NARO), ix) Farmer institutions (groups and associations), etc. Photos for the value proposition workshops for the four focus countries are presented in Annexes 3- 6.

2.2.2 The approach for co-designing value propositions

AFAAS was responsible for developing technical materials to guide the value proposition workshops. Thus, AFAAS prepared a detailed workshop Concept Note (Appendix 1) to equip the project partners with the

[11] Angouria-Tsorochidou, E., Teigiserova, D.A. and Thomsen, M., 2021. Limits to circular bioeconomy in the transition towards decentralized biowaste management systems. *Resources, Conservation and Recycling*, *164*, p.105207.

[12] Giurca, A., 2020. Unpacking the network discourse: Actors and storylines in Germany's wood-based bioeconomy. Forest Policy and Economics, 110, p.101754.

technical information and skills needed for organizing the workshops for co-designing the value propositions, accompanied by project pitch presentations customized for the bio-based products for each country (Appendix 2), as well as, the Workshop Reporting Template (Appendix 2). AFAAS also trained the BIO4AFRICA project partners on modalities of conducting successful value proposition co-designing workshops. The number of stakeholders invited and participated in co-designing the value propositions in each workshop organized for the Bio-based products in Uganda, Ghana, Cote D'Ivoire and Senegal are illustrated in Tables 5 and 6. Table 5 presents a list of the Bio4Africa institutions that led the value proposition design workshops on varied dates and the number of stakeholders who participated in the value proposition design workshops for each Bio4Africa focus country.

Table 5: List of Institutions, dates and stakeholders for value proposition design workshops

Country	Bio4Africa representatives	Date	Participants
Cote D' Ivoire	INP-HB	August 9th, 2022	15
Ghana	iHub & SAVANET	August 30th, 2022	17
Senegal	UASZ	August 12th, 2022	20
Uganda	AFAAS & KRC	September 29th, 2022	11

AFAAS deployed a user-centred and bottom-up approach[13]; as the participatory, gender-responsive, all-inclusive tool to inform the co-designing process for the value proposition for each bio-based product. A one-day workshop was conducted in each country to engage stakeholders in co-designing value propositions for the bio-based products through a structured design thinking process followed by group brainstorming sessions (Figure 4). A value proposition model canvas (Annex 1) was used to develop the value proposition for the bio-based products during the workshop sessions. Figure 16 presents a schematic illustration of the value proposition canvas tool and the co-designing process used.

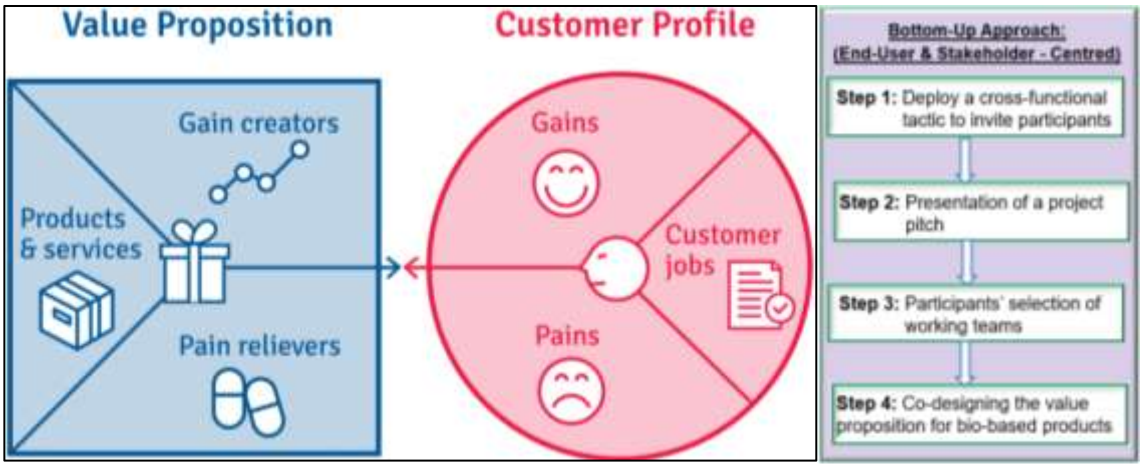

Figure 16: The value proposition canvas tool and the co-designing process used

[13] Brem, A., & Wolfram, P. (2014). Research and development from the bottom up-introduction of terminologies for new product development in emerging markets. Journal of Innovation and Entrepreneurship, 3(1), 1-22.

During the co-designing process (Figure 16), the participants developed the value proposition profiles for each of the bio-based products specifying gain creators, product features and pain relievers and the customer profiles describing the customer jobs, gains and pains (Annexe 1). Annexe 1 presents a new template for the standard value proposition model canvas, a modern tool that was employed the in co-designing the value propositions for the bio-based products during the workshop. This tool gives a detailed description of the key components of the value proposition and customer profiles.

2.3 Developing sustainable business models

2.3.1 The rationale for co-designing sustainable business models

Task 5.2 "Co-design inclusive and sustainable business models'' with the farmers and rural communities of the Bio4Africa pilot cases in Uganda, Ghana, Cote D' Ivoire and Senegal. The goal of co-designing a sustainable business model was to assess investment requirements and uncover insights regarding product-specific value propositions and customer profiles. The business models are tools for scaling commercial production and marketing novel bio-based products. In light of the above, the scope of Task 5.2 was to co-design value propositions and sustainable business models that are contextually relevant (inclusive, unique, effective and market-centred) and could be deployed to commercialize the products.

A business model canvas is a visual representation of a business model, highlighting all key strategic input-output factors. In the context of the Bio4Africa (Task 5.2), sustainable business models give a general, holistic and complete overview of the target customers, markets, market needs, and the role that the novel bio-based products play in meeting economic, environmental and social needs of the project target communities. The business models are tools to secure seed and equity financing whilst stimulating agro-industrialization and driving a green economy in the four project-focus countries.

The outcome of the value proposition workshop was comprehensive data for the novel Bio4Africa bio-based product that is being piloted in the four host countries (thus, Uganda, Ghana, Cote d'Ivoire and Senegal). The value proposition data included customer segments, product-specific gaps and opportunities for new ideas and bioeconomy solutions.

2.3.2 The approach for co-designing sustainable business models

AFAAS shall utilize the Triple-Layered Business Model Canvas (Annexe 2) in co-designing and developing sustainable business models that encompass 2-foremost operational steps: 1) value proposition designing and 2) business model designing. In addition, AFAAS leveraged the findings from Task 5.1 (thus, gender-sensitive market and value chain analyses) encompassing the three market analysis themes, namely: i) market structure analysis (suppliers, buyers, product substitutes, barriers to entry and competitive rivalry); ii) market penetration and socio-economic relationships, and iii) competitor product market performance analysis to co-design and develop the sustainable business models.

The sustainable business models were co-designed and developed using the new Triple Layered Business Model Canvas (TLBMC)[14]: as the modern tool for analyzing the economic, environmental and social aspects of the bio-based products based on the customer and stakeholder perspectives. By utilizing the Triple Layered Business Model Canvas tool, the new value proposition data from the co-designing workshop informed the designing of sustainable business models (thus, D5.2/T5.2) for the bio-based products being piloted under the Bio4Africa project. The TLBMC for each bio-based product was co-designed/ developed by analyzing data produced by the stakeholders during the value proposition design workshop. The data identifies clientele, markets and revenue streams, as well as the environmental and social benefits of the products, thereby setting a premise for successful co-designing, development and deployment of the TLBMs for facilitating the commercial production and marketing of the Bio4Africa bio-based products.

The TLBMC has three layers, namely the economic, environmental and social layers. The economic analysis layer of the TLBMC focused on the analysis of nine major components, namely the customer segments, customer relationships, channels to the customers and end-users, revenue streams, key activities, resources, partners, cost structure and value proposition (Annex 2). Similarly, nine (9) major components were also analyzed in the social layer of the new TLBMC, including the social value, employees, governance structures, communities, the scale of outreach, end-users, social impacts and social benefits. The nine key elements of the environmental layer of the TLMBC that were analyzed for each of the bio-based products; are functional value, materials, production, supplies and out-sourcing, distribution, use phase, end-of-life, environmental impacts, and environmental benefits (Annex 2).

[14] Joyce, A. and Paquin, R.L., 2016. The triple layered business model canvas: A tool to design more sustainable business models. Journal of cleaner production, 135, pp.1474-1486.

3. Results and discussion

3.1 Value propositions for the bio-based products

3.1.1 The value proposition for biochar as a soil amendment product

Figure 17 presents the value proposition for biochar as a soil amendment product.

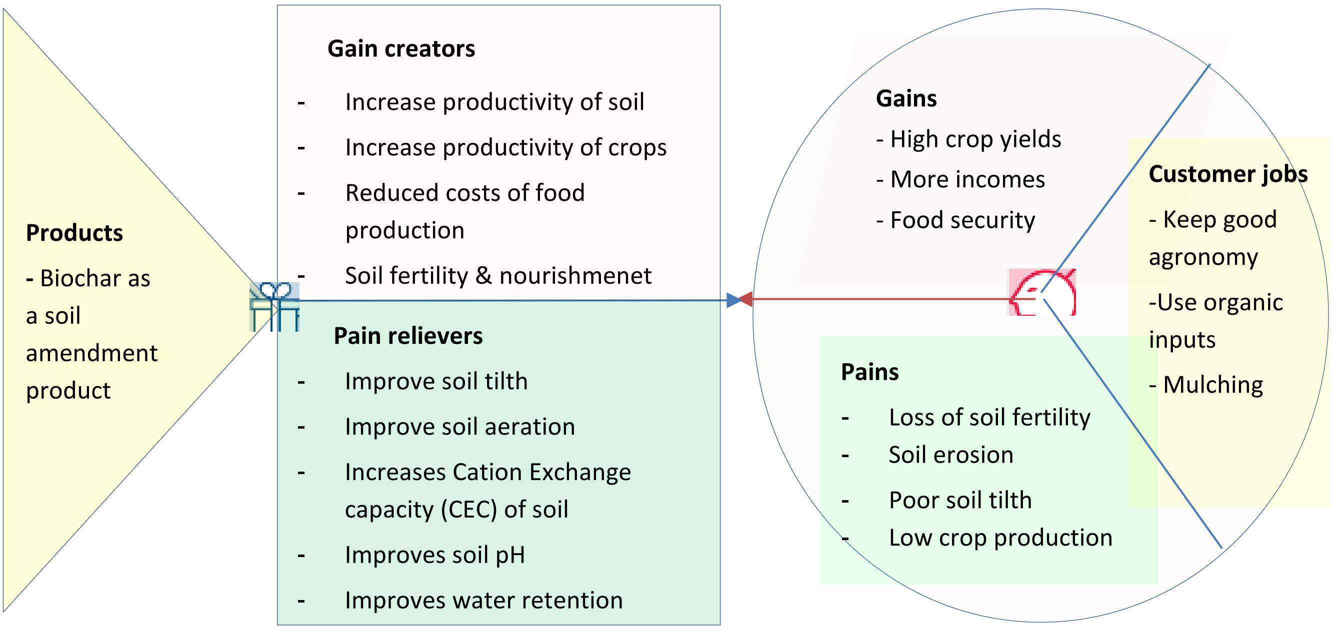

Figure 17: The value proposition canvas for biochar as a soil amendment product

3.1.2 The value proposition for biochar as a solid biofuel product

Figure 18 presents the value proposition for biochar as a solid biofuel product.

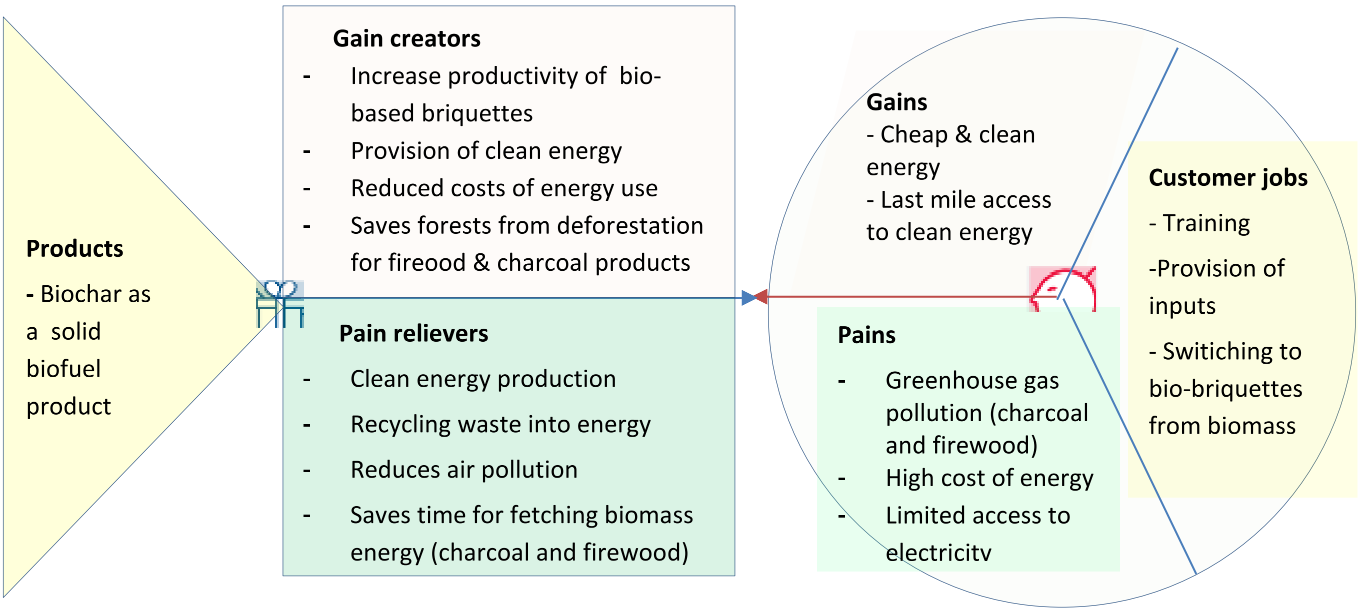

Figure 18: The value proposition canvas for biochar as a solid biofuel product developed

3.1.3 The value proposition for the biomass pellets as bio-feeds for livestock

Figure 19 presents the value proposition for the pyrolysis process employed in recycling agricultural waste into biomass pellets as bio-feeds for livestock.

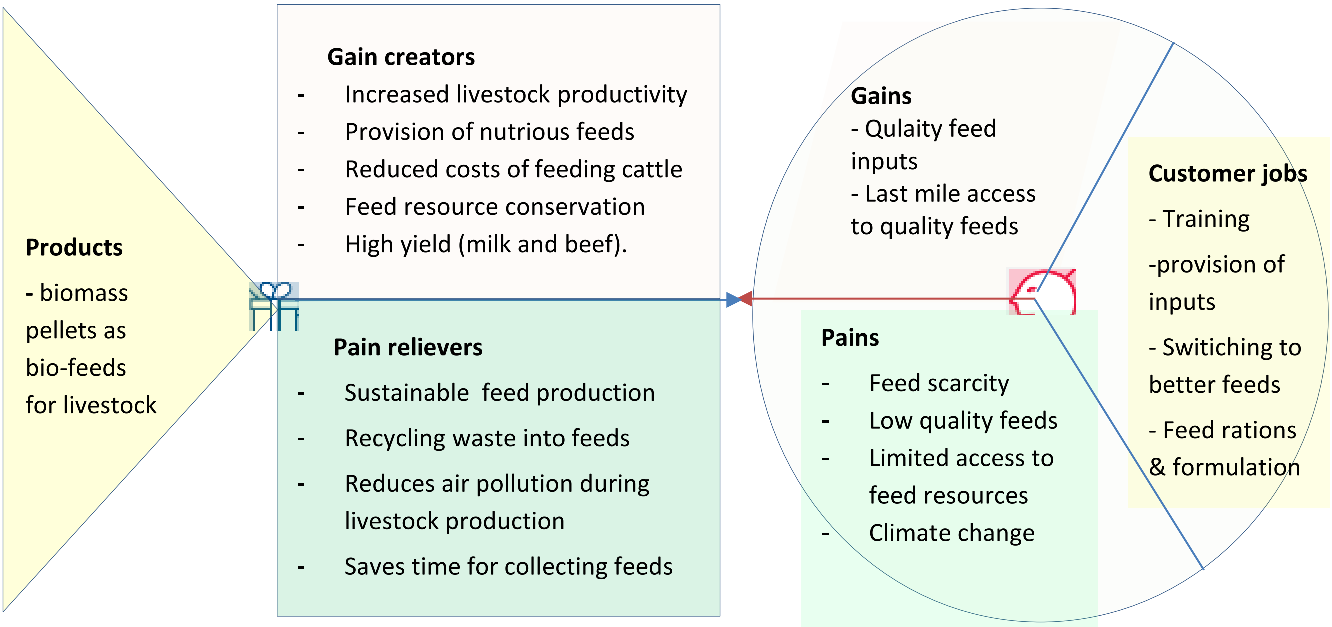

Figure 19: The value proposition canvas for recycling agro-waste into biomass pellets as bio-feeds

3.1.4 The value proposition for biochar as an additive in biogas production

Figure 20 presents the value proposition for biochar as an additive in biogas production.

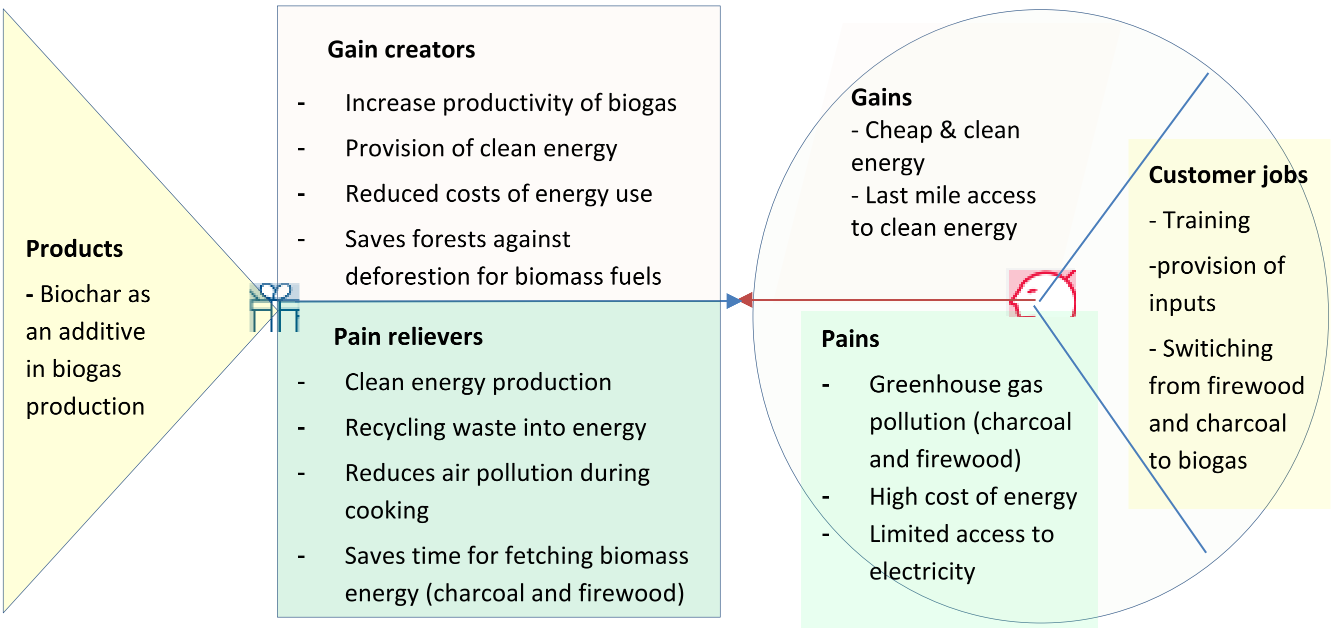

Figure 20: The value proposition canvas for biochar as an additive in biogas production.

3.1.5 The value proposition for the biochar powder as a medium for water filtration

Figure 21 presents the value proposition for the biochar powder as a medium for water filtration.

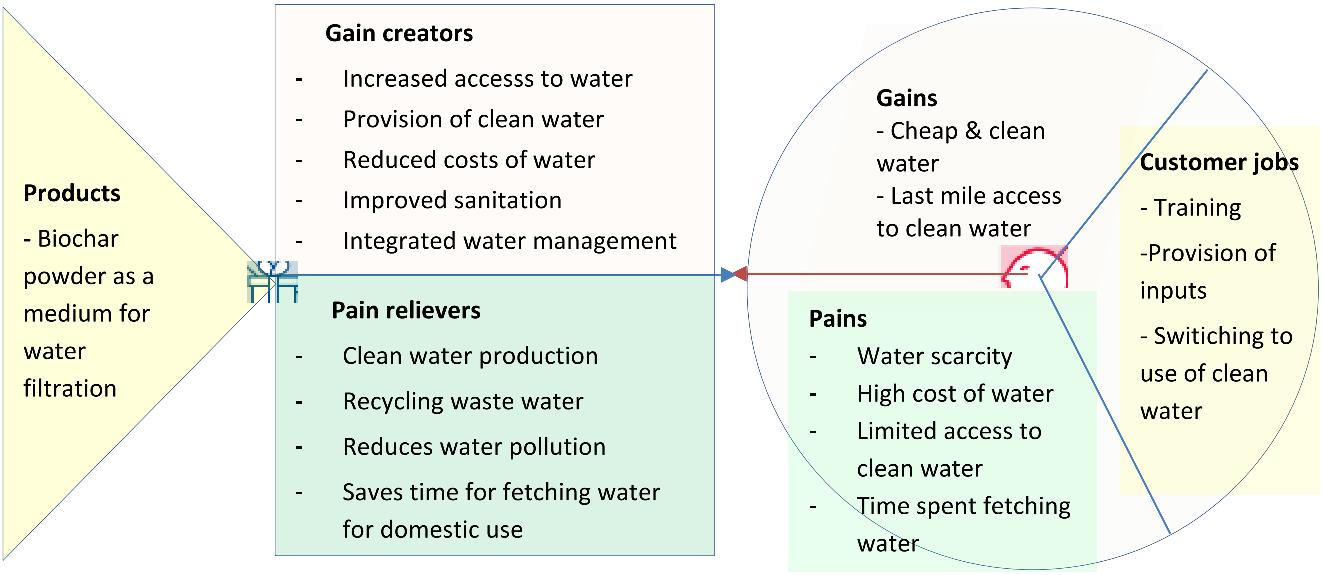

Figure 21: The value proposition canvas for the biochar powder as a medium for water filtration.

3.1.6 The value proposition for the press cakes as ruminant feeds (e.g., cattle)

Figure 21 presents the value proposition for the press cakes as ruminant feeds (e.g., cattle).

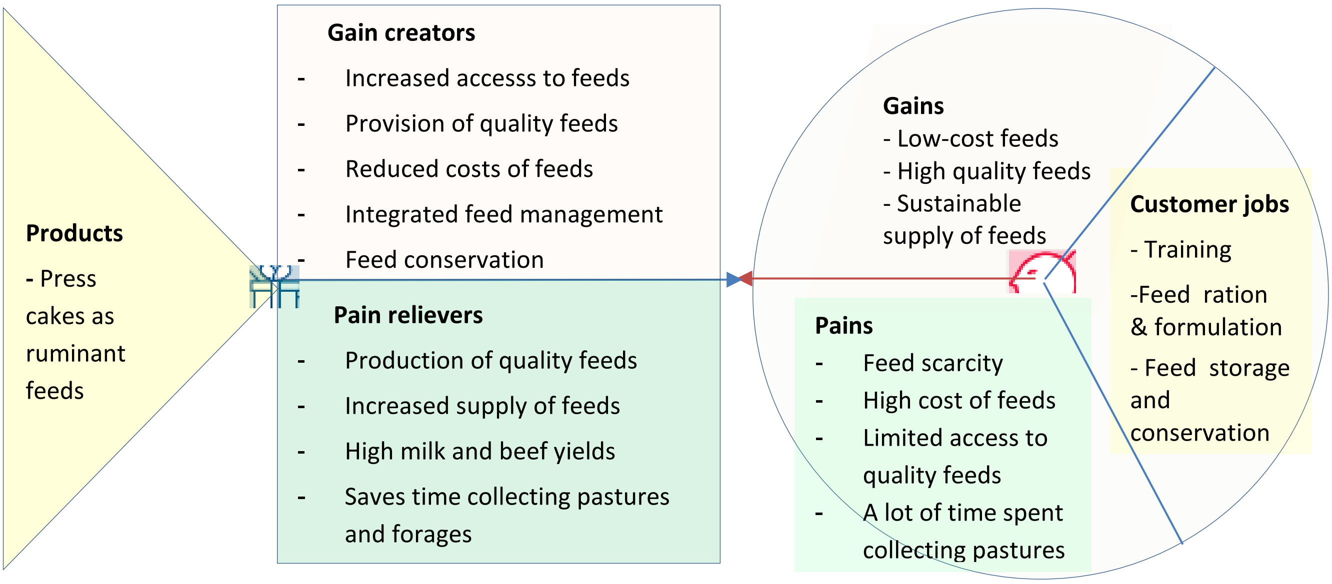

Figure 22: The value proposition canvas for the press cakes as ruminant feeds.

3.1.7 The value proposition for the protein concentrate as feed supplements for livestock, poultry and fisheries

Figure 21 presents the value proposition for the protein concentrate as feed supplements for livestock, poultry and fisheries.

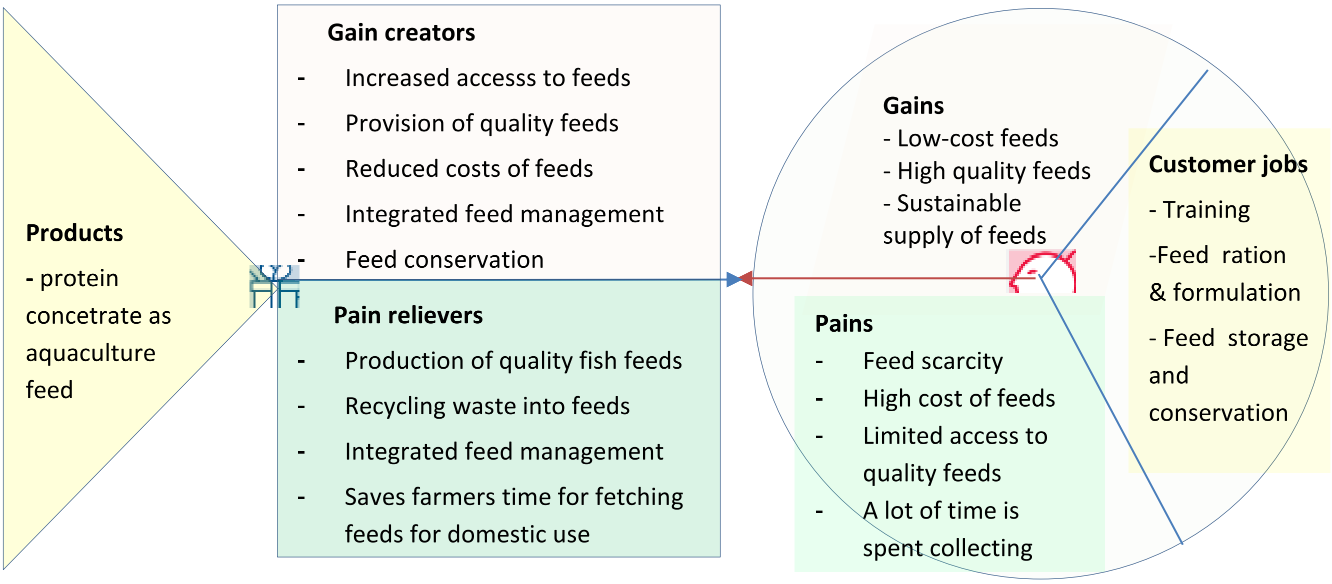

Figure 23: The value proposition canvas for the protein concentrate as feed supplements for livestock, poultry and fisheries.

3.1.8 The value proposition for the whey as monogastric feeds

Figure 24 presents the value proposition for whey as monogastric feeds (e.g., pigs).

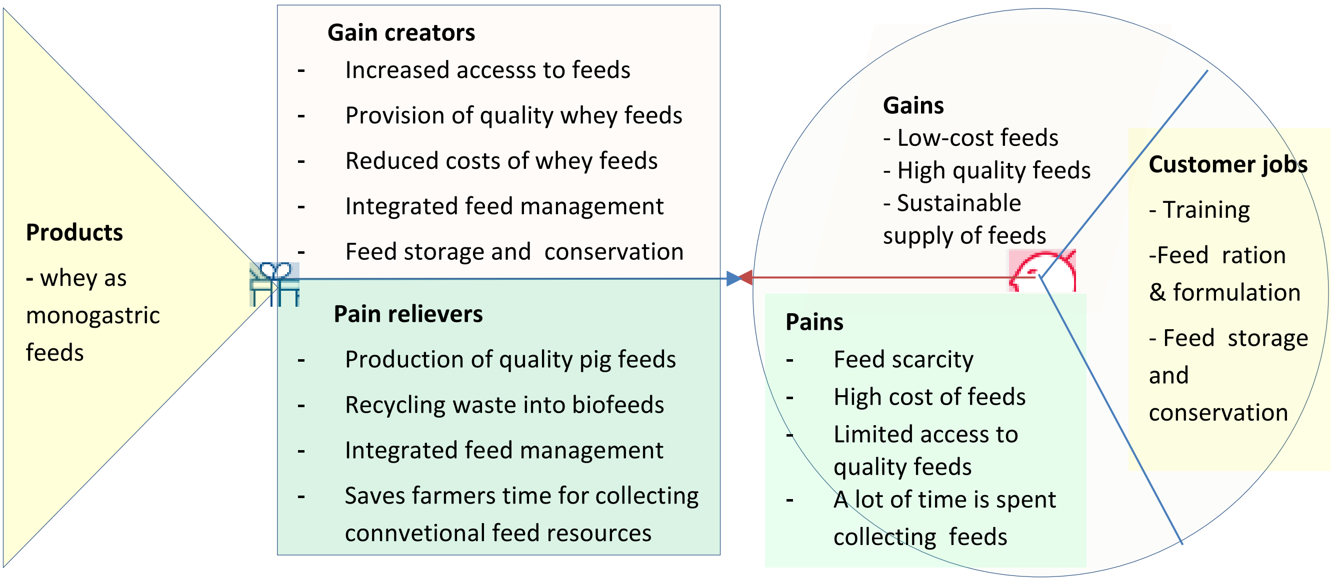

Figure 24: The value proposition canvas for the whey as monogastric feeds.

3.1.9 The value proposition for the Fish Feed Pellets

Figure 25 presents the value proposition for the Fish Feed Pellets.

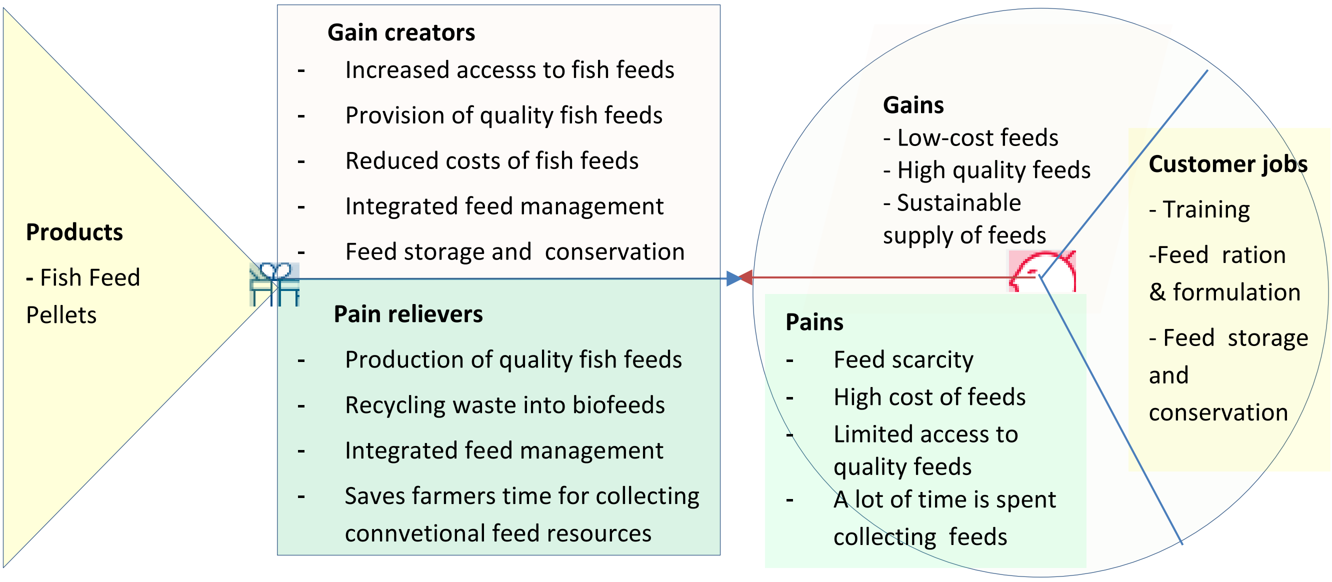

Figure 25: The value proposition canvas for the fish feeds.

3.1.10 The value proposition for the bioplastic and composites

Figure 26 presents the value proposition for the bioplastic and composites.

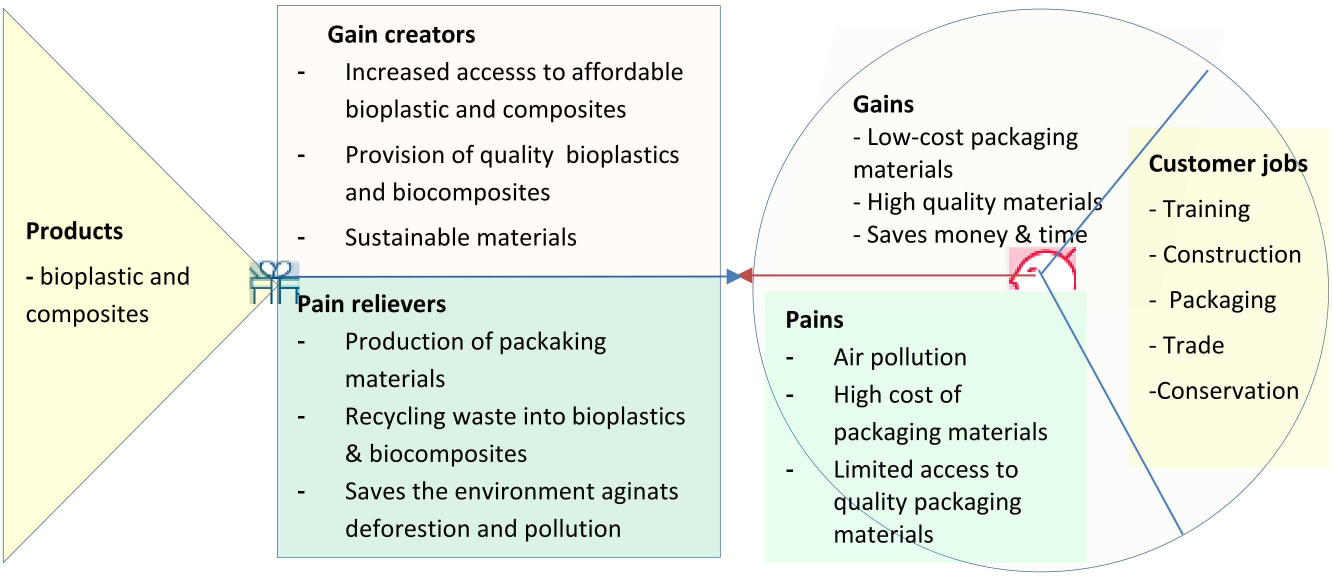

Figure 26: The value proposition canvas for the bioplastic and composites

3.2 The Sustainable Business Models for the bio-based products

3.2.1 The Triple Layered Business Model for biochar as a soil amendment product

The biochar market is divided into three major types, namely, large-scale users, medium-scale users, and small-scale clients and users. In the context of African rural farming communities, the small-scale users could domestically produce biochar (e.g., on-farm) to boost soil fertility and the food production systems whilst replacing environmentally-polluting inorganic fertilizers at the same time. The outcome of the analysis of the sustainable business for biochar production is shown in Tables 6-9, using the typical skeleton of the TLBMC presented in Annexe 2.

i) Economic layer of the TLBMC for the biochar as a soil amendment product

The economic aspects of the Triple Layered Business Model Canvas (TLBMC) biochar as a soil amendment product under the BIO4AFRICA project focus countries are illustrated in Table 6.

Key partners

The key partners are bioreactor technology developers and promoters (e.g., bioreactor/pyrolysis manufacturers, suppliers of spare parts for operation and maintenance of pyrolysis equipment), government agencies (e.g., agricultural/ environmental ministries), financial institutions or service providers, including the commercial banks, angel investors, venture capitalists; as they provide crucial relationships for production units and infrastructure. District local governments (DLGs); also provide equity financing and environmental subsidies. Public research institutions like the National Agricultural Research Organizations (NAROs) and academic institutions (e.g., universities, technical institutes and colleges) provide competent human resources or manpower to manage the operations of the biochar production facilities. The universities and NAROs also provide technical backstopping on the use of biochar through conducting agronomy trials and capacity training-building programs during extension and community outreach. District Local Governments (DLGs), policymakers and community leaders often set renewable energy targets both at the national and community level and also influence access to investment support training opportunities in biochar production, adoption and marketing among farmer institutions and target communities.

Key activities

The main activities are production process and product optimization; biochar producers are a collection of quality biomass as the raw input feedstock, processing (thus, drying and grinding) of feedstocks, eco-friendly processing and production of the biochar, maintenance of the pyrolysis reactors and marketing of biochar products via branding, packaging, distribution and trade activities. Organization of the logistics of deliveries to customers and end-users. Research and development activities to inform value addition of the raw biomass, product storage and quality control of biochar products for domestic or export markets. Customer relationships such as customer acquisition and trust creation, customer penetration, market penetration, and brand royalty, among others (Table 6).

Key resources

Several key resources are needed for biochar producers in order to create value. There are four key resource categories, namely majorly physical resources, human resources, financial resources and intellectual resources. The key physical resources are; i) raw materials and other input feedstock such as biomass (e.g., crop residues, animal waste, wood wastes, sawdust, straw, dry grass, hay, forage, reed, wood chips, pales); ii) pyrolysis equipment and technology for biomass production and storage facilities (e.g., biomass warehouses and yards); iii) land and infrastructure to support biochar production, iv) marketing and product distribution outlets and networks. The key human resources include competent and highly-skilled staff, a semi-skilled labour force, and joint ventures). The key financial resources include capital assets, seed funding, grants, equity financing, angel investments, venture capital, and private/own investments. The intellectual resources are intangible assets that encompass technical know-how, patents, user rights for production, and marketing of biochar (Table 6).

Value proposition

The main value proposition is the replacement of conventional inorganic fertilizers that accelerate greenhouse gas pollution and ecological deterioration with environmentally friendly biochar products, such as novel organic bio-fertilizers and soil amendment products. The raw materials in the form of biomass (e.g., crop residues and animal manure) are completely natural, renewable and sustainable. By recycling the waste and biomass residues coming from both the agricultural and forestry sectors, which would otherwise amplify greenhouse gas pollution, the socio-economic and environmental value is created since disposal costs are saved, and high-quality (nutrition and efficacy) bio-fertilizers are produced. Introducing commercial production of biochar shall definitely strengthen bioeconomy, and reduces the dependence on fossil fuel-based or inorganic fertilizers at the same time. Thus, the main focus shall lie not only on wealth creation but also on the socio-economic impact on developing societies, such as income and the creation of green jobs. There is the effect on the environment through the increased decarbonization and carbons sequestration, where the biochar enhances the soil moisture, fertility and microbiota while enhancing the soil sink capacity for greenhouse gas pollution.

Customer relationships

Maintaining a good customer relationship is important for attracting more clients, creating strong brand loyalty, market penetration and increasing the market share for the novel biochar products. In this regard, biochar entrepreneurs shall establish/ keep close customer relationships by offering competitive production and marketing services, including maintaining friendly pre-booking systems, aftersales services, attractive pricing and direct sales based on the product quality and effective demand from the different customer clusters, e-commerce (thus, direct sales through the internet), and distributorship outlets, advance purchase and supply contracts with all dedicated off-takers, deferred payment systems[15]. The entrepreneurs shall also build robust product traceability and quality assurance systems to prevent the duplication and counterfeits of the biochar products once put on the market. The main focus of these initiatives is to create sustainable relationships with the clients and customer base and ultimately build trust and brand loyalty for the new biochar products offered.

Customer segments

[15] Babich, V. and Tang, C.S., 2012. Managing opportunistic supplier product adulteration: Deferred payments, inspection, and combined mechanisms. Manufacturing & Service Operations Management, 14(2), pp.301-314.

The main customer segment for biochar soil amendment products is farmers, using biochar for Climate-smart agriculture. The other customer segments are agro-input dealers, Non-governmental Organizations (NGOs), and Community-based Organizations (CBOs) engaged in trade and promotion of eco-friendly, sustainable and climate-smart agricultural technologies and innovations. Other customer clusters are academic institutions (e.g., universities, schools and colleges) and public research institutions (e.g., National Agricultural Research Organizations – NAROs); that use novel biochar products for research studies, extension and technology promotion purposes.

Customer channels

The entrepreneurs shall exploit existing channels to reach the customers and also raise awareness about the manufactured biochar products and related services. The producers will use personal contacts, farmer institutions and district local government (DLG) departments, which promote eco-friendly food production and the use of new bio-based agro-inputs. In addition, mass media channels such as radios and TVs and electronic and social media will be used to advertise the product and also increase awareness across the local and international communities. The entrepreneurs will also advertise the biochar products using newspapers, magazines and home-delivered flyers. Existing agricultural trade shows and exhibitions coupled with the farmer institutions, community leaders and village meetings will also be used as grass root channels for marketing the biochar and reaching out to potential customers even in remote locations or rural communities (Table 6).

Costs

The costs that arise in the biochar business model shall be monitored appropriately by the producers. These major costs will come from the key activities, resources, and building and maintaining key partnerships that are highly required to engage in the commercial production and marketing of biochar. The producers start with the cost related to the initial investment in the infrastructure for the biochar production unit and continue with cost of production, including cost of raw materials (biomass), labour costs, operational expenses, and marketing costs. In addition, the maintenance costs are incurred to run the commercial biochar production business more efficiently. Nonetheless, the purchase of biomass feedstock requires constant investment, which could also be significantly reduced through economies of scale when larger quantities of the feedstock per purchase are bought from dedicated suppliers. Other costs are equipment and technology costs (e.g., pyrolysis reactor) and maintenance costs (Table 6).

Revenue streams

Revenue streams from the commercial production of biochar shall be generated by selling the produced bio-based fertilizers in the form of biochar soil amendment products directly to the farmers and other customer segments. Additional revenue will be generated from the expertise and intellectual property accrued by running pilot pyrolysis reactor facilities from which the operators and host entities shall benefit. These extra revenue benefits may appear by presenting the best-practice business models to venture capitalists and angel investors, as well as providing technical knowledge about novel biochar technology/facilities to 3rd parties for financial compensation. Lastly, the revenue shall be obtained from the sales of marketing services such as logistics, distribution network, product supply and delivery contracts to the dedicated off-takers (Table 6). Table 6 presents the economic layer of the TLBMC for the biochar as a soil amendment product.

Table 6: Economic layer of the TLBMC for the biochar as a soil amendment product

Partners	Activities	Value Proposition	Customer Relationship	Customer Segments
Local biomass suppliers (e.g., farmers); Pyrolysis technology developers & promoters; Government agencies; financial institutions; District local government; Public research institutions (e.g., NAROs), academic institutions (e.g., colleges & universities); Policymakers; Community leaders Technology suppliers and developers	Collection of raw material; Production process; Eco-friendly processing; Product optimization; Eco-friendly processing; Marketing to attract and retain customers; Research & development activities; Customer relationships	Eco-friendly bio-fertilizers (biochar products) High-quality biofertilizers that are nutritious and efficient Recycling wastes from agriculture & forestry Increased incomes & creation of green jobs Decarbonization and carbon sequestration for a more resilient bio-economy Enhanced soil tilth and biota	Pre-booking systems, after-sales services, Attractive pricing and direct sales, e-commerce and/ or trade, Advance purchase and supply contracts, Product traceability and quality assurance systems	Farmers (subsistence and commercial farmers) Agro-input dealers or traders NGOs CBOs Academic institutions (e.g., universities, schools and colleges), Public research institutions
	Resources		**Channels**	
	Physical resources (e.g., land, infrastructure, raw materials and technology) Financial resources (e.g., own capital, seed funding, equity financing, venture capital, grants, angel investments) Local labour force (e.g., joint venture, partnerships, staff, semi-skilled labour) Intellectual resources (e.g., patents, user rights)		Personal contacts; Farmer institutions; District local government (DLG); Mass media channels (e.g., TVs & Radio); Social media; Agricultural trade shows/exhibitions Farmer institutions; community leaders; village meetings	

Costs	Revenues
- The initial investment in the infrastructure; - Cost of raw materials (biomass), - Labour costs, - Operational expenses - Marketing costs - Costs for equipment and technology (e.g., pyrolysis reactor) and maintenance costs.	- Sale of biochar to farmers and other customers - Intellectual property rights - Seed funding from venture capitalists and angel investors - Sales of marketing services like the logistics, distribution network and supply)

ii) Environmental layer of the TLBMC for the biochar as a soil amendment product

The environmental aspects of the TLBMC for the biochar as a soil amendment product under the Bio4Africa project focus countries are illustrated in Table 8 below.

Supplies and outsourcing

The supplies and outsourcing depict several cross-cutting materials and productive activities that are important for the operational value but are not considered 'essential' to the firm organization[16]. Thus, within the environmental layer, examples of supplies are water, electricity, raw materials and pyrolysis reactors. The raw materials (e.g., biomass feedstock), water, and electricity are locally produced. Therefore, these supplies are outsourced from all dedicated local suppliers ranging from farmers for the biomass feedstock and private institutions and government agencies for the water and electricity supplies. However, there is no in-country production of modern equipment, mainly pyrolysis reactors. These pyrolysis reactors used for biochar production are imported from technology manufacturers in Europe. As such, biochar producers have no or little influence in the production and supply of pyrolysis reactor machines. In future, the producers are willing to take more control over the production of modern machinery and maintenance actions by, for example, creating machinery production units and utility services (Table 8).

Production

The production component extends the foremost components of the key activities from the economic layer to the environmental layer of the TLBMC and captures the core activities or arrangements in place that the organization should undertake to create value. Production for the biochar producers involves transforming biomass (as the primary raw or unfinished materials) into higher value outputs; in this case, the biochar products are to be used as a biofertilizer or a soil amendment product. The core products for the service providers; managing an ICT infrastructure, logistics, warehousing, administration, marketing and trade.

Functional value

The functional value describes the main points of focus of the products and services output delivered by the business. In this regard, the functional value encompasses the five key properties of biochar as a biofertilizer and soil amendment product; namely, i) recycling the agricultural waste and biomass into high-quality organic matter, ii) modification of soil pH and biophysical characteristics, iii) supply of plant available nutrients, iv) enhancing soil sink capacity for greenhouse gases (e.g., storage of carbon), v) soil nutrition and fertility enhancement, vi) erosion control through improved soil tilth (Table 8).

Materials

The materials component biophysical stocks are used by the producers or companies to achieve the functional value of the product and services offered. In other words, the raw materials component is the environmental extension of the key resources for the business. In the case of biochar production, the

[16] Stephan, A., Crawford, R. H. 2014. A multi-scale life-cycle energy and greenhouse gas emissions analysis model for residential buildings. Architectural Science Review, 57(1), 39-48

producers or firms purchase and transform biomass feedstock as the primary input physical materials, as well as the other physical materials like land, building infrastructure, pyrolysis reactors and machinery, office buildings, furniture, vehicles, ICT materials (e.g., the computers). Whereas introducing all materials into the TLBMC is not practical, it is worth noting that only the core materials facilitating the production of biochar are listed and their environmental impact. For the biochar business, the above-mentioned materials are estimated to offset nearly 15% of the environmental carbon footprint from the life cycle systems assessment [17].

Distribution

In the context of the modern TLBMC, distribution involves the transportation of goods or commodities to support primary production. In the case of biochar producers or firms, the distribution represents the physical means by which the farmers and other customers access the products for use or enjoy their functional value. Distribution is the combination of the modes of transport; the distances travelled and weights of products shipped, as well as the logistics involved in product packaging and delivery. The modes of transport are; road by train or trucks, and air and water shipment to in-country and in-region markets and off-takers (Table 8).

Use phase

The use phase focuses on the environmental impact of the product or service on the customers or end-users in relation to its functional value. The use phase includes the maintenance of biochar product quality based on the type of farm resource and product requirements of the farmers and other clients through their own use. The novel biochar products are organic bioproducts that are envisaged to be low-cost and highly efficient fertilizers suitable for organic horticulture, agroforestry, green dairying and other primary climate-smart farming enterprises. The application of biochar as a soil amendment product is envisaged to enhance the soil sink capacity for greenhouse gases, thereby increasing the carbon sequestration from ecosystems (Table 7).

End of life

End-of-life is when the client opts to end the use of the products or consumption of their functional value. The end-of-life phase often entails matters pertaining to the reuse of materials or secondary by-products, such as the re-manufacturing, re-purposing and the options for res-use/ waste recycling, disassembly, incineration and disposal of by-products or supplementary packaging materials. From an environmental perspective, the end-of-life component supports the biochar producers in exploring eco-friendly ways of managing adverse impacts of the products on the ecosystems and its services, such as nitrifications and greenhouse gas pollution upon misuse by the target farmers and other end-users. The detrimental impacts to the ecosystems are averted and/ or minimized through waste recycling strategies that also extend the responsibility of using bio-based products and their by-products beyond the initially conceived value propositions. In this regard, biochar products present an unexploited potential for the development of

[17] Alexandre J., Raymond L. P., 2016. The triple layered business model canvas: A tool to design more sustainable business models. Journal of Cleaner Production 135 (2016) 1474e1486.

circular bioeconomies beyond soil amendment and carbon sequestration in farming systems, such as the use of the biochar products for water treatment and clean energy production[18].

Environmental impact

The environmental impact component addresses the environmental costs of the producers based on the product life cycle, as estimated by the Life Cycle Assessment (LCA) tool[19]. Besides all financial costs, the Environmental Impact Assessment (EIA) of the production facility further extends to the ecological costs and biophysical indicators[20]. For biochar products, the environmental impact indicator metrics are greenhouse gas (GHG) fluxes (e.g., CO_2 emissions and carbon footprint), human health, ecosystem impacts on the soil tilth, microbiota and biochemical profiles, natural resource depletion, water use and quality, and energy consumption, water use and GHG emissions (Table 8).

Environmental benefits

There is a positive correlation relationship between environmental impacts, costs and benefits that extends the value creation of the products and services offered beyond their financial value accrued to the producers, entrepreneurs and/ or promoter firms. The environmental benefits encompass all the ecological value and/ or advantages the bio-based products or services create through the regenerative positive ecological value or conserving the integrity of the natural ecosystems and its key services. The environmental benefits of biochar as a novel biofertilizer and soil amendment product shall be estimated using the LCA approach.

The biochar products increase soil fertility by altering the soil tilth, moisture and physiochemical properties such as soil pH, structure, porosity, nutrient cycling and moisture retention. The beneficial changes in these soil properties and the presence of biochar itself definitely positively influence the abundance, diversity and activity of the soil biota. In addition to enhancing the soil sink capacity for greenhouse gases (thus, methane nitrous oxides), carbon sequestration reduces the leaching of nitrate and runoff (Table 7). As a result, the application of biochar will increase soil microbial biomass and soil water availability for plants[21] and ultimately boost crop yields with a knock-on effect on the income, food and nutritional security in the target population and farming communities across Africa. Table 7 presents a summary of the environment impacts and indicator parameters for the novel biochar products produced under the BIO4FARICA project.

Table 7: A brief description of the environmental impacts and indicator parameters for the biochar

Ecosystem services	Environment parameters	Biochar impact	Description of impact
Carbon storage	Soil carbon/ C sequestration	√√√√√√√√	Increase
Greenhouse gas fluxes	Carbon dioxide/ nitrous oxide	√√√√√√√√	High ecological footprint

[18] Boscolo, M., Lehtonen, P. and Pra, A. 2021. Developing bankable business plans – A learning guide for forest producers and their organizations. Forestry Working Paper No. 24. Rome, FAO. https://doi .org/10. 4060/cb4520en.

[19] De Benedetto, L., Klemes, J., 2009. The Environmental Performance Strategy Map: an integrated LCA approach to support the strategic decision-making process. J. Clean. Prod. Early-Stage Energy Technol. Sustain. Future 17 (10), 900e906.

[20] Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R., 2003. IMPACT 2002þ: a new life cycle impact assessment methodology. Int. J. Life Cycle Assess. 8 (6), 324e330.

[21] Gwenzi, W., Chaukura, N., Mukome, F.N., Machado, S. and Nyamasoka, B., 2015. Biochar production and applications in sub-Saharan Africa: Opportunities, constraints, risks and uncertainties. Journal of environmental management, 150, pp.250-261.

Soil biology	Microbial biomass	√√√√√√√√	Increases
Water erosion	Runoff & nutrient loss	√√√√√	Decreases
Nutrient leaching	Nitrates	√√√	Reduces
Available water	Available water	√√√√√√√	Increases
Soil fertility	Nutrient acidity	√√√√√	Improves nutrient use
Crop yields	Degraded/ low fertility loss	√√√	Increases productivity

Notice: the number of ticks indicates the extent of biochar impact

The benefits of biochar shall depend on the design of pyrolysis reactors, which includes parameters such as type of biomass feedstock, pyrolysis temperatures, application rates of the biochar, biochar properties, soil properties, agronomic practices, weather and other agroecological conditions. In this regard, the pyrolysis reactors and biochar production systems are designed to maximize the product quality and ultimately take full advantage of the environmental impacts and benefits of the biochar (Table 8). Thus, Table 8 presents a summary of the Environmental layer of Triple Layered Business Model Canvas (TLBMC) for the biochar as the bio-fertilizer and soil amendment product.

Table 8: The Environmental layer of the TLBMC for the biochar as a soil amendment product

<table>
<tr><th>Supplies & Out-sourcing</th><th>Production</th><th>Functional Value</th><th>End of Life</th><th>Use Phase</th></tr>
<tr><td rowspan="3">Importation of machinery and equipment (e.g., pyrolysis reactors)

Production of raw materials (e.g., crop biomass & feedstock)

Supply of utilities (e.g., water and electricity)</td><td>Transformation of raw materials into biochar
Provision of support services (e.g., ICT, logistics, marketing & trade, warehouse, and administration</td><td rowspan="3">Recycling of waste biomass into high-quality organic matter
Modification of soil pH and biophysical characteristics
Supply of plant-available nutrients
Increased soil sink capacity for greenhouse gases
soil nutrition and fertility enhanced
Erosion control via improved soil tilth.</td><td>Water treatment

Clean energy production</td><td rowspan="3">Maintenance of biochar product quality
Efficient fertilizers suitable for organic horticulture, agroforestry, green dairying and other primary climate-smart farming enterprises
Enhance soil sink capacity for greenhouse gases & increase carbon sequestration</td></tr>
<tr><td>Materials</td><td>Distribution</td></tr>
<tr><td>Physical materials: land, building infrastructure, pyrolysis reactors and machinery, office buildings, furniture, vehicles, and ICT materials (e.., computers).</td><td>Modes of transport (e.g., train or trucks, and air & water shipment)

Distances travelled

Weights of products</td></tr>
<tr><th colspan="2">Environmental Impacts</th><th colspan="3">Environmental Benefits</th></tr>
<tr><td colspan="2">Greenhouse gas (GHG) fluxes (e.g., CO_2 emissions and carbon footprint), human health, ecosystem impacts on the soil tilth, microbiota and biochemical profiles, natural resource depletion, water use and quality, energy consumption, and water use.</td><td colspan="3">Improves soil tilth and environmental footprint:

Carbon storage and carbon sequestration; Greenhouse gas (methane and nitrous) fluxes; Soil biology; Water erosion; Nutrient leaching; Available water; Soil fertility and Crop yields.</td></tr>
</table>

iii) Social layer of the TLBMC for the biochar as a soil amendment product

The social aspects of the Triple Layered Business Model Canvas (TLBMC) for the biochar as a soil amendment product under the bio4Africa project focus countries are illustrated in Table 9. The social layer of the TLBMC is informed by the data obtained through a stakeholder approach that captures the mutual benefits and influences between both the producers and stakeholders. Also, the social layer captures the key social impacts of the biochar products derived from the producer and the stakeholder relationships. Employing the bottom-up approach in building the social layer provides a better understanding of the primary social impacts and insight for exploring ways to innovate along the production and marketing cycles of biochar to create social value and improve its potential. By leveraging the stakeholder approach, the nine components of the social layer of the TLBMC are discussed below.

Communities

Whereas the economic relationships are built between the producer and their business partners, the social relationships are built between the producers, suppliers and the local host communities. In the context of the TLBMC, the stakeholders from producers, suppliers, and traders (e.g., farmers and other off-takers), constitute a community that influences production and maintains mutually beneficial relationships. Local agribusinesses such as agro-input dealers, commercial farmers and traders will work with the district local governments (DLGs), and farmer institutions shall lead training and media campaigns towards stimulation of interest for scaling commercial production and adoption of biochar products (Table 9).

Employees

The employee component considers the role of staff and workforce in the production cycle and at the core organizational stakeholder. A number of employee factors considered are the number, skills and qualifications of the employees, as well as their salient social demographics such as variations in sex, payments, salaries, gender, ethnicity, and education levels within the producer organizations. In addition, the employee component also encompasses employee-oriented programs, primarily tailored capacity-building training, professional development and other support programs that also contribute to the viability and success of the producer organizations and firms (Table 9).

Social value

The social value speaks to the mission of producers that focuses on creating important benefits for the stakeholders and society in a broader context. For sustainability-oriented biochar production, creating social value is likely a clear part of its mission. The intended social value is interpreted in the context of the product "roadmap for sustainable growth"[22], as one of the core competencies is developing long-term value from the mutually beneficial relationships between the producers and stakeholders. The social values for biochar production are i) enhance the quality of consumers' lives by offering eco-friendly, safer, and healthier food production systems, ii) develop long-term value from mutually beneficial with the farmers and stakeholders, and iii) ecosystems restoration (Table 9).

Social culture

The societal culture component recognizes the potential impact of the producers on society and host communities as a whole. In other words, the commercial production of biochar and related business cannot

[22] Nespresso, 2015. Our Values at Nespresso. Careers at Nespresso, available at: http://www.careersatnespresso.com/working-at-nespresso/our-values/

succeed when the host society fails. Therefore, the social culture component leverages the concept of 'sustainable value'[23], to acknowledge the potential impact of the biobased products on host communities and the bioeconomy, and how though bioeconomy positively influences society. Non-governmental organizations (NGOs) and Community-Based Organizations (CBOs) form part of the societal culture space as they carry social agendas through advocacy and influencing societal culture in the businesses (Table 9).

Governance

The governance component captures the organizational structures and decision-making policies of the biochar producers or firms. The governance also looks at the key stakeholders such as the district local government (DLG), agro-input dealers, processors, government agencies, farmers and other product off-takers; the producer firms often profile and engage them in scaling commercial production of the bio-based products. The four main governance aspects for biochar production are: i) the ownership of business firms as cooperative, for profit or not ventures, privately owned for-profit, publicly traded, or under the public-private partnership (PPP) arrangement, ii) internal organizational structures (e.g., organizational hierarchy, production and functional units, product specialization), iii) organigram and decision-making policies (e.g., organization policies, transparency, consultation and non-financial criteria), and iv) shareholding and profit sharing arrangements. Each of these factors shall influence how the producers engage stakeholders and external parties in creating social value as an autonomous business unit for the commercial production of biochar (Table 9).

Scale of outreach

The scale of outreach describes the depth and breadth of the relationships built between the producers or firms and the key stakeholders through their production and marketing activities over time. In this regard, the scale of outreach for bio-based products includes: i) developing long-term and integrative relationships between both the producers or entrepreneurs and stakeholders (e.g., farmers); ii) the outreach of impact of producer-stakeholder relationship across spatial scales and geographically at the local, regional and global focus; iii) impact of producer-stakeholder relationship as to whether or how they address societal differences such as locally interpreting core ethical and or cultural actions across different consumer societies and cultures. The deep and diverse outreach will be achieved when creating supplementary social programs such as gender mainstreaming, language education and micro-credit programs for its production, supply and marketing value chains (Table 9).

End-users

The end-users are the persons at the end of the product value chain who ultimately use/ consume the value proposition. Under the business model analysis, the end-users component describes how the value proposition of the bio-based products addresses the needs of the end-users by contributing to the quality of life or livelihood. The users with similar needs for the biochar bio-based fertilizers and/ or soil amendment products are segmented according to the socio-economic and demographic profiles such as spatial location,

[23] Laszlo, C., 2008. Sustainable Value: How the World's Leading Companies Are Doing Well by Doing Good. Stanford University Press.

sex, age, income, ethnicity, education level, effective demand, farm size, crop type, agronomy and farming systems, among the other cross-cutting factors (Table 9).

Social impacts

The social impacts component addresses the social costs related to the production and marketing of bio-based products, and in this case, biochar as a biofertilizer and soil amendment product. It also complements and extends both the financial costs of the economic layer and the bio-physical impacts of the environmental layer of the TLBMC (Tables 6-9). Based on the commonest social impact metrics of Benoît-Norris[24], the social impact indicators will include working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs), among others.

On the other hand, negative social impacts for the biochar products could stem from misinformation and misuse by the farmers, which may also compromise the performance of the products upon application on-farm. The low performance of the biochar products could also disrupt the existing cultural farming, and social practices and eventual retard the progress made in climate-smart agriculture and technology promotion in the target communities. In response, product misinformation and misuse shall be averted by establishing a robust and effective product quality management system coupled with the provision of farmer-led or demand-driven advisory, extensions and training services (Table 9).

Social benefits

The social benefits are the positive social value created by the production of novel bio-based products. The social benefit component considers the interpersonal and cultural benefits derived from the new products (e.g., biochar as a biofertilizer or soil amendment product). In this case, the social benefits confirmed for the biochar products are social costs, capacity building and training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and resilient bioeconomy in the Bio4Africa project target communities (Table 9). Table 9 presents a summary of the social layer of Triple Layered Business Model Canvas (TLBMC) for biochar as the bio-fertilizer and soil amendment product.

Table 9: The Social layer of the TLBMC for the biochar as a soil amendment product

Local Communities	Governance	Social Value	Societal Culture	End Users
Stakeholders (e.g., producers, traders and suppliers) Local agribusinesses (e.g., agro-input dealers, traders and commercial farmers)	Stakeholder involvement in the product value chain Ownership of business firms Internal organizational structures	Enhance the quality of consumer's lives through bioeconomy Develop long-term value from mutually beneficial with	Sustainable values Societal and cultural spaces (NGOs and CBOs)	End-user segmentation based on socio-economic and demographic profiles (e.g., sex, age, income, ethnicity, education level,

[24] Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., Mazijn, B., 2011. Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. Int. J. Life Cycle Assess. 16 (7), 682e690.

District local governments (DLGs) and farmer institutions	Shareholding and profit sharing arrangements	the farmers & stakeholders Ecosystem restoration actions		effective demand, farm size, crop type, agronomy and farming systems)
	Employees		**Scale of Outreach**	
	Labour force & staff profiles (skills and qualifications of staff) Salient social demographics of staff		Long-term and integrative relationships for producers and stakeholders Outreach and impact of the producer-stakeholder relationships	
Social Impacts		**Social Benefits**		
Social impact metrics such as working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs).		Social costs, capacity-building training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and a resilient bioeconomy.		

3.2.2 The Triple Layered Business Model for biochar as a solid biofuel product

The biochar market shall be divided into three major types, namely large-scale users, medium-scale users, and small-scale clients and users. In the context of African rural farming communities, as the main target, end-users could domestically produce biochar biofuel for cooking food, hence replacing environmentally polluting charcoal and saving the local forest ecosystems against deforestation. The outcome of the analysis of the sustainable business for biochar production is shown in Tables 6-9, using the typical skeleton of the TLBMC presented in Annex 2.

i) Economic layer of the TLBMC as a solid biofuel product

The economic aspects of the Triple Layered Business Model Canvas (TLBMC) for biochar as a bio-fuel product under the Bio4Africa project focus countries are illustrated in Table 10.

Key partners

The key partners are bioreactor technology developers and Kiln promoters (e.g., bioreactor/pyrolysis manufacturers, suppliers of spare parts for the operation and maintenance of pyrolysis equipment), local financial institutions and/ or service providers, including commercial banks, angel investors and venture capitalists; as they too provide crucial relationships for production units and infrastructure. District local governments (DLGs); provide equity financing and environmental subsidies. Other key partners are transporters, customers, and government departments like the National Environment Management Authority (NEMA), which provides a supportive policy framework for investments in clean energy and environment sub-sectors.

Key activities

The main activities are production planning and production that involve the collection of quality Biomass as the raw materials and input feedstock, processing (thus, the drying and grinding action) of feedstocks, making of eco-friendly Kilns, actual production of the biochar, and maintenance of the pyrolysis reactors and Kilns, as well as trade activities for marketing of biochar through packaging, distribution and sell of quality charcoal products to different customer clusters. Other activities include the maintenance of customer relationships like customer acquisition and trust creation, customer penetration, market penetration, and brand royalty, among others (Table 10).

Key resources

Several key resources are needed for biochar producers in order to create value. There are four key resource categories, namely physical resources, human resources and financial resources. The key physical resources include; i) raw materials such as biomass (e.g., crop residues, animal waste, wood wastes); ii) pyrolysis devices and kilns for biomass production and/ or storage facilities (e.g., biomass warehouses and yards); iii) land and infrastructure to support biochar production, iv) marketing and product distribution outlets and networks. The key human resources include both skilled and semi-skilled labour force. The key financial resources are seed funding, grants and venture capital, and private and owned investments for the producers (Table 10).

Value proposition

The key value proposition encompasses bio-fuel products, namely biochar and charcoal. The novel quality bio-fuel products are perfectly dry, providing clean energy with no powder. The products will be well-packaged and distributed to a network of dedicated off-takers, customers and consumers. As such, the most important value proposition is the replacement of non-renewable fossil fuels such as coal, kerosene and natural gas, and environmentally-polluting biofuels like Firewood and charcoal; which accelerate greenhouse gas pollution and ecological deterioration with environmentally friendly that which are renewable and sustainable. By recycling the agricultural waste and biomass residues coming from both the agricultural and forestry sectors, which would amplify greenhouse gas pollution, socio-economic and environmental value is created since disposal costs are saved, and high-quality biofuels (mainly biochar and charcoals) are produced. The biofuels will accelerate decarbonization and carbon sequestration where the biochar enhances soil moisture, fertility and microbiota whilst enhancing the soil sink capacity for greenhouse gas pollution.

Customer relationship

Maintaining a good customer relationship is important for attracting more clients, creating strong brand loyalty, market penetration and increasing the market share for biochar products. The biochar producers shall sell to stable, loyal customers and on-spot markets. The degree of customer loyalty shall depend on the quality of the value proposition, and it is confirmed that good customer relations are important for the success of bio-fuel businesses in the target communities.

In the biochar business, mistrust happens when producers consider themselves to be exploited by intermediaries or due to default in payment of product suppliers and other off-takers. In response, biochar entrepreneurs establish close customer relationships by offering competitive production and marketing services, including maintaining profitable and lucrative pre-booking systems, aftersales services, attractive pricing and direct sales based on the product quality and effective demand from the different customer clusters[25].

Customer segments

The direct buyers from producers are intermediaries who shall transport the biochar or charcoal and take care of both the transport and wholesale of the produced charcoal. Downstream end customer segments consist of the majority of households, restaurants, schools, universities, hospitals and private business enterprises, such as the fish sellers who are engaged in smoking and selling fish on the streets of urban centres.

Channels

The entrepreneurs shall exploit existing channels to reach the customers and also raise awareness about the manufactured biochar products and related services. The producers will use personal contacts and farmer institutions. In addition, customer referrals blended with mass media channels such as radios, TVs and social media will be used to advertise the bio-fuel products to customers.

Costs

The costs that arise in the biochar business model shall be monitored appropriately by the producers. These major costs will come from key activities, resources, and building and maintaining the key partnerships that are highly required to engage in the commercial production and marketing of biochar. The producers start with the cost related to the initial investment in the infrastructure for the biochar production unit and continue with cost of production, including cost of raw materials (Biomass), labour costs, operational expenses, and marketing costs. However, the purchase of quality biomass feedstock requires constant investment, which could be significantly reduced through economies of scale when larger quantities of the feedstock per purchase are bought from dedicated suppliers. Other costs are equipment and technology costs (e.g., pyrolysis reactor and kiln) and maintenance costs (Table 10).

Revenue streams

Revenue streams from the commercial production of biochar shall be generated by selling biofuels in the form of biochar and charcoal directly to the customer segments. Other key revenue streams are seed funding from venture capitalists and angel investors. Lastly, revenue shall be obtained from other support services such as supplies of key raw materials, distribution network, product supply and delivery contracts to the dedicated off-takers and consumers (Table 10).

Table 10: Economic layer of the TLBMC for the biochar as a bio-fuel product

Partners	Activities	Value Proposition	Customer Relationship	Customer Segments
Bioreactor technology developers and Kiln promoters	Supply and collection of raw materials or biomass feedstock;	Eco-friendly bio-fuel products	Pre-booking systems, after-sales services,	✓ Households, ✓ Restaurants,

[25] Babich, V. and Tang, C.S., 2012. Managing opportunistic supplier product adulteration: Deferred payments, inspection, and combined mechanisms. Manufacturing & Service Operations Management, 14(2), pp.301-314.

Suppliers of spare parts for the operation and maintenance of pyrolysis Local financial institutions or service providers, including commercial banks, angel investors and venture capitalists District local governments Government departments	Planning of the Kiln or pyrolysis production process; Eco-friendly production processing of biochar; Marketing of biochar through packaging, distribution and sale of quality charcoal products Maintenance of customer relationships, e.g., customer acquisition and trust creation, customer penetration, market penetration, brand royalty	(biochar and charcoal) High-quality (dry and clean) energy products Recycling wastes from agriculture & forestry Decarbonization and carbon sequestration for a more resilient bio-economy	Attractive pricing and direct sales, Advance purchase and supply contracts,	✓ Schools, ✓ Universities, ✓ Hospitals ✓ Private Business Enterprises
	Resources		Channels	
	Physical resources (e.g., raw materials infrastructure, land, bioreactor and kiln technology) Financial resources (e.g., private or own capital of producers, seed funding, equity financing, venture capital, grants, angel investments) Local labour force (e.g., joint venture, partnerships, staff, semi-skilled employees)		Personal contacts; Farmer institutions; Customer referrals, Mass media channels Social media; leaders; Village meetings	
Costs		Revenues		
The initial investment in the infrastructure; Cost of raw materials (Biomass), Labour costs, Operational expenses Marketing costs Costs for equipment and technology (e.g., pyrolysis reactor) and maintenance costs.		Sale of biochar and charcoal to customers Seed funding from venture capitalists and angel investors Supplies of raw materials, distribution network, product supply and delivery contracts to the dedicated off-takers and consumers		

ii) Environmental layer of the TLBMC as a solid biofuel product

The environmental aspects of the Triple Layered Business Model Canvas (TLBMC) biochar as a bio-fuel product under the Bio4Africa project focus countries are illustrated in Table 11.

Supplies and outsourcing

The supplies and outsourcing depict several cross-cutting materials and productive activities that are important for the operational value but are not considered 'essential' to the firm organization[26]. Thus, within the environmental layer, examples of supplies of raw materials, pyrolysis reactors and kilns. The raw materials in the form of biomass feedstock and Kilns are locally produced. However, there is no in-country production of modern equipment, mainly pyrolysis reactors. The pyrolysis reactors for the advanced production of biochar are imported from technology manufacturers in Europe. As such, biochar producers have no or little influence in the production and supply of modern pyrolysis reactor machines. In the future, producers shall be willing to take more control over the production of modern machinery and maintenance actions by, for example, creating machinery production units and utility services (Table 11).

Production

The production component extends the foremost components of the key activities from the economic layer to the environmental layer of the TLBMC and captures the core activities or arrangements in place that the organization should undertake to create value. Production for the biochar producers involves transforming biomass (as the primary raw or unfinished materials) into higher value outputs. In this case, the biochar products are to be used as biofuel products. The core products for the service providers involve managing the process for biochar carbonization, packaging and marketing, as well as warehousing and administration services (Table 11).

Functional value

The functional value describes the main points of focus of the products and services output delivered by the business. In this regard, the functional value encompasses the five key properties of biochar as a biofertilizer and soil amendment product; namely, i) recycling the agricultural waste and biomass into high-quality bio-fuel products (biochar and charcoal), ii) saving ecosystems against deforestation for charcoal and Firewood, iii) enhancing soil sink capacity for greenhouse gases (e.g., storage of carbon), v) adoption of clean energy technologies for climate resilience and energy security.

Materials

The materials component biophysical stocks are used by the producers or companies to achieve the functional value of the product and services offered. In other words, the materials component is an extension of the environment component involving the key resources and assets for the business. In the case of biochar production, the producers/firms purchase and transform biomass feedstock as the primary input physical materials, as well as the other physical materials like land, building infrastructure, pyrolysis reactors and machinery, office buildings, furniture, vehicles, and ICT equipment. Whereas introducing the materials into

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[26] Stephan, A., Crawford, R. H. 2014. A multi-scale life-cycle energy and greenhouse gas emissions analysis model for residential buildings. Architectural Science Review, 57(1), 39-48

the TLBMC is not practical, it is worth noting that only the core materials facilitating the production of biochar are listed and their environmental impact. The biochar business, the above-mentioned materials are estimated to offset nearly 15% of the environmental carbon footprint from the life cycle systems assessment [27].

Distribution

In the context of the modern TLBMC, distribution involves the transportation of goods or commodities to support primary production. In the case of biochar producers or firms, the distribution represents the physical means by which the farmers and other customers access the products for use or enjoy their functional value. The distribution component is the combination of the modes of transport, the distances travelled and weights of products shipped, as well as the logistics involved in product packaging and delivery. The modes of transport are; road by train or trucks, and air and water shipment to in-country and in-region markets and off-takers (Table 11).

Use phase

The use phase focuses on the environmental impact of the product or service on the customers or end-users in relation to its functional value. The use phase also includes biochar production and sustaining the productivity of the pyrolysis bioreactors and kilns, and maintenance of biochar product quality based as a clean energy resource for the target communities (Table 11).

End of life

End-of-life is when the client opts to end the use of the products or consumption of their functional value. The end-of-life phase often entails matters pertaining to the re-use of materials or secondary by-products, such as the re-manufacturing, re-purposing and the options for re-use/ waste recycling, disassembly, incineration and disposal of by-products or supplementary packaging materials. From an environmental perspective, the end-of-life component supports the biochar producers in exploring eco-friendly ways of managing adverse impacts of the products on the ecosystems and its services, such as greenhouse gas pollution upon misuse by the end-users. The detrimental impacts to the ecosystems are averted and/ or minimized through waste recycling strategies that also extend the responsibility of using bio-based products and their by-products beyond the initially conceived value propositions. In this regard, clean bio-fuel products present an unexploited potential for the development of circular bio economies beyond climate change and carbon sequestration whilst protecting fragile ecosystems such as forests against deforestation for charcoal and Firewood[28].

Environmental Impact

[27] Alexandre J., Raymond L. P., 2016. The triple layered business model canvas: A tool to design more sustainable business models. Journal of Cleaner Production 135 (2016) 1474e1486.

[28] Boscolo, M., Lehtonen, P. and Pra, A. 2021. Developing bankable business plans – A learning guide for forest producers and their organizations. Forestry Working Paper No. 24. Rome, FAO. https://doi .org/10. 4060/cb4520en.

The environmental impact component addresses the environmental costs of the producers based on the product life cycle, as estimated by Life Cycle Assessment (LCA) tool[29]. Besides all financial costs, the Environmental Impact Assessment (EIA) of the production facility further extends to the ecological costs and biophysical indicators[30]. For the biochar products, the environmental impact indicator metrics are the greenhouse gas (GHG) fluxes (e.g., CO_2 emissions and carbon footprint), Increased biodiversity and genetic resources coupled with enhanced air quality, climate regulation, and restoration of the degraded forest ecosystems by providing clean energy other than using traditional firewood and charcoal (Table 11).

Environmental benefits

There is a positive correlation relationship between environmental impacts, costs and benefits that extends the value creation of the products and services offered beyond their financial value accrued to the producers, entrepreneurs or promoter firms. The environmental benefits encompass the ecological value/ advantages the bio-based products or services create through the regenerative positive ecological value or conserving the integrity of the natural ecosystems and their key services (Table 11).

The environmental benefits of biochar as a bio-fuel product are estimated using the LCA approach. The benefits of biochar shall depend on the design of the pyrolysis reactors, which includes the key parameters such as type of biomass feedstock, pyrolysis temperatures, biochar quality and output rate. In this regard, the pyrolysis reactors and biochar production systems are designed to maximize the product quality and ultimately take full advantage of the environmental impacts and benefits of the biochar (Table 11). Table 11 presents a summary of the Environmental layer of Triple Layered Business Model Canvas (TLBMC) for Biochar as the bio-fuel product.

Table 11: Environmental layer of the TLBMC for the Biochar as the bio-fuel product

Supplies and Out-sourcing	Production	Functional Value	End of Life	Use Phase
Importation of machinery and equipment (e.g., pyrolysis reactors) Production of raw materials (e.g., crop biomass & feedstock) and kiln	Production of biochar from primary raw or unfinished biomass materials Provision of support services (e.g., trade or marketing)	Recycling of waste biomass into high-quality bio-fuel products (biochar & charcoal) Saving ecosystems against deforestation for charcoal & Firewood Enhancing soil sink capacity for greenhouse	Clean energy production Recycling of packaging materials Ecosystem protection against deforestation	Biochar production Sustaining the productivity of pyrolysis bioreactors and kilns Maintenance of biochar product

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[29] De Benedetto, L., Klemes, J., 2009. The Environmental Performance Strategy Map: an integrated LCA approach to support the strategic decision-making process. J. Clean. Prod. Early-Stage Energy Technol. Sustain. Future 17 (10), 900e906.

[30] Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R., 2003. IMPACT 2002þ: a new life cycle impact assessment methodology. Int. J. Life Cycle Assess. 8 (6), 324e330.

	Warehouses and administration services	gases (e.g., storage of carbon) Adoption of clean energy technologies for climate resilience and energy security		quality based on a clean energy resource
	Materials		Distribution	
	Physical materials: land, building infrastructure, pyrolysis reactors and machinery, office buildings, furniture, vehicles, and ICT materials (e.g., computers).		Modes of transport (e.g., train or trucks, and air & water shipment) Distances travelled Weights of products	
Environmental Impacts		Environmental Benefits		
Greenhouse gas (GHG) fluxes (e.g., CO_2 emissions and carbon footprint); increase biodiversity & genetic resources; improve air quality; climate regulation; and restoration of degraded forest ecosystems.		Improves environmental footprint: increases soil sink capacity for carbon storage and carbon sequestration; Greenhouse gas (methane and nitrous) fluxes by providing alternative clean energy rather than using traditional wood fuel and charcoal.		

iii) Social layer of the TLBMC for the biochar as a solid bio-fuel product

The social aspects of the Triple Layered Business Model Canvas (TLBMC) for the biochar as a bio-fuel under the Bio4Africa project focus countries are illustrated in Table 12. The social layer of the TLBMC is informed by the data obtained through a stakeholder approach that captures the mutual benefits and influences between both the producers and stakeholders. Also, the social layer captures key social impacts of the biochar products derived from the producer and the stakeholder relationships. Employing a bottom-up approach in building the new social layer provides a better understanding of the primary social impacts and insight for exploring ways to innovate along the production and marketing cycles of biochar to create social value and improve its potential. By leveraging the stakeholder approach, the nine components of the social layer of the TLBMC are discussed below.

Communities

Whereas the economic relationships are built between the producer and their business partners, the social relationships are built between the producers, suppliers and the local host communities. In the context of the TLBMC, the stakeholders from producers, suppliers, and traders (e.g., farmers and other off-takers), constitute a community that influences production and maintains mutually beneficial relationships. Local agribusinesses such as bio-fuel dealers and traders will work with the district local governments (DLGs), and farmer institutions shall lead training and media campaigns towards stimulation of interest for scaling commercial production and adoption of biochar products (Table 12).

Employee

The employee component considers the role of staff and workforce in the production cycle and at the core organizational stakeholder. Employee factors considered are the number, skills and qualifications of the employees, as well as their salient social demographics, such as variations in sex, payments, wages, gender, ethnicity, and education levels within the producer organizations. In addition, the employee component encompasses employee-oriented programs, primarily tailored capacity-building training, professional development and other support programs that also contribute to the viability and success of the producer organizations and firms (Table 12).

Social value

The social value speaks to the mission of producers that focuses on creating important benefits for the stakeholders and society in a broader context. For sustainability-oriented biochar production, creating social value is likely a clear part of its mission. The intended social value is interpreted in the context of the product "roadmap for sustainable growth"[31], as one of the core competencies is developing long-term value from the mutually beneficial relationships between the producers and stakeholders. The social values for biochar production are i) enhance the quality of consumers' lives by offering eco-friendly, safer and healthier food production systems, ii) developing long-term value from the mutually beneficial with the farmers and stakeholders, and iii) ecosystems restoration (Table 12).

Societal culture

The societal culture component recognizes the potential impact of the producers on society and host communities as a whole. In other words, the commercial production of biochar and related business cannot succeed when the host society fails. Therefore, the social culture component leverages the concept of 'sustainable value'[32], to acknowledge the potential impact of the biobased products on host communities and the bioeconomy, and how the bioeconomy positively influences society.

Non-governmental organizations (NGOs) and Community-Based Organizations (CBOs) form part of the societal culture space as they carry social agendas through advocacy and influencing societal culture in the businesses (Table 12).

Governance

The governance component captures both the organizational structures and decision-making policies of the biochar producers or firms. The governance also looks at the key stakeholders such as the district local government (DLG), agro-input dealers, processors, government agencies, farmers and other product off-takers; the producer firms often profile and engage them in scaling commercial production of the bio-based products. The four main governance aspects for biochar production are: i) the ownership of business firms as cooperative, for profit or not ventures, privately owned for-profit, publicly traded, or under the public-

[31] Nespresso, 2015. Our Values at Nespresso. Careers at Nespresso, available at: http://www.careersatnespresso.com/working-at-nespresso/our-values/

[32] Laszlo, C., 2008. Sustainable Value: How the World's Leading Companies Are Doing Well by Doing Good. Stanford University Press.

private partnership (PPP) arrangement, ii) internal organizational structures (e.g., organizational hierarchy, production and functional units, product specialization), iii) organigram and decision-making policies (e.g., organization policies, transparency, consultation and non-financial criteria), and iv) shareholding and profit sharing arrangements. Each of these factors shall influence how the producers engage stakeholders and external parties in creating social value as an autonomous business unit for the commercial production of biochar (Table 12).

Scale of outreach

The scale of outreach describes the depth and breadth of the relationships built between the producers or firms and the key stakeholders through their production and marketing activities over time. In this regard, the scale of outreach for bio-based products includes: i) developing long-term and integrative relationships between both the producers or entrepreneurs and stakeholders (e.g., farmers); ii) the outreach of impact of producer-stakeholder relationship across spatial scales and geographically at the local, regional and global focus; iii) impact of producer-stakeholder relationship as to whether or how they address societal differences such as locally interpreting core ethical and or cultural actions across different consumer societies and cultures. The deep and diverse outreach will be achieved when creating supplementary social programs such as gender mainstreaming, language education and micro-credit programs for its production, supply and marketing value chains (Table 12).

End-users

The end-users are the persons at the end of the product value chain who ultimately use/ consume the value proposition. Under the business model analysis, the end-users component describes how the value proposition of the bio-based products addresses the needs of the end-users by contributing to the quality of life or livelihood. The users with similar needs for the biochar product are segmented on the relevant socio-economic and demographic profiles such as spatial location, sex, age, income, ethnicity, education level, effective demand, and other cross-cutting factors (Table 12).

Social impacts

The social impacts component addresses the social costs related to the production and marketing of bio-based products, and in this case, biochar as a bio-fuel product. It also complements and extends both the financial costs of the economic layer and the bio-physical impacts of the environmental layer of the TLBMC. Based on the commonest social impact metrics of Benoît-Norris[33], the social impact indicators will include working hours, cultural heritage, health and safety, fair competition, and community engagement, among others. On the other hand, negative social impacts for the biochar products could stem from misinformation and misuse by the farmers, which may also compromise the performance of the products upon application on-farm. The low performance of the biochar products could also disrupt the existing cultural farming, and social practices and eventual retard the progress made in climate-smart agriculture and technology promotion in the target communities. In response, product misinformation and misuse shall be averted by

[33] Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., Mazijn, B., 2011. Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. Int. J. Life Cycle Assess. 16 (7), 682e690.

establishing a robust and effective product quality management system coupled with the provision of farmer-led or demand-driven advisory, extensions and training services (Table 12).

Social benefits

The social benefits are the positive social value created by the production of bio-based products. The social benefit component considers the interpersonal and cultural benefits derived from the new products (e.g., biochar as a bio-fuel product). In this case, social benefits confirmed for the biochar products are social costs, capacity building and training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and a resilient bioeconomy under the Bio4Africa project target communities (Table 12). Table 12 presents the summary of the social layer of Triple Layered Business Model Canvas (TLBMC) for Biochar as the bio-fuel product.

Table 12: Social layer of the TLBMC for the Biochar as the bio-fuel product

<table>
<tr><th>Local Communities</th><th>Governance</th><th>Social Value</th><th>Societal Culture</th><th>End Users</th></tr>
<tr><td rowspan="3">Stakeholders (e.g., producers, traders and suppliers)
Local businesses (e.g., traders and commercial farmers)
District local governments (DLGs) and farmer institutions</td><td>Stakeholder involvement in the product value chain
Ownership of business firms
Internal organizational structures
Shareholding and profit sharing arrangements</td><td rowspan="3">Enhance the quality of consumer's lives through bioeconomy
Develop long-term value from the mutually beneficial with the farmers and stakeholders
Ecosystem restoration actions</td><td>Sustainable values
Societal and cultural spaces (NGOs and CBOs)</td><td rowspan="3">End-user segmentation based on socio-economic and demographic profiles (e.g., sex, age, income, ethnicity, education level, effective demand, farm size, crop type, agronomy and farming systems)</td></tr>
<tr><th>Employees</th><th>Scale of Outreach</th></tr>
<tr><td>Labour force & staff profiles (skills and qualifications of staff)
Salient social demographics of staff</td><td>Long-term relationships for stakeholders
Outreach and impact of the producer-stakeholder relationships</td></tr>
<tr><th colspan="2">Social Impacts</th><th colspan="3">Social Benefits</th></tr>
<tr><td colspan="2">Social impact metrics such as working hours, cultural heritage, health and safety, fair competition, and community engagement</td><td colspan="3">Social costs, capacity-building training opportunities for the farmers and other end-users, business opportunities, personal development and community engagement by staff and employees, partnership by suppliers, and a resilient bioeconomy.</td></tr>
</table>

3.2.3 The Triple Layered Business Model for biomass pellets as bio-feeds for livestock

Table 13 presents the Triple Layered Business Model (TLBM) for biomass pellets as bio-feeds for livestock.

Table 13: The TLBMC for Biochar as the bio-fuel product

<table>
<tr><th>A</th><th>Partners</th><th>Activities</th><th>Value Proposition</th><th>Customer Relationship</th><th>Customer Segments</th></tr>
<tr><td rowspan="5">Economic Business Model Canvas</td><td rowspan="3">o Farmers
o Agro-input dealers
o District local government
o Community leaders</td><td>o Livestock production
o Milk and beef trade
o Climate-smart farming
o Agribusiness</td><td rowspan="3">o Reliable supply of feeds
o High-quality feeds
o Recycling waste into bio-feeds
o Low-cost feeds</td><td>o After-sales service
o Agribusiness training
o Direct sales
o Competitive prices</td><td rowspan="3">o Subsistence farmers
o Commercial farmers
o Agro-input dealers
o NGOs and CBOs</td></tr>
<tr><td>Resources</td><td>Channels</td></tr>
<tr><td>o Physical resources
o Financial resources</td><td>o Mass media
o Social media
o Farmer institutions</td></tr>
<tr><td colspan="2">Costs</td><td colspan="3">Revenues</td></tr>
<tr><td colspan="2">o Capital investment in the infrastructure;
o Cost of raw materials
o Labour costs,
o Operational expenses
o Marketing costs</td><td colspan="3">o Direct sale of bio-feeds
o Seed funding
o Equity finance
o Intellectual property</td></tr>
<tr><td>B</td><td>Supplies and Out-sourcing</td><td>Production</td><td>Functional Value</td><td>End of Life</td><td>Use Phase</td></tr>
<tr><td rowspan="5">Environmental Lifecycle Business Model Canvas</td><td rowspan="3">Importation of machinery
Production of raw materials (e.g., crop biomass & feedstock)
Supply of utilities (e.g., feeds)</td><td>Transformation of raw materials into biochar
Provision of support services (e.g., ICT</td><td rowspan="3">Recycling of waste biomass into high-quality feeds
Modification of the feeding systems for higher productivity
Supply of quality-assured feeds</td><td>Recycling of agricultural biomass
Climate-smart feed production</td><td rowspan="3">Last-mile access to bio-feeds by farmers
Low-cost feeding
Green dairying
Agribusiness</td></tr>
<tr><td>Materials</td><td>Distribution</td></tr>
<tr><td>Livestock farms;
Livestock species ;
Labour force</td><td>Train, trucks and air transport</td></tr>
<tr><td colspan="2">Environmental Impacts</td><td colspan="3">Environmental Benefits</td></tr>
<tr><td colspan="2">Reduced greenhouse gas emissions from the livestock production systems</td><td colspan="3">Climate change mitigation</td></tr>
<tr><td>C</td><td>Local Communities</td><td>Governance</td><td>Social Value</td><td>Societal Culture</td><td>End User</td></tr>
</table>

Social Stakeholder Business Model Canvas	Stakeholders (e.g., producers, traders and suppliers) Local agribusinesses (e.g., agro-input dealers, traders and commercial farmers) District local governments (DLGs) and farmer institutions	Stakeholder involvement Ownership of business firms Shareholding and profit sharing arrangements	Increased incomes Increased food and nutritional security Improved livelihoods of farmers Socio-economic transformation of societies	Sustainable values Societal and cultural spaces (NGOs and CBOs)	End-user segmentation based on livestock types and farming systems
		Employees		Scale of Outreach	
		Casual labour force Farm managers		Medium to long term	
	Social Impacts		Social Benefits		
	Social impact metrics such as working hours, cultural heritage, health and safety, fair competition and community engagement.		Social costs, capacity-building training opportunities for the farmers and other end-users, agribusiness opportunities and community development.		

3.2.4 The Triple Layered Business Model for biochar as an additive in biogas production

Table 14 presents the Triple Layered Business Model (TLBM) for biochar as an additive in biogas production.

Table 14: The TLBMC for the Biochar as an additive in biogas production

A	Partners	Activities	Value Proposition	Customer Relationship	Customer Segments
Economic Business Model Canvas	○ Farmers ○ Agro-input dealers ○ District local government ○ Community leaders	○ Training ○ Provision of inputs ○ Switching from firewood and charcoal to biogas	○ Increase productivity of biogas ○ Provision of clean energy ○ Reduced costs of energy use ○ Saves forests against deforestation for biomass fuels	○ After-sales service ○ Agribusiness training ○ Direct sales ○ Competitive prices	○ Subsistence farmers ○ Commercial farmers ○ Agro-input dealers ○ NGOs and CBOs
		Resources		Channels	
		○ Physical resources ○ Financial resources		○ Mass media ○ Social media ○ Farmer institutions	
	Costs		Revenues		
	○ Capital investment ○ Cost of raw materials ○ Labour costs, ○ Marketing costs		○ Direct sale ○ Seed funding ○ Equity finance ○ Intellectual property		
B	Supplies and Out-sourcing	Production	Functional Value	End of Life	Use Phase

Environmental Lifecycle Business Model Canvas	Production of raw materials (e.g., crop biomass & feedstock) Supply of utilities (e.g., bioelectricity)	Transformation of biochar into an additive for biogas Provision of support services	Recycling of waste biomass into high-quality biochar Modification of the biogas systems for higher productivity Supply of quality-assured inputs for biogas production	Recycling of agricultural biomass into energy Clean energy production	Last-mile access to clean energy Low-cost energy Local energy business
		Materials		Distribution	
		Local households Farmers		Train, trucks and air transport	
	Environmental Impacts		Environmental Benefits		
	Reduced greenhouse gas emissions from the use of fossil fuels		Climate change mitigation		
C	Local Communities	Governance	Social Value	Societal Culture	End User
Social Stakeholder Business Model Canvas	Stakeholders (e.g., producers, traders and suppliers) Local energy business District local governments (DLGs) Farmer institutions	Stakeholder involvement Ownership of business firms Shareholding and profit sharing arrangements	Increased incomes Increased energy security Improved livelihoods of farmers Socio-economic transformation of societies	Sustainable values Societal and cultural spaces (NGOs and CBOs)	End-user segmentation based on energy demand and use types
		Employees		Scale of Outreach	
		Casual laborforce Farm managers		Medium to long-term use	
	Social Impacts		Social Benefits		
	Social impact metrics such as working hours, cultural heritage, health and safety, fair competition and community engagement.		Social costs, capacity-building training opportunities for the farmers and other end-users and clean energy business opportunities for sustainable development.		

3.2.5 The Triple Layered Business Model for the biochar powder as a medium for water filtration

The market for biochar as a water filtration product shall be divided into three major types, namely, large-scale users, medium-scale users, and small-scale users. In the context of African rural farming communities, the small-scale users who could domestically produce biochar for domestic water treatment are the local target clients. The outcome of the sustainable business for biochar production as a new water treatment product is shown in Tables 15-17, using a typical skeleton of the new Triple Layered Business Model Canvas (TLBMC), as presented in Annexe 2.

i) Economic layer of the TLBMC for the biochar powder as a medium for water filtration

The economic aspects of the Triple Layered Business Model Canvas (TLBMC) for biochar powder as a medium for water filtration under the Bio4Africa project focus countries are illustrated in Table 15.

Key partners

The key partners include the bioreactor technology developers and promoters (e.g., bioreactor/pyrolysis manufacturers, suppliers of spare parts for operation and maintenance of pyrolysis equipment), government agencies and ministries for public health, water and environment, financial institutions or service providers, including the commercial banks, angel investors and venture capitalists; as they provide seed funding for the commercial production infrastructure. The District Local Governments (DLGs), policymakers and community leaders often set clean water supply and distribution targets at the national and community level (Table 10).

Key activities

The main activities are the production of biochar, where the producers are engaged in the collection of quality biomass as the raw materials in the form of the input feedstock and processing (thus, drying and grinding) of feedstocks, eco-friendly processing and production of the biochar and maintenance of the pyrolysis reactors, as well as the use of biochar for water filtration. In addition, marketing of biochar as water filtration products through branding, packaging, product distribution and trade activities. Other activities include capacity building of target communities and traders in the production of biochar, technical training on the use of biochar water filters, marketing and sales training, market sensitization, and supply and trade of clean water (Table 7).

Key resources

Several key resources are needed for biochar producers in order to create value. There are four key resource categories, physical resources, human resources, financial resources and intellectual resources. The physical resources are; i) raw materials and other input feedstock such as biomass (e.g., crop residues, animal waste, wood wastes, sawdust, straw, dry grass, hay, forage, reed, wood chips, pales); ii) pyrolysis equipment and technology for biomass production and storage facilities (e.g., biomass warehouses and yards); iii) land and infrastructure to support biochar production, iv) marketing and product distribution outlets and networks. The human resources include competent staff and a skilled labour force (e.g., joint ventures, partnerships, staff and semi-skilled employees). The financial resources include capital assets, seed funding, grants, equity financing, angel investments, venture capital, and private investments. Other key resources are training materials and sales and marketing facilities such as distributorship outlets for water (Table 15).

Value proposition

Provision of purified, safe water for human and livestock consumption, as well as crop irrigation. Capacity building and training of certified community health agents as trainers of trainees (ToTs); to engage the local communities and families to help them understand their expenditures on water-related illnesses. A healthier population means less strain on the already resource-constrained public health care systems. In the end, the clean water facilities reduce the burden of boiling water for drinking, thereby saving energy and time for other productive domestic chores (Table 15).

Customer relationship

Maintaining a good customer relationship is important for attracting more clients, creating strong brand loyalty and market penetration and increasing the market share for biochar as water filters. As such, the customer relationship shall include; i) educating and providing great customer services to the homeowners who purchase the biochar filters or clean water for domestic consumption, ii) provision of competitive prices and discounted sales for wholesale traders, iii) sales promotion activities, iv) pre-booking systems and after-sales services, and v) attractive pricing and direct sales.

Customer segments

The main customer segment is rural communities, with resource-constrained families engaged in subsistence farming and often thriving on less than US$ 1 a day. They shall be eligible to get biochar filters or clean water products at highly subsidized or discounted prices. Other customer segments are communities in urban and peri-urban areas, schools, hospitals, universities, wholesalers, retail traders, government agencies and the private sector.

Channels

The entrepreneurs shall exploit existing channels to reach the customers and also raise awareness about the manufactured biochar filters and clean water products. Mass media channels such as radio, TV, and social media channels (e.g., Facebook, Youtube and Instagram) will be used to advertise the product; and increase awareness among the target customer segments and clients. The producers will use door-to-door physical channels to engage communities through community health agents, ToTs and traders, community meetings with entrepreneurs or agents, and social events (e.g., trade shows and exhibitions) to reach out to the clients. Lastly, the producers or entrepreneurs will also advertise the biochar filters and clean water products in the local newspapers, magazines and home-delivered flyers (Table 15).

Costs

These major costs will come from the key activities, resources, and the building and maintaining key partnerships that are highly required to engage in commercial production and marketing of bio-fuel products (thus, biochar and charcoal). The initial investment costs go to the establishment of the infrastructure for the biochar production unit, and cost is associated with the purchase of raw materials, labour costs, operational expenses and marketing costs. In addition, key variable costs, like maintenance costs to run the commercial biochar business more efficiently. Nonetheless, the purchase of biomass feedstock requires constant investment, which could also be significantly reduced through economies of scale when larger quantities of the feedstock per purchase are bought from dedicated suppliers. Other costs are equipment and technology costs (e.g., pyrolysis reactor) and maintenance costs of the water filtration device. Biofilter fixed and variable costs, pricing based on break-even analysis. Wholesalers are compensated by retail versus wholesale pricing.

Revenue streams

Revenue streams from the commercial production of biochar shall be generated by selling the new biochar and water filters directly to the new customer segments. Additional revenue will be generated from the sale of biochar and biofilters (full price and discounted), the trade of bottled water to wholesale traders and retailers, venture capital and seed grants from angel investors.

Table 15: Economic layer of the TLBMC for the Biochar powder as a medium for water filtration

<table>
<tr><th>Partners</th><th>Activities</th><th>Value Proposition</th><th>Customer Relationship</th><th>Customer Segments</th></tr>
<tr>
<td rowspan="3">Suppliers of inputs;
Pyrolysis technology;
developers & promoters;
Government agencies;
Financial institutions;
District local government;</td>
<td>Collection of raw materials (feedstock input)
Processing of the raw materials (drying and grinding);
Eco-friendly production of biochar and water filtration activities
Marketing of biochar as water filtration products through branding, packaging, product distribution and trade activities,
Capacity building and technical training</td>
<td rowspan="3">Purified safe water for human and livestock consumption, and crop irrigation
Capacity building and training of trainers (ToTs)
Reduced costs and expenditures on water-related illnesses
Clean water facilities reduce the burden of boiling water for drinking,</td>
<td>Educate & provide great customer services
Provision of competitive prices and discounted sales for wholesale traders
Sales promotion activities
Pre-booking systems and after-sales services
Attractive pricing and direct sales</td>
<td rowspan="3">Rural communities
Communities in the urban and peri-urban areas
Schools
Hospitals
Universities
Wholesalers
Retail traders,
Government agencies
Private sector</td>
</tr>
<tr><th>Resources</th><th>Channels</th></tr>
<tr>
<td>Physical resources (e.g., land, infrastructure, raw materials and pyrolysis technology)
Financial resources (e.g., capital assets, seed funding, grants, equity financing, angel investments, venture capital, and private investments)
Local labour force (e.g., joint venture,
partnerships, staff, semi-skilled employees)</td>
<td>Mass media channels such as the radio, TV and social media channels (e.g., Facebook, Youtube)
Physical channels involving door-to-door to engage the communities
Local newspapers, magazines and home-delivered flyers</td>
</tr>
<tr><th colspan="2">Costs</th><th colspan="3">Revenues</th></tr>
<tr>
<td colspan="2">The initial investment in the infrastructure;
Cost of raw materials
Labour costs,
Operational expenses
Marketing costs
Costs for equipment and technology (e.g., pyrolysis reactor) and maintenance costs.</td>
<td colspan="3">Selling the produced biochar and water filters directly to the new customer segments;
Additional revenue will be generated from the sale of biochar and biofilters (full price and discounted),
Trade of bottled water (wholesale and retail),
Venture capital and seed grants from angel investors.</td>
</tr>
</table>

ii) Environmental layer of the TLBMC for the biochar powder as a medium for water filtration

The environmental aspects of a Triple Layered Business Model Canvas (TLBMC) biochar as a water filtration product under the Bio4Africa project focus countries are illustrated in Table 16.

Supplies and out-sourcing

The supplies and out-sourcing depict several cross-cutting materials and productive activities that are important for the operational value but are not considered 'essential' to the firm organization[34]. Thus, within the environmental layer, examples of supplies are raw materials and pyrolysis reactors. The raw materials, mainly biomass residues and feedstock, and water facilities, are produced locally. Therefore, these supplies are outsourced from all dedicated suppliers ranging from farmers for the biomass feedstock and private institutions and government agencies for the water supplies. However, there is no in-country production of modern machinery and equipment, mainly pyrolysis reactors. The new pyrolysis reactors used for biochar production are imported from technology manufacturers in Europe. As such, the biochar producers have no or little influence in the production and supply of pyrolysis reactor machines. The water filtration facilities are locally produced.

Production

The production component extends the foremost components of the key activities from the economic layer to the environmental layer of the TLBMC and captures the core activities or arrangements in place that the organization should undertake to create value. Production for the biochar producers involves transforming biomass (as the primary raw or unfinished materials) into higher value outputs; in this case, the biochar and charcoal products are employed for water filtration purposes. The core products for the service providers involve the establishment of local water treatment facilities, water filtration and distribution of clean water resources within the target Bio4Africa communities (Table 16).

Functional value

The functional value describes the main points of focus of the products and services output delivered by the business. In this regard, the functional value encompasses the five key properties of biochar and charcoal as a water filtration product; namely, i) recycling agricultural waste and biomass into high-quality biochar and charcoal, ii) water filtration and treatment actions, iii) supply of clean water for livestock and human consumption, and iv) enhancing public health.

Materials

The materials component biophysical stocks are used by the producers or companies to achieve the functional value of the product and services offered. In other words, the materials component refers to the environmental extension of the key resources for the business. In the case of biochar production, the producers or firms purchase and transform biomass feedstock as the primary bio-input physical materials, as well as other physical materials like land, building infrastructure, pyrolysis reactors and machinery, water facilities, training and marketing materials. Whereas introducing all materials into the TLBMC is not practical,

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[34] Stephan, A., Crawford, R. H. 2014. A multi-scale life-cycle energy and greenhouse gas emissions analysis model for residential buildings. Architectural Science Review, 57(1), 39-48

it is worth noting that only the core materials facilitating the production of biochar are listed and their environmental impact. For the biochar business, the above-mentioned materials are estimated to offset nearly 11% of the environmental carbon footprint from the life cycle systems assessment[35].

Distribution

In the context of the modern TLBMC, distribution involves the transportation of goods or commodities to support primary production. In the case of biochar producers or firms, the distribution represents the physical means by which the farmers and other customers access the products for use or enjoy their functional value. Distribution is the combination of the modes of transport and the distances travelled and weights of products shipped, as well as the logistics involved in product packaging and delivery. The modes of transport are; road by train or trucks, and air and water shipment to in-country and in-region markets and off-takers (Table 16).

Use phase

The use phase focuses on the environmental impact of the product or service on the customers or end-users in relation to its functional value. The use phase includes the maintenance of biochar product quality based on the type of farm resource and product requirements of the farmers and other clients through their own use. The novel biochar products are organic bioproducts that are envisaged to be low-cost and highly efficient fertilizers suitable for organic horticulture, agroforestry, green dairying and other primary climate-smart farming enterprises. The application of biochar as a water filtration product is envisaged to enhance water quality and clean water supply (Table 16).

End of life

End-of-life is when the client opts to end the use of the products or consumption of their functional value. The end-of-life phase often entails matters pertaining to the reuse of materials or secondary byproducts such as the re-manufacturing, re-purposing and the options for res-use/ waste recycling, disassembly, incineration and disposal of byproducts or supplementary packaging materials. From an environmental perspective, the end-of-life component supports the biochar producers in exploring eco-friendly ways of managing adverse impacts of the products on the ecosystems and its services, such as nitrifications and greenhouse gas pollution upon misuse by the target farmers and other end-users. The detrimental impacts to the ecosystems are averted and/ or minimized through waste recycling strategies that also extend the responsibility of using bio-based products and their byproducts beyond the initially conceived value propositions. In this regard, biochar products present an unexploited potential for the development of circular bio economies beyond soil amendment and carbon sequestration in farming systems, such as the use of biochar products for water treatment and clean energy production[36].

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[35] Alexandre J., Raymond L. P., 2016. The triple layered business model canvas: A tool to design more sustainable business models. Journal of Cleaner Production 135 (2016) 1474e1486.

[36] Boscolo, M., Lehtonen, P. and Pra, A. 2021. Developing bankable business plans – A learning guide for forest producers and their organizations. Forestry Working Paper No. 24. Rome, FAO. https://doi .org/10. 4060/cb4520en.

Environmental impact

The environmental impact component addresses the environmental costs of the producers based on the product life cycle, as estimated by the Life Cycle Assessment (LCA) tool[37]. Besides all financial costs, the Environmental Impact Assessment (EIA) of the production facility further extends to the ecological costs and biophysical indicators[38]. For the biochar products, the environmental impact indicator metrics are greenhouse gas (GHG) fluxes (thus, CO_2 emissions and the carbon footprint), human health and ecosystem impacts on the water and natural resource depletion, water use and quality, and energy consumption, water use and GHG emissions (Table 16).

Environmental benefits

There is a positive correlation relationship between environmental impacts, costs and benefits that extends the value creation of the products and services offered beyond their financial value accrued to the producers, entrepreneurs or promoter firms. The environmental benefits encompass the ecological value/ advantages the bio-based products or services create through the regenerative positive ecological value or conserving the integrity of the natural ecosystems and their key services. The environmental benefits of biochar as a water filtration product shall be estimated using the LCA approach. As a result, the application of biochar in water filtration and novel biochar will help recycle wastewater for domestic use, human and livestock consumption, and crop irrigation during dry-season farming schemes. The biochar will increase both the availability and supply of clean water resources and ultimately boost human health and crop yields with a knock-on effect on the income, food and nutritional security in the Bio4Africa target communities.

The productivity of biochar and its efficacy in water filtration and treatment shall depend on the design of pyrolysis reactors and water treatment facilities, which includes parameters such as type of biomass feedstock, application rates of the biochar, biochar properties, and quality of the water resource. In this regard, the pyrolysis reactors and water treatment facilities are designed to maximize product quality and ultimately take full advantage of the environmental impacts and benefits of biochar (Table 16). Table 16 presents a summary of the Environmental layer of Triple Layered Business Model Canvas (TLBMC) for the Biochar as the water filtration and treatment product.

Table 16: Environmental layer of the TLBMC for the Biochar powder as a medium for water filtration

Supplies and Out-sourcing	Production	Functional Value	End of Life	Use Phase
Importation of machinery and equipment (e.g., pyrolysis reactors)	Transformation of raw materials into biochar Production of biochar & charcoal products	Recycling agricultural waste and biomass into high-quality biochar and charcoal	Water filtration and treatment Recycling of wastewater for human	Recycling agricultural waste and biomass into high-quality

[37] De Benedetto, L., Klemes, J., 2009. The Environmental Performance Strategy Map: an integrated LCA approach to support the strategic decision-making process. J. Clean. Prod. Early-Stage Energy Technol. Sustain. Future 17 (10), 900e906.

[38] Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R., 2003. IMPACT 2002þ: a new life cycle impact assessment methodology. Int. J. Life Cycle Assess. 8 (6), 324e330.

Production of raw materials (e.g., crop biomass & feedstock) Supply of utilities (e.g., water facilities)	Establishment of water treatment facilities, Water filtration and distribution of clean water resources	Water filtration and treatment actions Supply of clean water for livestock and human consumption Enhancing public health	consumption and horticulture	biochar and charcoal Water filtration and treatment actions Supply of clean water for livestock and human consumption Enhancing public health
	Materials		Distribution	
	Physical materials, e.g., land, building infrastructure, pyrolysis reactors and machinery, water facilities, training and marketing materials		Modes of transport (e.g., train or trucks, and air & water shipment)	
Environmental Impacts		Environmental Benefits		
Greenhouse gas (GHG) fluxes (e.g., CO2 emissions and carbon footprint), human health, ecosystem impacts on water and natural resource depletion, water use and quality, energy consumption and water use.		Increased production and supply of clean water resources, recycling of wastewater for home use and agriculture, and environmental footprint: and capacity building of the communities in Integrated Water Management (IWM) schemes.		

iii) Social layer of the TLBMC for the biochar powder as a medium for water filtration

The social aspects of the Triple Layered Business Model Canvas (TLBMC) for the biochar as a water filtration product under the Bio4Africa project focus countries are illustrated in Table 10. The social layer of the TLBMC is informed by the data obtained through a stakeholder approach that captures the mutual benefits and influences between the producers and stakeholders. Also, the social layer captures the key social impacts of the biochar products derived from the producer and the stakeholder relationships. Employing the bottom-up approach in building the social layer provides a better understanding of the primary social impacts and insight for exploring ways to innovate along the production and marketing cycles of biochar to create social value and improve its potential. By leveraging the stakeholder approach, the nine components of the social layer of the TLBMC are discussed below.

Communities

Whereas the economic relationships are built between the producer and their business partners, the social relationships are built between the stakeholders such as the biochar producers, suppliers and the local host communities. In the context of the TLBMC, all the stakeholders, from producers, water suppliers and traders, constitute a community that influences mutually beneficial relationships. Local water business entities such as water suppliers, outlet dealers and commercial traders. These will work with the district local governments (DLGs) in capacity-building training to stimulate interest in water recycling and treatment and towards integrated water management practices (Table 17).

Employees

The employee component considers the role of staff and workforce in the production cycle and at the core organizational stakeholder. A number of employee factors considered are the number, skills and qualifications of the employees, as well as their salient social demographics, such as the variations in sex, payments, gender and education levels within the biochar producer organizations. In addition, the employee component also encompasses employee-oriented programs, tailored capacity-building training, professional development and other support programs that also contribute to the viability and success of the producer organizations and firms (Table 17).

Social value

The social value speaks to the mission of producers that focuses on creating important benefits for the stakeholders and society in a broader context. For sustainability-oriented biochar production, creating social value is likely a clear part of its mission. The intended social value is interpreted in the context of the product "roadmap for sustainable growth"[39], as one of the core competencies is developing long-term value from the mutually beneficial relationships between the producers and stakeholders. The social values for biochar production are; i) water filtration, ii) water treatment and supply of clean water resources, ii) developing long-term value from the mutually beneficial with the stakeholders, and iii) ecosystems restoration through recycling wastewater and crop residues (Table 17).

Societal culture

The societal culture component recognizes the potential impact of the producers on society and host communities as a whole. In other words, the commercial production of biochar and related business cannot succeed when the host society fails. Therefore, the social culture component leverages the concept of 'sustainable value'[40]; to acknowledge the potential impact of the biobased products on host communities and the bioeconomy, and how though bioeconomy positively influences society.

Non-governmental organizations (NGOs) and Community-Based Organizations (CBOs) also form part of the societal culture space as they carry social agendas through advocacy and influencing societal culture in the businesses (Table 17).

Governance

The governance component captures both the organizational structures and decision-making policies of the biochar producers or firms. The governance looks at the key stakeholders such as district local governments (DLG), agro-input dealers, processors, government agencies, farmers and other product off-takers; the producer firms often profile and engage them in scaling commercial production of the bio-based products. The four main governance aspects for biochar production are i) ownership of business firms as cooperative, for profit or not ventures, privately owned for-profit, publicly traded, or under the public-private partnership

[39] Nespresso, 2015. Our Values at Nespresso. Careers at Nespresso, available at: http://www.careersatnespresso.com/working-at-nespresso/our-values/

[40] Laszlo, C., 2008. Sustainable Value: How the World's Leading Companies Are Doing Well by Doing Good. Stanford University Press.

(PPP) arrangement, ii) internal organizational structures (e.g., organizational hierarchy, production and functional units, product specialization), iii) organigram and decision-making policies (e.g., organization policies, transparency, consultation and non-financial criteria), and iv) the shareholding and profit sharing arrangements. Each of these factors shall influence how the producers engage stakeholders and external parties in creating social value as an autonomous business unit for the commercial production of biochar, water treatment and trade (Table 17).

Scale of outreach

The scale of outreach describes the depth and breadth of relationships built between the producers or firms and the key stakeholders through their production and marketing activities over time. In this regard, the scale of outreach for bio-based products includes: i) developing long-term and integrative relationships between both the producers or entrepreneurs and stakeholders; ii) the outreach of impact of producer-stakeholder relationship across spatial scales and geographically at the local, regional and global focus; iii) the impact of the producer-stakeholder relationship as to whether or how they address societal differences such as locally interpreting core ethical and or cultural actions across different consumer societies and cultures. The deep and diverse outreach will be achieved when creating supplementary social programs such as gender mainstreaming, language education and micro-credit programs for its production, supply and marketing value chains (Table 17).

End-users

The end-users are the persons at the end of the product value chain who ultimately use/ consume the value proposition. Under the business model analysis, the end-users component describes how the value proposition of the bio-based products addresses the needs of the end-users by contributing to the quality of life or livelihood. The users with similar needs for the biochar water filter products are segmented on the relevant socio-economic and demographic profiles like spatial location, sex, age, income, ethnicity, education level, effective demand, farm size, crop type, agronomy and farming systems, among the other cross-cutting factors (Table 17).

Social impacts

The social impacts component addresses the social costs related to the production and marketing of bio-based products, and in this case, biochar as a water filtration product. It also complements and extends both the financial costs of the economic layer and the bio-physical impacts of the environmental layer of the TLBMC (Tables 15-17). Based on the commonest social impact metrics of Benoît-Norris[41], the social impact indicators will include working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs), among others.

On the other hand, a few negative social impacts for biochar products could stem from misinformation and misuse by the farmers, which may also compromise the performance of the biochar upon application at domestic water facilities. The low performance of the biochar products could also disrupt the existing cultural farming and social practices, and eventual retard the progress made in the promotion of climate-smart

[41] Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., Mazijn, B., 2011. Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. Int. J. Life Cycle Assess. 16 (7), 682e690.

technologies in integrated water management within the Bio4Africa target communities. In response, product misinformation and misuse shall be averted by establishing a robust and effective product quality management system coupled with the provision of demand-driven advisory, extensions and training services in sustainable water use (Table 17).

Social benefits

The social benefits are the positive social value created by the production of novel bio-based products. The social benefit component considers the interpersonal and cultural benefits derived from the new products (e.g., biochar as a new water filtration product). In this case, the social benefits confirmed for the biochar products are social costs, capacity building and training opportunities for communities in integrated water management (Table 17). Table 17 presents a summary of the social layer of the Triple Layered Business Model Canvas (TLBMC) for biochar as the novel medium for water filtration and water treatment product.

Table 17: Environmental layer of the TLBMC for the Biochar powder as a medium for water filtration

<table>
<tr><th>Local Communities</th><th>Governance</th><th>Social Value</th><th>Societal Culture</th><th>End Users</th></tr>
<tr>
<td rowspan="3">Stakeholders (e.g., biochar producers, traders and suppliers)
Local businesses (e.g., water suppliers, outlet dealers and commercial traders)
District local governments (DLGs) and farmer institutions for capacity building in integrated water management</td>
<td>Stakeholder involvement in the product value chain
Ownership of business firms
Internal organizational structures
Shareholding and profit sharing arrangements</td>
<td rowspan="3">Water filtration and Water treatment
Supply of clean water resources
Developing long-term value from the mutually beneficial with the stakeholders
Ecosystems restoration through recycling wastewater and crop residues</td>
<td>Sustainable values
Societal and cultural spaces (NGOs and CBOs) for advocacy and influencing societal culture in the biochar and water businesses</td>
<td rowspan="3">End-user segmentation based on socio-economic and demographic profiles (e.g., sex, age, income, ethnicity, education level, effective demand, farm size, crop type, agronomy and farming systems)</td>
</tr>
<tr><th>Employees</th><th>Scale of Outreach</th></tr>
<tr>
<td>Labour force & staff profiles (skills and qualifications of staff)
Salient social demographics of staff (thus variations in sex, payments, gender and education levels).</td>
<td>Long-term and integrative relationships for producers and stakeholders
Outreach and impact of the producer-stakeholder relationships</td>
</tr>
<tr><th colspan="2">Social Impacts</th><th colspan="3">Social Benefits</th></tr>
<tr><td colspan="2">Social impact metrics such as working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs).</td><td colspan="3">Social costs, capacity-building training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and a resilient bioeconomy.</td></tr>
</table>

3.2.6 The Triple Layered Business Model for the press cakes as ruminant feeds (e.g., cattle)

Table 18 presents the Triple Layered Business Model (TLBM) for the press cakes as ruminant feeds

Table 18: The TLBMC for the press cakes as ruminant feeds

A	Partners	Activities	Value Proposition	Customer Relationship	Customer Segments
Economic Business Model Canvas	○ Subsistence farmers ○ Commercial farmers ○ Agro-input dealers ○ District local government ○ Community leaders	○ Livestock production ○ Milk and beef trade ○ Climate-smart farming ○ Training ○ Feed storage/ conservation **Resources** ○ Physical resources ○ Financial resources	○ Increased access to feeds ○ Provision of quality feeds ○ Reduced costs of feeds ○ Integrated feed management ○ Feed conservation	○ After-sales service ○ Agribusiness training ○ Direct sales ○ Competitive prices **Channels** ○ Mass media ○ Social media ○ Farmer institutions	○ Subsistence farmers ○ Commercial farmers ○ Agro-input dealers ○ NGOs and CBOs
	Costs		**Revenues**		
	○ Capital investment in the infrastructure; ○ Cost of raw materials ○ Labour costs, ○ Operational expenses ○ Marketing costs		○ Direct sale of bio-feeds ○ Seed funding ○ Equity finance ○ Intellectual property for novel bio-feeds		
B	**Supplies and Out-sourcing**	**Production**	**Functional Value**	**End of Life**	**Use Phase**
Environmental Lifecycle Business Model Canvas	Importation of machinery Production of raw materials (e.g., crop biomass & feedstock) Supply of utilities (e.g., feeds)	Transformation of raw materials into biochar Provision of support services **Materials** Livestock farms; Livestock types; Labour force	Recycling of waste biomass into high-quality feeds Modification of the feeding systems for higher productivity Supply of quality-assured feeds	Recycling of agricultural biomass Climate-smart feed production **Distribution** Train, trucks and air transport	Last-mile access to bio-feeds by farmers Low-cost feeding Green dairying Agribusiness
	Environmental Impacts		**Environmental Benefits**		
	Reduced greenhouse gas emissions from the livestock production systems		Climate change mitigation Climate-smart livestock production systems		

C	Local Communities	Governance	Social Value	Societal Culture	End User
Social Stakeholder Business Model Canvas	Stakeholders (e.g., producers, traders and suppliers) Local agribusinesses (e.g., agro-input dealers, traders and commercial farmers) District local governments (DLGs) and farmer institutions	Stakeholder involvement Ownership of business firms Shareholding and profit sharing arrangements	Increased incomes Increased food and nutritional security Improved livelihoods of farmers Socio-economic transformation of societies	Sustainable values Societal and cultural spaces (NGOs and CBOs)	End-user segmentation based on livestock types and farming systems
		Employees		Scale of Outreach	
		Casual labour force Farm managers		Medium to long-term use on-farm	
	Social Impacts		Social Benefits		
	- Production of quality feeds - Increased supply of feeds - High milk and beef yields - Saves time collecting pastures and forages		Social costs, capacity-building training opportunities for the farmers and other end-users, agribusiness opportunities and community development.		

3.2.7 *The Triple Layered Business Model for the protein concentrate as feed supplements for livestock, poultry and fisheries*

The Bio4Africa project seeks to engage value chain actors at the different nodes of the feed value chain and support the commercial production of livestock feeds and protein fish feed supplements. The feed resources are adapted to the local context and needs of the Bio4Africa target communities, and the producers are to sustain the supply of the products to farmers under a business mode. In this regard, a sustainable business model for bio-based feed products, namely livestock feeds and protein fish feed supplements, was developed under the Bio4Africa project Task T5.2. The outcome of the analysis of the sustainable business is also presented in Tables 19-21, using the typical skeleton of the triple-layered business model canvas (TLBMC) as shown in Annexe 2.

i) Economic layer of the TLBMC for protein concentrate as feed supplements for livestock, poultry and fisheries

The economic aspects of the Triple Layered Business Model Canvas (TLBMC) for livestock feed and protein fish feed supplements are illustrated in Table 19.

Key partners

The network of partners that make the TLBMC for the feed resources work are farmers and suppliers of raw materials, mainly the crop biomass feedstock for feed processing, industrial partners and feed processors who are engaged during feed processing or conservation, and academic and research institutions (e.g., universities and agricultural research bodies); who execute applied feed research to find new applications. Other partners are agro-input dealers and traders who act as the off-takers of novel feed resources. The subsistence and commercial farmers are the final beneficiaries and end-users of the novel feed resources, namely livestock feeds and protein fish feed supplements.

Key activities

The key activities include; i) collection of the raw biomass and other feedstock materials from the farming communities and other suppliers, ii) feedstock reception and warehousing, iii) feedstock processing that involves grading and strict quality control such as checking for moisture levels, dry matter content and phytosanitary aspects (e.g., dust contamination levels and free from crop pests, residual chemicals like pesticides and fertilizers), iii) the primary production of the feeds using the established biorefinery facilities, iv) processing of the feeds into concentrated protein meals, v) optimizing the biorefinery technology to fit into existing operations for scaling commercial feed production, vi) conduct efficacy feed trails to accelerate adoption by traders and farmers as the target customers and off-takers, vii) marketing activities (branding, registration, patenting of the feed products, and advertising), and viii) trade activities to support market entry, market penetration and customer retention (Table 19).

Key resources

The key resources are needed for the feed producers to create value. There are four key resource categories, physical resources, human resources, financial resources and intellectual resources. The physical resources are; i) raw biomass materials as feedstocks (e.g., crop residues), ii) a small-scale facility for recycling biomass into nutritious animal feeds; iii) land and infrastructure to support feed production, iv) marketing and product distribution outlets and networks. The human resources include competent and highly-skilled staff, skilled and semi-skilled labour force, and joint ventures). The financial resources are capital assets, seed funding, grants, equity financing, angel investments, venture capital, and private investments. The intellectual resources are the intangible assets that encompass technical know-how, patents, user rights for production, and marketing of feeds (Table 19).

Value proposition

The main value proposition is the replacement of conventional feeds that accelerate greenhouse gas pollution and ecological deterioration with eco-friendly feed products, such as livestock feeds and protein fish feed supplements. There are tailored sustainable agribusiness solutions for the production and trade of high-quality feed resources in the form of feed producers, processors, and input dealerships, among others. A scalable solution to recycle excess agriculture residues or biomass into valuable feed-quality and storable protein feed products with high nutritional profiles, thereby implementing a new sustainable, circular bioeconomy in Africa. Protein from crop biomass with a protein content of up to 60%) is suitable for dairy cattle, fish, poultry and other livestock, providing essential amino acids, which are easily digestible and are usually low in the conventional feeds sold on the informal markets. The substrate that remains after the isolation of protein and amino acids during feed processing has a fertilizer value, and in this case, the by-products are a good source of organic fertilizers. The novel feed resources are a good source of safe feed products adaptable to a wide range of livestock and organic food production systems, making the food value chains more eco-friendly or sustainable (Table 19).

Customer relationships

Maintaining a good customer relationship is important for attracting more clients, creating more strong brand loyalty, market penetration and increasing market share for novel bio-based products. For the livestock feeds and protein fish feed supplements, the foremost customer relationship will be through both the 'Business to Business (B2B)' and 'Business to Customers (B2C)' sales strategies (Table 19).

As such, the feed producers and entrepreneurs shall maintain a close customer relationship with traders and off-takers through competitive feed production and marketing services, including maintaining friendly pre-booking systems, aftersales services, and attractive and competitive pricing of the bio-feed products. The producers will offer direct sales to clients based on the product quality and effective demand from the customer clusters and also ensure effective and sustainable product distributorship outlets. The producers will also implement flexible trade systems for the customers, including offering advance purchase and supply contracts with dedicated off-takers and deferred payment systems[42]. The entrepreneurs shall build robust product traceability and quality assurance systems to prevent the duplication and counterfeits of the feed products once put on the markets. The main focus of the initiatives is to create sustainable relationships with the clients and customer base and ultimately build trust and brand loyalty for the new feed products offered.

Customer segments

The main customer segment for bio-feeds, namely livestock feeds and protein fish feed supplements, are farmers using the feed resource to boost livestock productivity. The other customer segments are the input dealers, Non-governmental Organizations (NGOs) and Community-based Organizations (CBOs), who are engaged in the trade and promotion of eco-friendly, sustainable and climate-smart agricultural technologies and innovations. Other customer clusters are academic institutions (e.g., universities, schools and colleges) and public research institutions that use novel feed products for research studies, extension and technology promotion purposes (Table 19).

Channels

The entrepreneurs shall exploit existing channels to reach the customers and also raise awareness about the bio-feed products. The producers will use personal contacts and customer referrals which shall be blended with the farmer institutions and district local government (DLG) departments. These channels shall promote eco-friendly food production and the use of new bio-based feed products. In addition, mass media channels such as radios and TVs and electronic and social media will be used to advertise the novel bio-based feed products and also increase awareness across the local and international communities. The entrepreneurs will advertise the feeds products using newspapers, magazines and home-delivered flyers. Existing agricultural trade shows and exhibitions coupled with the farmer institutions, community leaders and village meetings will also be used as grass root channels for marketing the livestock feeds and protein fish feed supplements and reaching out to potential customers even in remote locations or rural communities (Table 19).

Costs

The costs that arise in the feed business shall be incurred and monitored by the feed producers. The costs will come from the key activities, resources, and the building and maintaining key partnerships that are highly required to engage in commercial production and marketing of feeds. The producers start with the cost related to the initial investment in the infrastructure for the feed production facilities, including the cost of

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[42] Babich, V. and Tang, C.S., 2012. Managing opportunistic supplier product adulteration: Deferred payments, inspection, and combined mechanisms. Manufacturing & Service Operations Management, 14(2), pp.301-314.

production, raw biomass materials, labour and related operational expenses, as well as the marketing costs. In addition, the maintenance costs are incurred to run the commercial feed production business more efficiently. Nonetheless, the purchase of biomass feedstock requires constant investment, which could be significantly reduced through economies of scale when larger quantities of the feedstock per purchase are bought from dedicated suppliers. Other costs are equipment and technology costs (e.g., green biorefinery reactors) and maintenance costs (Table 19).

Revenue streams

Revenue streams from the commercial production of feeds shall be generated by selling the produced bio-based feeds in the form of livestock feeds and protein fish feed supplement products directly to the farmers and other customer segments. Additional revenue will be generated from the expertise and intellectual property accrued by running pilot biorefinery facilities from which the operators and host entities shall benefit. These extra revenue benefits may appear by presenting the best-practice business models to venture capitalists and angel investors, as well as providing technical knowledge about novel feed production facilities to third parties for financial compensation. Lastly, revenue shall be obtained from the sales of marketing services such as logistics, distribution network, product supply and delivery contracts to the dedicated off-takers (Table 19).

Table 19: Economic layer of the TLBMC for protein concentrate as feed supplements

Partners	Activities	Value Proposition	Customer Relationship	Customer Segments
Farmers and suppliers of raw materials Industrial partners and feed processor Academic and research institutions (e.g., universities and agricultural research bodies) Agro-input dealers and traders Subsistence farmers Commercial farmers	Collection of raw biomass and feedstock materials; Feedstock reception and warehousing Feedstock processing (grading and quality control) Primary production of the feeds Optimizing biorefinery technology to support commercial production Conduct efficacy feed trials to accelerate the adoption Marketing to attract and retain customers Trade of feeds	Eco-friendly livestock feeds Sustainable agribusiness solutions for feed production and trade Recycling of excess agriculture residues or biomass into the valuable feed-quality Supply of feeds with essential amino acids; Production of organic fertilizers from feed by-products. Safe feed products	Business to Business (B2B) and Business Customers' sales strategies competitive feed production and marketing services (e.g., pre-booking systems, aftersales services, attractive and competitive pricing) Direct sales to clients based Flexible trade systems for the customers, including the offering of advance purchase and supply contracts with dedicated	Farmers (subsistence and commercial farmers) Agro-input dealers or traders NGOs CBOs Academic institutions (e.g., universities, schools and colleges), Public research institutions

		adaptable to a wide range of livestock and organic food production system	off-takers (e.g., deferred payment systems) Robust product traceability and quality assurance systems	
	Resources		**Channels**	
	Physical resources (e.g., land, infrastructure, raw biomass materials and green biorefinery facility and technology) Financial resources (e.g., own capital, seed funding, equity financing, venture capital, grants, angel investments) Local labour force (e.g., joint venture, staff, partnerships, skilled employees) Intellectual resources (e.g., patents, user rights)		Personal contacts and customer referrals Farmer institutions; District local government (DLG); Mass media channels (e.g., TVs & Radio); Farmer institutions; community leaders; village meetings	
Costs		**Revenues**		
The initial investment in the infrastructure; Cost of raw materials (Biomass), Labour costs Operational expenses Marketing costs Costs for equipment and technology (e.g., green biorefinery) and maintenance costs.		Direct sale of feeds to farmers and other customers Intellectual property rights Seed funding from venture capitalists and angel investors Sales of marketing services like the logistics, distribution network and supply)		

ii) Environmental layer of the TLBMC for protein concentrate as feed supplements for livestock, poultry and fisheries

The environmental aspects of the Triple Layered Business Model Canvas (TLBMC) for the livestock feeds and protein fish feed supplements under the Bio4Africa project focus countries are illustrated in Table 20.

Supplies and out-sourcing

The supplies and out-sourcing depict several cross-cutting materials and productive activities that are important for the operational value but are not considered 'essential' to producer organizations[43]. Thus,

[43] Stephan, A., Crawford, R. H. 2014. A multi-scale life-cycle energy and greenhouse gas emissions analysis model for residential buildings. Architectural Science Review, 57(1), 39-48

within the environmental layer, examples of supplies are water, electricity, raw materials, and green biorefinery facilities. The raw materials (e.g., biomass or feedstock), water, and electricity are locally produced. Therefore, the supplies are outsourced from dedicated local suppliers ranging from farmers for biomass feedstock and private institutions and government agencies for the water and electricity supplies.

However, there is no in-country production of modern equipment, mainly green biorefinery reactors. These biorefinery facilities used for feed production are imported from technology manufacturers in Europe. As such, the feed producers have no and/ or little influence in the production and supply of green biorefinery machines. In future, the local producers shall take more control over the production of modern machinery and maintenance actions by, for example, creating machinery production units and utility services (Table 20).

Production

The production component extends the foremost components of the key activities from the economic layer to the environmental layer of the TLBMC and captures the core activities or arrangements in place that the organization should undertake to create value. Production for the producers of novel feeds involves transforming biomass (as the primary raw and unfinished materials) into higher-value feed outputs. The production aspects involve the administration and management of feed production facilities, personnel, ICT infrastructures, logistics, warehousing, marketing, and trade (Table 20).

Functional value

The functional value describes the main points of focus of the products and services output delivered by the business. In this regard, the functional value encompasses the five key properties of feeds, namely, i) recycling agricultural waste and biomass into high-quality feeds, ii) supply of sustainable feed products, iii) eco-friendly feed source conservation, and iv) promoting a safer food value chain (Table 20).

Materials

The materials component biophysical stocks are used by the producers or companies to achieve the functional value of the product and services offered. In other words, the materials component is the environmental extension of the key resources for the business. In the case of feed production, the producers purchase and transform biomass feedstock as the primary input physical materials, as well as other physical materials like land, building infrastructure, green biorefineries, machinery, office buildings, furniture, vehicles, and ICT materials (e.g., computers).

Distribution

In the context of the modern TLBMC, distribution involves the transportation of goods or commodities to support primary production. In the case of the feed producers or firms, the distribution represents the physical means by which the farmers and other customers access the novel feed products for use and hence, enjoy their functional value. Distribution is the combination of the modes of transport and the distances travelled and weights of products shipped, as well as the key logistics involved in product packaging and delivery of the feeds. The modes of transport are based on distances, thus road by train or trucks, and air and water shipment to in-country and in-region markets and off-takers (Table 20).

Use phase

The use phase focuses on the environmental impact of the product or service on the customers or end-users in relation to its functional value. The use phase includes maintenance of the feed quality and sustainable supply of feeds based on the type of farm and product requirements from farmers and other off-takers. The novel feed products are organic bio-products that are envisaged to be low-cost and efficient feeds suitable for organic livestock, green dairying, poultry and fisheries enterprises (Table 20).

End of life

End-of-life is when the client opts to end the use of the products or consumption of their functional value. The end-of-life phase often entails matters pertaining to the reuse of materials or secondary by-products, such as the re-manufacturing, re-purposing and the options for res-use/ waste recycling, disassembly, incineration and disposal of by-products or supplementary packaging materials. From an environmental perspective, the end-of-life component supports the feed producers in exploring eco-friendly ways of managing adverse impacts of the feed products on the ecosystems and their impact on ecosystems, such as nitrifications and greenhouse gas pollution upon misuse by farmers. The detrimental impacts to the ecosystems are averted and/ or minimized through waste recycling strategies that also extend the responsibility of using the feed products and their by-products beyond the conceived value propositions. In this regard, feed products present an unexploited potential for the development of circular bioeconomies beyond recycling agricultural waste into feeds, such as the use of feed by-products as bio-fertilizers for organic horticulture and clean energy production[44].

Environmental impact

The environmental impact component addresses the environmental costs of the producers based on the product life cycle, estimated by the Life Cycle Assessment (LCA) tool[45]. Besides all financial costs, the Environmental Impact Assessment (EIA) of the production facility further extends to the ecological costs and biophysical indicators[46]. For the novel feed products, the environmental impact indicator metrics are greenhouse gas (GHG) fluxes (thus, CO_2 emissions and the carbon footprint), animal performance, livestock productivity, impact on human health and ecosystem services.

Environmental benefit

There is a positive correlation relationship between environmental impacts, costs and benefits that extends the value creation of the products and services offered beyond their financial value accrued to the producers, entrepreneurs and/ or promoter firms. The environmental benefits encompass all the ecological value/ advantages the bio-based products or services create through the regenerative positive ecological value or

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[44] Boscolo, M., Lehtonen, P. and Pra, A. 2021. Developing bankable business plans – A learning guide for forest producers and their organizations. Forestry Working Paper No. 24. Rome, FAO. https://doi .org/10. 4060/cb4520en.

[45] De Benedetto, L., Klemes, J., 2009. The Environmental Performance Strategy Map: an integrated LCA approach to support the strategic decision-making process. J. Clean. Prod. Early-Stage Energy Technol. Sustain. Future 17 (10), 900e906.

[46] Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R., 2003. IMPACT 2002þ: a new life cycle impact assessment methodology. Int. J. Life Cycle Assess. 8 (6), 324e330.

conserving the integrity of the natural ecosystems and its key services. The environmental benefits of feed products shall be estimated using the LCA approach.

The benefits of feeds shall depend on the design of biorefinery facilities, which includes parameters such as type of biomass feedstock, operational temperatures, application rates of the feeds, nutrition of feeds, waste recycling and disposal practices. The environmental benefits include recycling agricultural wastes into high-value feeds, mitigating greenhouse gas pollution in livestock production systems, feed conservation and ecosystem restoration for green dairying. In this regard, the green biorefinery and other feed production systems are designed to maximize product quality and ultimately take full advantage of the environmental impacts and benefits of the feeds (Table 20). Table 20 shows the schematic depiction of the Environmental layer of the Triple Layered Business Model Canvas (TLBMC) for the feeds.

Table 20: Environmental layer of the TLBMC for protein concentrate as feed supplements

<table>
<tr><th>Supplies and Out-sourcing</th><th>Production</th><th>Functional Value</th><th>End of Life</th><th>Use Phase</th></tr>
<tr><td rowspan="3">Importation of machinery and equipment (e.g., biorefinery reactors)

Production of raw materials (e.g., crop biomass & feedstock)

Supply of utilities (e.g., water and electricity)</td><td>Transformation of raw materials into feed resources

Provision of support services (e.g., ICT, logistics, marketing & trade, warehouse, and administration</td><td rowspan="3">Recycling agricultural waste and biomass into high-quality feeds

Supply of sustainable feed products,

Eco-friendly feed source conservation,

Promotion of a safer food value chain</td><td>Recycling of agricultural waste

Transformation of the feed by-products into fertilizers

Clean energy production</td><td rowspan="3">Maintenance of product quality for the feeds

Maintain a sustainable supply of feeds

Provision of low-cost and efficient feeds suitable for organic livestock, green dairying, poultry and fisheries enterprises</td></tr>
<tr><td>Materials</td><td>Distribution</td></tr>
<tr><td>Physical materials: land, building infrastructure, green biorefineries, machinery, office buildings, furniture, vehicles, and ICT materials (e.g., computers).</td><td>Modes of transport (e.g., train or trucks, and air & water shipment)

Distances travelled</td></tr>
<tr><td colspan="2">Environmental Impacts</td><td colspan="3">Environmental Benefits</td></tr>
<tr><td colspan="2">Greenhouse gas (GHG) fluxes (e.g., CO_2 emissions and carbon footprint), animal performance, livestock productivity, impact on human health and ecosystem services.</td><td colspan="3">Recycling agricultural wastes into high-value feeds, mitigating greenhouse gas pollution in the livestock production systems, feed conservation and ecosystem restoration for green dairying.</td></tr>
</table>

iii) Social layer of the TLBMC for protein concentrate as feed supplements for livestock, poultry and fisheries

The social aspects of the Triple Layered Business Model Canvas (TLBMC) for the feeds are in Table 21. The social layer of the TLBMC is informed by the data obtained through a stakeholder approach that captures the mutual benefits and influences between both the producers and stakeholders. Also, the social layer captures the key social impacts of the feed products derived from the producer and the stakeholder relationships. Employing the bottom-up approach in building the social layer provides a better understanding of the primary social impacts and insight for exploring ways to innovate along the production and marketing cycles of the feeds to create social value and improve its potential. By leveraging the new stakeholder approach, the nine components of the social layer of the TLBMC are discussed below.

Communities

Whereas the economic relationships are built between the producer and their business partners, the social relationships are built between the producers, suppliers and the local host communities. In the context of the TLBMC for the feeds, stakeholders ranging from the feed producers, suppliers, and traders (e.g., farmers and other off-takers) constitute a community that influences production and maintains mutually beneficial relationships. Local agribusinesses such as agro-input dealers, commercial farmers and traders will work with the district local governments (DLGs), and farmer institutions shall lead training and media campaigns towards stimulation of interest for scaling commercial production and adoption of the feed products (Table 21).

Employee

The employee component considers the role of staff and workforce in the production cycle and at the core organizational stakeholder. The employee factors considered are the number, skills and qualifications of the employees, as well as their salient social demographics, such as variations in sex, payments/ salaries, gender, ethnicity, and education levels within the producer organizations. In addition, the employee component also encompasses employee-oriented programs, primarily tailored capacity-building training, professional development and other support programs that also contribute to the viability and success of the feed producer organizations and firms (Table 21).

Social value

The social value speaks to the mission of producers that focuses on creating important benefits for the stakeholders and society in a broader context. For sustainable feed production, creating social value is likely a clear part of its mission. The intended social value is interpreted in the context of the product "roadmap for sustainable growth"[47], as one of the core competencies is developing long-term value from the mutually beneficial relationships between the producers and stakeholders. The social values for feed production are; i) enhancing the quality of consumers' lives by offering eco-friendly, safe and healthy food production systems, ii) developing long-term value from the mutually beneficial with the farmers and stakeholders, and iii) safe foods and ecosystems restoration (Table 21).

[47] Nespresso, 2015. Our Values at Nespresso. Careers at Nespresso, available at: http://www.careersatnespresso.com/working-at-nespresso/our-values/

Social culture

The societal culture component recognizes the potential impact of the producers on society and host communities as a whole. In other words, the commercial production of feeds and related businesses cannot succeed when the host society fails. Therefore, the social culture component leverages the concept of 'sustainable value'[48]; to acknowledge the potential impact of the quality feed products on host communities and the bioeconomy, and how the bioeconomy positively influences society. Non-governmental organizations (NGOs) and Community-Based Organizations (CBOs) also form part of the societal culture space as they carry social agendas through advocacy and influencing societal culture in the businesses (Table 21).

Governance

The governance component captures both the organizational structures and decision-making policies of the feed producers and firms. The governance also looks at the key stakeholders such as district local governments (DLG), agro-input dealers, processors, government agencies, farmers and other product off-takers; the producer firms often profile and engage them in scaling commercial production of the bio-based feed products. The four main governance aspects for feed production are: i) the ownership of business firms as cooperative, for profit or not ventures, privately owned for-profit, publicly traded, under public-private partnership arrangement, ii) internal organizational structures (e.g., organizational hierarchy, production and functional units, product specialization), iii) organigram and decision-making policies (e.g., organization policies, transparency, consultation and non-financial criteria), and iv) shareholding and profit sharing (PPP) arrangements. Each of these factors shall influence how the producers engage stakeholders and external parties in creating social value as an autonomous business unit for the commercial production of feeds.

Scale of outreach

The scale of outreach describes the depth and breadth of relationships built between the producers or firms and the key stakeholders through their production and marketing activities over time. In this regard, the scale of outreach for bio-based products includes: i) developing long-term and integrative relationships between both the producers or entrepreneurs and stakeholders (e.g., farmers); ii) the outreach of impact of producer-stakeholder relationship across spatial scales and geographically at the local, regional and global focus; iii) the impact of the producer-stakeholder relationship as to whether or how they address societal differences such as locally interpreting core ethical and or cultural actions across different consumer societies and cultures. The deep and diverse outreach will be achieved when creating supplementary social programs such as gender mainstreaming, language education and micro-credit programs for its production, supply and marketing value chains (Table 21).

End users

The end-users are the persons at the end of the product value chain who ultimately use/ consume the value proposition. Under the business model analysis, the end-users component describes how the value proposition of the bio-based products addresses the needs of the end-users by contributing to the quality of

[48] Laszlo, C., 2008. Sustainable Value: How the World's Leading Companies Are Doing Well by Doing Good. Stanford University Press.

life or livelihood. The users with similar needs for the bio-based animal feed products are segmented on the relevant socio-economic and demographic profiles such as spatial location, sex, age, income, ethnicity, education level, effective demand, farm size, type of livestock and local farming systems, among the other cross-cutting factors (Table 21).

Social impacts

The social impacts component addresses the social costs related to the production and marketing of bio-based feed products. It also complements and extends both the financial costs of the economic layer and the bio-physical impacts of the environmental layer of the TLBMC (Tables 20-22). Based on the commonest social impact metrics of Benoît-Norris[49], the social impact indicators will include working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs), among others.

Social benefits

The social benefits are the positive social value created by the production of novel bio-based products. The social benefit component considers the interpersonal and cultural benefits derived from the new animal feed products. In this case, the social benefits confirmed for the animal feed products are social costs, capacity building and training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and a resilient bioeconomy under Bio4Africa project host communities (Table 21). Table 21 presents a summary of the social layer of the Triple Layered Business Model Canvas (TLBMC) for animal feeds.

Table 21: Social layer of the TLBMC for protein concentrate as feed supplements

Local Communities	Governance	Social Value	Societal Culture	End Users
Stakeholders (e.g., producers, traders and suppliers) Local agribusinesses (e.g., agro-input dealers, traders and commercial farmers) District local governments (DLGs) Farmer institutions and farmer groups	Stakeholder involvement in the product value chain Ownership of business firms Internal organizational structures Shareholding and profit sharing arrangements	Enhance the quality of consumer's lives through bioeconomy Develop long-term value from the mutually beneficial with the farmers and stakeholders	Sustainable values Societal and cultural spaces (NGOs and CBOs) Social agendas through advocacy and influencing societal culture in the businesses	End-user segmentation based on socio-economic and demographic profiles (e.g., sex, age, income, ethnicity, education level, effective demand, farm size, type of livestock
	Employees		Scale of Outreach	

[49] Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., Mazijn, B., 2011. Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. Int. J. Life Cycle Assess. 16 (7), 682e690.

	Labour force & staff profiles (skills and qualifications of staff) Salient social demographics of staff	Ecosystem restoration actions	Long-term and integrative relationships for producers and stakeholders Outreach and impact of the producer-stakeholder relationships	agronomy and farming systems)
Social Impacts		Social Benefits		
Social impact metrics such as working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs).		Social costs, capacity-building training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and a resilient bioeconomy.		

3.2.8 The Triple Layered Business Model for the whey as monogastric feeds

Table 22 presents the Triple Layered Business Model (TLBM) for whey as monogastric feeds (e.g., pigs and piglets).

Table 22: The TLBMC for the whey as monogastric feeds

A	Partners	Activities	Value Proposition	Customer Relationship	Customer Segments
Economic Business Model Canvas	○ Subsistence farmers ○ Commercial farmers	○ Livestock production ○ Climate-smart farming ○ Training ○ Feed conservation	○ Increased access to whey ○ Provision of quality whey ○ Reduced costs of feeds ○ Integrated feed management ○ Feed conservation	○ After-sales service ○ Direct sales ○ Competitive prices	○ Subsistence farmers ○ Commercial farmers ○ Agro-input dealers
		Resources		Channels	
		○ Physical resources ○ Financial resources ○ IP resources		○ Mass media ○ Social media ○ Farmer institutions	
	Costs		Revenues		
	○ Capital ○ Raw materials ○ Marketing costs		○ Direct sale of bio-feeds ○ Seed funding ○ Equity finance		
B	Supplies and Out-sourcing	Production	Functional Value	End of Life	Use Phase

Environmental Lifecycle Business Model Canvas	Importation of machinery and equipment Production of raw materials (e.g., crop biomass & feedstock) Supply of utilities (e.g., feeds)	Transformation of raw materials into whey Provision of training and other support services	Recycling of waste biomass into high-quality feeds Modification of the feeding systems for higher productivity Supply of quality-assured feeds	Recycling of agricultural biomass Climate-smart feed production	Last-mile access to bio-feeds by farmers Low-cost feeding Green dairying Agribusiness
		Materials		Distribution	
		Livestock farms; Livestock types; Labour force		Train, trucks and air transport	
	Environmental Impacts		Environmental Benefits		
	Reduced greenhouse gas emissions from the livestock production systems		Climate change mitigation Climate-smart livestock production systems		
C	Local Communities	Governance	Social Value	Societal Culture	End User
Social Stakeholder Business Model Canvas	Stakeholders (e.g., producers, traders and suppliers) Local agribusinesses (e.g., agro-input dealers, traders and commercial farmers) District local governments (DLGs) and farmer institutions	Stakeholder involvement Ownership of business firms Shareholding and profit sharing arrangements	Increased incomes Increased food and nutritional security Improved livelihoods of farmers Socio-economic transformation of societies	Sustainable values Societal and cultural spaces (NGOs and CBOs)	End-user segmentation based on livestock types and farming systems
		Employees		Scale of Outreach	
		Casual labour force Farm managers		Medium to long-term use on-farm	
	Social Impacts		Social Benefits		
	- Production of quality feeds - Increased supply of feeds - High milk and beef yields - Saves time collecting pastures and forages		Social costs, capacity-building training opportunities for the farmers and other end-users, agribusiness opportunities and community development.		

3.2.9 The Triple Layered Business Model for the Fish Feed Pellets

The Bio4Africa project seeks to engage value chain actors at the different nodes of the feed value chain and support the commercial production of fish feed pellets. The feed resources are adapted to the local context and needs of the Bio4Africa target communities, and the producers are to sustain the supply of the products to farmers under a business mode. In this regard, a sustainable business model for bio-based feed products, namely fish feed pellets, was developed under the Bio4Africa project Task T5.2. The outcome of the analysis of the sustainable business is also presented in Tables 23-25, using the typical skeleton of the triple-layered business model canvas (TLBMC) as shown in Annexe 2.

i) Economic layer of the TLBMC for the Fish Feed Pellets

The economic aspects of the Triple Layered Business Model Canvas (TLBMC) for the fish feed pellets are illustrated in Table 23.

Key partners

The network of partners that make the TLBMC for the feed resources work are farmers and suppliers of raw materials, mainly the crop biomass feedstock for feed processing, industrial partners and feed processors who are engaged in the feed processing or conservation, and academic and research institutions (e.g., universities and agricultural research bodies); who execute applied feed research to find new applications. Other partners are agro-input dealers and traders who act as the off-takers of novel feed resources. The subsistence and commercial farmers are the final beneficiaries and end-users of the novel feed resources, namely fish feed pellets.

Key activities

The key activities include; i) collection of raw biomass and other feedstock materials from the farming communities and other suppliers, ii) feedstock reception and warehousing, iii) feedstock processing that involves grading and strict quality control like checking for moisture levels, dry matter content and phytosanitary aspects (e.g., dust contamination levels and free from the crop pests, residual chemicals like pesticides and fertilizers), iii) the primary production of the feeds using the established pelletisation and densification facilities, iv) processing of the feeds into concentrated protein meals, v) optimizing the pelletisation and densification technology to fit into existing operations for scaling commercial feed production, vi) conduct efficacy feed trails to accelerate adoption by traders and farmers as the target customers and off-takers, vii) marketing activities (branding, registration, patenting of the feed products, and advertising), and viii) trade activities to support market entry, market penetration and customer retention (Table 23).

Key resources

The key resources are needed for the feed producers to create value. There are four key resource categories, physical resources, human resources, financial resources and intellectual resources. The physical resources are; i) raw biomass materials as feedstocks (e.g., crop residues), ii) a small-scale facility for recycling biomass into nutritious feeds; iii) land and infrastructure to support feed production, iv) marketing and product distribution outlets and networks. The human resources include competent and highly-skilled staff, skilled and semi-skilled labour force, and joint ventures).

The financial resources are capital assets, seed funding, grants, equity financing, angel investments, venture capital, and private investments. The intellectual resources are the key intangible assets that encompass technical know-how, patents, user rights for production, and marketing of feeds (Table 23).

Value proposition

The main value proposition is the replacement of conventional feeds that accelerate greenhouse gas pollution and ecological deterioration with eco-friendly feed products, such as fish feed pellets. There are tailored sustainable agribusiness solutions for the production and trade of high-quality feed resources in the form of feed producers, processors, and input dealerships, among others. A scalable solution to recycle excess agriculture residues or biomass into valuable feed-quality and storable protein feed products with high nutritional profiles, thereby implementing a new sustainable, circular bioeconomy in Africa. Protein from the crop biomass with a protein content of up to 60%) is suitable for dairy cattle, fish, poultry and other livestock, providing essential amino acids, which are easily digestible and are usually low in the conventional feeds sold on the informal markets. The substrate that remains after the isolation of protein and amino acids during feed processing has a fertilizer value, and in this case, the by-products are a good source of organic fertilizers. The novel feed resources are a good source of safe feed products adaptable to a wide range of livestock and organic food production systems, making food value chains more eco-friendly or sustainable.

Customer relationship

Maintaining a good customer relationship is important for attracting more clients, creating more strong brand loyalty, market penetration and increasing market share for novel bio-based products. For the fish feed pellets, the foremost customer relationship will be through both the Business Business (B2B) and Business Customers' sales strategies.

In this regard, the feed pellet producers and entrepreneurs shall maintain a close customer relationship with traders and off-takers through competitive feed production and marketing services, including maintaining friendly pre-booking systems, aftersales services, and attractive and competitive pricing of the bio-feed products. The producers will offer direct sales to clients based on the product quality and effective demand from the customer clusters and also ensure effective and sustainable product distributorship outlets. The producers will also implement flexible trade systems for the customers, including offering advance purchase and supply contracts with dedicated off-takers and deferred payment systems[50]. The entrepreneurs shall build robust product traceability and quality assurance systems to prevent the duplication and counterfeits of the feed products once put on the markets. The main focus of the initiatives is to create sustainable relationships with the clients and customer base and ultimately build trust and brand loyalty for the new feed products offered.

Customer segments

The main customer segment for bio-feeds, namely fish feed pellets, are farmers using the feed resource to boost livestock productivity. Other customer segments are input dealers, Non-governmental Organizations (NGOs) and Community-based Organizations (CBOs), who are engaged in the trade and promotion of eco-friendly, sustainable and climate-smart agricultural technologies and innovations. Other customer clusters are academic institutions (e.g., universities, schools and colleges) and public research institutions that use novel feed products for research studies, extension and technology promotion purposes.

Channels

The entrepreneurs shall exploit existing channels to reach the customers and also raise awareness about the bio-feed products. The producers will use personal contacts and customer referrals which shall be blended with the farmer institutions and district local government (DLG) departments. These channels shall promote

[50] Babich, V. and Tang, C.S., 2012. Managing opportunistic supplier product adulteration: Deferred payments, inspection, and combined mechanisms. Manufacturing & Service Operations Management, 14(2), pp.301-314.

eco-friendly food production and the use of new bio-based feed products. In addition, mass media channels such as radios and TVs and electronic and social media will be used to advertise the novel bio-based feed products and also increase awareness across the local and international communities. The entrepreneurs will advertise the feeds products using newspapers, magazines and home-delivered flyers. Existing agricultural trade shows and exhibitions coupled with the farmer institutions, community leaders and village meetings will also be used as grass root channels for marketing the fish feed pellets and reaching out to potential customers even in remote locations or rural communities (Table 23).

Costs

The costs that arise in the feed business shall be incurred and monitored by the feed producers. The costs will come from the key activities, resources, and the building and maintaining key partnerships that are highly required to engage in commercial production and marketing of feeds. The producers start with the cost related to the initial investment in the infrastructure for the feed production facilities, including the cost of production, raw materials, labour and related operational expenses, as well as the marketing costs. In addition, the maintenance costs are incurred to run the commercial feed production business more efficiently. Nonetheless, the purchase of biomass requires investment, which could be significantly reduced through economies of scale when larger quantities of feedstock per purchase are bought from dedicated suppliers. Other costs are equipment and technology (e.g., pelletisation and densification) and maintenance.

Revenue streams

Revenue streams from the commercial production of feeds shall be generated by selling the produced bio-based feeds in the form of livestock feeds and protein fish feed supplement products directly to the farmers and other customer segments. Additional revenue will be generated from the expertise and intellectual property accrued by running pilot pelletisation and densification facilities from which the operators and host entities shall benefit. These extra revenue benefits may appear by presenting the best-practice business models to venture capitalists and angel investors, as well as providing technical knowledge about novel feed production facilities to third parties for financial compensation. Lastly, revenue shall be obtained from the sales of marketing services like logistics, distribution network, and supply contracts to the dedicated off-takers (Table 23).

Table 23: Economic layer of the TLBMC for fish feed pellets

<table>
<tr><th>Partners</th><th>Activities</th><th>Value Proposition</th><th>Customer Relationship</th><th>Customer Segments</th></tr>
<tr>
<td rowspan="3">Farmers and suppliers of raw materials
Industrial partners and feed processor
Academic and research institutions (e.g., universities and agricultural research bodies)
Agro-input dealers and traders
Subsistence farmers
Commercial farmers</td>
<td>Collection of raw biomass and feedstock materials;
Feedstock reception and warehousing
Feedstock processing (grading and quality control)
Primary production of the feeds
Conduct efficacy feed trials to accelerate the adoption
Marketing to attract and retain customers
Trade of feeds</td>
<td rowspan="3">Eco-friendly livestock feeds
Sustainable agribusiness solutions for feed production and trade
Recycling of excess agriculture residues or biomass into the valuable feed-quality
Supply of feeds with essential amino acids;
Production of organic fertilizers from feed by-products.</td>
<td>Business to Business (B2B) and Business Customers' sales strategies
competitive feed production and marketing services (e.g., pre-booking systems, aftersales services, attractive and competitive pricing)
Direct sales to clients based
Flexible trade systems for the customers</td>
<td rowspan="3">Farmers (subsistence and commercial farmers)
Agro-input dealers or traders
NGOs
CBOs
Academic institutions (e.g., universities, schools and colleges),
Public research institutions</td>
</tr>
<tr><th>Resources</th><th>Channels</th></tr>
<tr>
<td>Physical resources (e.g., land, infrastructure, raw biomass materials and pelletisation and densification facility and technology)
Financial resources (e.g., own capital, seed funding, equity financing, venture capital, grants, angel investments)
Local labour force (e.g., joint venture, staff, partnerships, skilled employees)
Intellectual resources (e.g., patents, user rights)</td>
<td>Personal contacts and customer referrals
Farmer institutions;
District local government (DLG);
Mass media channels (e.g., TVs & Radio);
Social media;
Farmer institutions; community leaders; village meetings</td>
</tr>
<tr><th colspan="2">Costs</th><th colspan="3">Revenues</th></tr>
</table>

The initial investment in the infrastructure; Cost of raw materials (Biomass), Labour costs Operational expenses Marketing costs Costs for equipment and technology (e.g., green biorefinery) and maintenance costs.	Direct sale of feeds to farmers and other customers Intellectual property rights Seed funding from venture capitalists and angel investors Sales of marketing services like the logistics, distribution network and supply)

ii) Environmental layer of the TLBMC for the Fish Feed Pellets

The environmental aspects of the Triple Layered Business Model Canvas (TLBMC) for the fish feed pellets under the Bio4Africa project focus countries are illustrated in Table 24.

Supplies and out-sourcing

The supplies and out-sourcing depict several cross-cutting materials and productive activities that are important for the operational value but are not considered 'essential' to producer organizations[51]. Thus, within the environmental layer, examples of supplies are water, electricity, raw materials, and pelletisation and densification facilities. The raw materials (e.g., biomass or feedstock), water, and electricity are locally produced. Therefore, the supplies are outsourced from dedicated local suppliers ranging from farmers for the biomass feedstock and private institutions and government agencies for the water and electricity supplies.

Production

The production component extends the foremost components of the key activities from the economic layer to the environmental layer of the TLBMC and captures the core activities or arrangements in place that the organization should undertake to create value. Production for the producers of novel feeds involves transforming biomass (as the primary raw and unfinished materials) into higher-value feed outputs. The production aspects involve the administration and management of feed production facilities, personnel, ICT infrastructures, logistics, warehousing, marketing, and trade (Table 24).

Functional value

The functional value describes the main points of focus of the products and services output delivered by the business. In this regard, the functional value encompasses the five key properties of feeds, namely, i) recycling agricultural waste and biomass into high-quality feeds, ii) supply of sustainable feed products, iii) eco-friendly feed source conservation, and iv) promoting a safer food value chain.

Materials

The materials component biophysical stocks are used by the producers or companies to achieve the functional value of the product and services offered. In other words, the materials component is the

[51] Stephan, A., Crawford, R. H. 2014. A multi-scale life-cycle energy and greenhouse gas emissions analysis model for residential buildings. Architectural Science Review, 57(1), 39-48

environmental extension of the key resources for the business. In the case of feed production, the producers purchase and transform biomass feedstock as the primary input physical materials, as well as other physical materials like land, building infrastructure, green biorefineries, machinery, office buildings, furniture, vehicles, and ICT materials (e.g., computers).

Distribution

In the context of the modern TLBMC, distribution involves the transportation of goods or commodities to support primary production. In the case of the feed producers or firms, the distribution represents the physical means by which the farmers and other customers access the novel feed products for use and hence, enjoy their functional value. Distribution is the combination of the modes of transport and the distances travelled and weights of products shipped, as well as the key logistics involved in product packaging and delivery of the feeds. The modes of transport are based on distances, thus road by train or trucks, and air and water shipment to in-country and in-region markets and off-takers (Table 24).

Use phase

The use phase focuses on the environmental impact of the product or service on the customers or end-users in relation to its functional value. The use phase includes maintenance of the feed quality and sustainable supply of feeds based on the type of farm and product requirements from farmers and other off-takers. The novel feed products are organic bio-products that are envisaged to be low-cost and efficient feeds suitable for organic livestock, green dairying, poultry and fisheries enterprises (Table 24).

End of life

End-of-life is when the client opts to end the use of the products or consumption of their functional value. The end-of-life phase often entails matters pertaining to the reuse of materials or secondary by-products, such as the re-manufacturing, re-purposing and the options for res-use/ waste recycling, disassembly, incineration and disposal of by-products or supplementary packaging materials. From an environmental perspective, the end-of-life component supports the feed producers in exploring eco-friendly ways of managing adverse impacts of the feed products on the ecosystems and their impact on ecosystems, such as nitrifications and greenhouse gas pollution upon misuse by farmers (Table 24).

The detrimental impacts to the ecosystems are averted and/ or minimized through waste recycling strategies that also extend the responsibility of using the feed products and their by-products beyond the conceived value propositions. In this regard, feed products present an unexploited potential for the development of circular bioeconomies beyond recycling agricultural waste into feeds, such as the use of feed by-products as bio-fertilizers for organic horticulture and clean energy production[52].

Environmental impact

The environmental impact component addresses the environmental costs of the producers based on the product life cycle, estimated by the Life Cycle Assessment (LCA) tool[53]. Besides all financial costs, the

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[52] Boscolo, M., Lehtonen, P. and Pra, A. 2021. Developing bankable business plans – A learning guide for forest producers and their organizations. Forestry Working Paper No. 24. Rome, FAO. https://doi .org/10. 4060/cb4520en.

[53] De Benedetto, L., Klemes, J., 2009. The Environmental Performance Strategy Map: an integrated LCA approach to support the strategic decision-making process. J. Clean. Prod. Early-Stage Energy Technol. Sustain. Future 17 (10), 900e906.

Environmental Impact Assessment (EIA) of the production facility further extends to the ecological costs and biophysical indicators[54]. For the novel feed products, the environmental impact indicator metrics are greenhouse gas (GHG) fluxes (thus, CO_2 emissions and the carbon footprint), animal performance, livestock productivity, impact on human health and ecosystem services.

Environmental benefits

There is a positive correlation relationship between environmental impacts, costs and benefits that extends the value creation of the products and services offered beyond their financial value accrued to the producers, entrepreneurs and/ or promoter firms. The environmental benefits encompass all the ecological value/ advantages the bio-based products or services create through the regenerative positive ecological value or conserving the integrity of the natural ecosystems and its key services. The environmental benefits of feed products shall be estimated using the LCA approach.

The benefits of feeds shall depend on the design of pelletisation and densification facilities, which includes parameters such as type of biomass feedstock, operational temperatures, application rates of the feeds, nutrition of feeds, waste recycling and disposal practices. The environmental benefits include recycling agricultural wastes into high-value feeds, mitigating greenhouse gas pollution in livestock production systems, feed conservation and ecosystem restoration for green dairying.

In this regard, both the pelletisation and densification and other feed production systems are designed to maximize product quality and ultimately take full advantage of the environmental impacts and benefits of the feeds (Table 24). Table 24 shows a schematic depiction of the Environmental layer of the Triple Layered Business Model Canvas (TLBMC) for the fish feed pellets.

Table 24: Environmental layer of the TLBMC for fish feed pellets

<table>
<tr><th>Supplies and Out-sourcing</th><th>Production</th><th>Functional Value</th><th>End of Life</th><th>Use Phase</th></tr>
<tr><td rowspan="3">Importation of machinery and equipment (e.g., pelletisation and densification devices)
Production of raw materials (e.g., crop biomass & feedstock)
Supply of utilities (e.g., water and electricity)</td><td>Transformation of raw materials into feed resources
Provision of support services (e.g., ICT, logistics, marketing & trade, warehouse, and administration</td><td rowspan="3">Recycling agricultural waste and biomass into high-quality feeds
Supply of sustainable feed products,
Eco-friendly feed source conservation,
Promotion of a safer food value chain</td><td>Recycling of agricultural waste
Transformation of the feed by-products into fertilizers
Clean energy production</td><td rowspan="3">Maintenance of product quality for the feeds
Maintain a sustainable supply of feeds
Provision of low-cost and efficient feeds suitable for organic livestock, green dairying, poultry and</td></tr>
<tr><td>Materials</td><td>Distribution</td></tr>
<tr><td></td><td></td></tr>
</table>

[54] Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R., 2003. IMPACT 2002þ: a new life cycle impact assessment methodology. Int. J. Life Cycle Assess. 8 (6), 324e330.

	Physical materials: land, building infrastructure, green biorefineries, machinery, office buildings, furniture, vehicles, and ICT materials (e.g., computers).		Modes of transport (e.g., train or trucks, and air & water shipment) Distances travelled	fisheries enterprises
Environmental Impacts		Environmental Benefits		
Greenhouse gas (GHG) fluxes (e.g., CO_2 emissions and carbon footprint), animal performance, livestock productivity, impact on human health and ecosystem services.		Recycling agricultural wastes into high-value feeds, mitigating greenhouse gas pollution in the livestock production systems, feed conservation and ecosystem restoration for green dairying.		

ii) Social layer of the TLBMC for the Fish Feed Pellets

The social aspects of the Triple Layered Business Model Canvas (TLBMC) for the fish feed pellets are in Table 25. The social layer of the TLBMC is informed by the data obtained through a stakeholder approach that captures the mutual benefits and influences between both the producers and stakeholders. Also, the social layer captures the key social impacts of the feed products derived from the producer and the stakeholder relationships. Employing the bottom-up approach in building the social layer provides a better understanding of the primary social impacts and insight for exploring ways to innovate along the production and marketing cycles of the feeds to create social value and improve its commercialization potential. By leveraging the new stakeholder approach, the nine components of the social layer of the TLBMC are discussed below.

Communities

Whereas the economic relationships are built between the producer and their business partners, the social relationships are built between the producers, suppliers and the local host communities. In the context of the TLBMC for the feeds, stakeholders ranging from the feed producers, suppliers, and traders (e.g., farmers and other off-takers) constitute a community that influences production and maintains mutually beneficial relationships. Local agribusinesses such as agro-input dealers, commercial farmers and traders will work with the district local governments (DLGs), and farmer institutions shall lead training and media campaigns towards stimulation of interest for scaling commercial production and adoption of the feed products (Table 25).

Employee

The employee component considers the role of staff and workforce in the production cycle and at the core organizational stakeholder. The employee factors considered are the number, skills and qualifications of the employees, as well as their salient social demographics, such as variations in sex, payments/ salaries, gender, ethnicity, and education levels within the producer organizations. In addition, the employee component also encompasses employee-oriented programs, tailored capacity-building training, professional development and other support programs that contribute to the viability and success of the feed producer organizations and firms (Table 25).

Social value

The social value speaks to the mission of producers that focuses on creating important benefits for the stakeholders and society in a broader context. For sustainable feed production, creating social value is likely a clear part of its mission. The intended social value is interpreted in the context of the product "roadmap for sustainable growth"[55], as one of the core competencies is developing long-term value from the mutually beneficial relationships between the producers and stakeholders. The social values for feed production are; i) enhancing the quality of consumers' lives by offering eco-friendly, safe and healthy food production systems, ii) developing long-term value from the mutually beneficial with the farmers and stakeholders, and iii) safe foods and ecosystems restoration.

Societal culture

The societal culture component recognizes the potential impact of the producers on society and host communities as a whole. In other words, the commercial production of feeds and related businesses cannot succeed when the host society fails. Therefore, the social culture component leverages the concept of 'sustainable value'[56]to acknowledge the potential impact of quality feed products on host communities and the bioeconomy, and how the bioeconomy positively influences society. Non-governmental organizations (NGOs) and Community-Based Organizations (CBOs) also form part of the societal culture space as they carry social agendas through advocacy and influencing societal culture in the businesses (Table 25).

Governance

The governance component captures both the organizational structures and decision-making policies of the feed producers and firms. The governance also looks at the key stakeholders such as district local governments (DLG), agro-input dealers, processors, government agencies, farmers and other product off-takers; the producer firms often profile and engage them in scaling commercial production of the bio-based feed products. The four main governance aspects for feed production are: i) the ownership of business firms as cooperative, for profit or not ventures, privately owned for-profit, publicly traded, under the public-private partnership (or the PPP) arrangement, ii) internal organizational structures (e.g., organizational hierarchy, production and functional units, product specialization), iii) organigram and decision-making policies (e.g., organization policies, transparency, consultation and non-financial criteria), and iv) shareholding and profit sharing arrangements. Each of these factors shall influence how the producers engage stakeholders and external parties in creating social value as an autonomous business unit for the commercial production of feeds (Table 25).

Scale of outreach

The scale of outreach describes the depth and breadth of relationships built between the producers or firms and the key stakeholders through their production and marketing activities over time. In this regard, the scale

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[55] Nespresso, 2015. Our Values at Nespresso. Careers at Nespresso, available at: http://www.careersatnespresso.com/working-at-nespresso/our-values/

[56] Laszlo, C., 2008. Sustainable Value: How the World's Leading Companies Are Doing Well by Doing Good. Stanford University Press.

of outreach for bio-based products includes i) developing long-term and integrative relationships between both the producers or entrepreneurs and stakeholders (e.g., farmers); ii) the outreach of impact of producer-stakeholder relationship across spatial scales and geographically at the local, regional and global focus; iii) the impact of the producer-stakeholder relationship as to whether or how they address societal differences such as the locally interpreting core ethical and or cultural actions across different consumer societies and cultures. The deep and diverse outreach will be achieved when creating supplementary social programs such as gender mainstreaming, language education and micro-credit programs for its production, supply and marketing value chains (Table 25).

End users

The end-users are the persons at the end of the product value chain who ultimately use/ consume the value proposition. Under the business model analysis, the end-users component describes how the value proposition of the bio-based products addresses the needs of the end-users by contributing to the quality of life or livelihood. The users with similar needs for the bio-based fish feed products are segmented on the relevant socio-economic and demographic profiles such as spatial location, sex, age, income, ethnicity, education level, effective demand, farm size, type of livestock and local farming systems, among the other cross-cutting factors (Table 25).

Social impacts

The social impacts component addresses the social costs related to the production and marketing of bio-based feed products. It also complements and extends both the financial costs of the economic layer and the bio-physical impacts of the environmental layer of the TLBMC (Tables 24 and 25). Based on the commonest social impact metrics of Benoît-Norris[57], the social impact indicators will include working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs), among others.

Social benefits

The social benefits are the positive social value created by the production of novel bio-based products. The social benefit component considers the interpersonal and cultural benefits derived from the fish feed products. In this case, the social benefits confirmed for the feed products are social costs, capacity building and training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and a resilient bioeconomy under Bio4Africa project host communities (Table 25). Table 25 presents a summary of the social layer of the Triple Layered Business Model Canvas (TLBMC) for fish feed pellets.

[57] Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., Mazijn, B., 2011. Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. Int. J. Life Cycle Assess. 16 (7), 682e690.

Table 25: Social layer of the TLBMC for fish feed pellets

<table>
<tr><th>Local Communities</th><th>Governance</th><th>Social Value</th><th>Societal Culture</th><th>End Users</th></tr>
<tr><td rowspan="3">Stakeholders (e.g., producers, traders and suppliers)
Local agribusinesses (e.g., agro-input dealers, traders and commercial farmers)
District local governments (DLGs)
Farmer institutions and farmer groups</td><td>Stakeholder involvement in the product value chain
Ownership of business firms
Internal organizational structures
Shareholding and profit sharing arrangements</td><td rowspan="3">Enhance the quality of consumer's lives through bioeconomy
Develop long-term value from the mutually beneficial with the farmers and stakeholders
Ecosystem restoration actions</td><td>Sustainable values
Societal and cultural spaces (NGOs and CBOs)
Social agendas through advocacy and influencing societal culture in the businesses</td><td rowspan="3">End-user segmentation based on socio-economic and demographic profiles (e.g., sex, age, income, ethnicity, education level, effective demand, farm size, type of livestock agronomy and farming systems)</td></tr>
<tr><th>Employees</th><th>Scale of Outreach</th></tr>
<tr><td>Labour force & staff profiles (skills and qualifications of staff)
Salient social demographics of staff</td><td>Long-term and integrative relationships for producers and stakeholders
Outreach and impact of producer-stakeholder relationships</td></tr>
<tr><th colspan="2">Social Impacts</th><th colspan="3">Social Benefits</th></tr>
<tr><td colspan="2">Social impact metrics such as working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs).</td><td colspan="3">Social costs, capacity-building training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and a resilient bioeconomy.</td></tr>
</table>

3.2.10 The Triple Layered Business Model for the bioplastics and biocomposites

The Bio4Africa project seeks to engage value chain actors at the different nodes of the feed value chain and support the commercial production of bioplastics and biocomposites. The feed resources are adapted to the local context and needs of the Bio4Africa target communities, and the producers are to sustain the supply of the products to farmers under a business mode. A sustainable business model for bio-based feed products, namely bioplastics and biocomposites, was developed under the Bio4Africa project Task T5.2. The outcome of the detailed analysis of the sustainable business is also presented in Tables 26-28, using the typical skeleton of the triple-layered business model canvas (TLBMC) as shown in Annexe 2.

i) Economic layer of the TLBMC for the Fish Feed Pellets

The economic aspects of the new Triple Layered Business Model Canvas (TLBMC) for novel bioplastics and biocomposites are illustrated in Table 26.

Key partners

Key partner segments include the large-scale manufacturer; government agencies (e.g., ministries of agriculture, water and environment), the city councils and municipality management authorities; NGOs and other (non-profit) associations. Less common but more unique partners are the local private sector partners with business start-ups/SMEs engaged in recycling plastics and manufacturing eco-friendly packaging materials. Other value chain actors such as product distributors and users (e.g., supermarkets or companies that sold bulk biomass and finished packaging products); suppliers of parts like metals, glass, and plastic; regulatory compliance agencies; biotechnology companies and final marketing and distribution partners.

Key activities

In general, the key activities tend to vary between organizations depending on the overarching focus and field of work for waste recycling, technology promotion and the use for commercial production of bioplastics and biocomposites. Unique activities are cultivation or collection of plant biomass as the raw materials; manufacturing of the final bioplastics and biocomposites products; customized system design and training of staff in production and marketing, bioprocessing process development and optimization; marketing and trade of final bioplastics and biocomposites (Table 26).

Key resources

The key resources are needed for the feed producers to create value. There are four key resource categories, physical resources, human resources, financial resources and intellectual resources. The physical resources are; i) raw biomass materials as feedstocks (e.g., crop residues), ii) a small-scale facility for the production of bioplastics and biocomposites; iii) land and infrastructure to support feed production, iv) marketing and product distribution outlets and networks. The human resources include competent and highly-skilled staff, skilled and semi-skilled labour force, and joint ventures).

The financial resources are capital assets, seed funding, grants, equity financing, angel investments, venture capital, and private investments. The intellectual resources are the key intangible assets that encompass technical know-how, patents, user rights for production, and marketing of new products (Table 26).

Key value proposition

Bioplastics and biocomposites are crafted from plant-based biomass substances. The plant-based oils make the bioplastics and biocomposites enhance their performance, making them less brittle and more flexible. For example, a typical bioplastic cup is transparent, flexible and durable. Also, bioplastics produce minimal greenhouse gases than conventional plastics over their lifespan or upon disposal. Other value proposition elements are: they can be recycled for reuse, product safety without or with minimal plastic pollution, improved food safety, eco-friendly and make better use of natural resources and are better for business through attracting eco-conscious customers.

Customer relationship

Maintaining a good customer relationship is important for attracting more clients, creating more strong brand loyalty, market penetration and increasing market share for novel bio-based products. For the bioplastics and biocomposites, the foremost customer relationship will be through both the Business to Business (B2B) and Business Customers' sales strategies. Entrepreneurs shall maintain a close customer relationship with traders and off-takers through competitive feed production and marketing services, including maintaining pre-booking systems, aftersales services, and attractive and competitive pricing of bio-based products. The producers will offer direct sales to clients based on the product quality and effective demand from the customer clusters and also ensure effective and sustainable product distributorship outlets. The producers will also deploy flexible trade systems for the customers, including offering advance purchase and supply contracts with dedicated off-takers and deferred payment systems[58].

Customer segments

The main customer segment for bioplastics and biocomposites are SMEs and companies that use the products as packaging materials and for construction purposes, such as supermarkets, food traders, retail shops, and manufacturing companies, among others. Other customer segments are input dealers, local Non-governmental Organizations (NGOs) and Community-based Organizations (CBOs), who are engaged in trade and promotion of eco-friendly, sustainable and climate-smart agricultural technologies and innovations. Other customer clusters are the academic institutions (e.g., universities, schools and colleges) and public research institutions that use novel feed products for research studies, extension and technology promotion purposes.

Channels

The entrepreneurs shall exploit existing channels to reach the customers and also raise awareness about the novel bio-based products. The producers will use personal contacts and customer referrals which shall be blended with the district local government (DLG) departments. These channels shall promote eco-friendly food production and the use of bioplastics and biocomposites. In addition, mass media channels such as radios and TVs and electronic and social media will be used to advertise bio-based products and increase awareness across communities. The entrepreneurs will advertise the bioplastics and biocomposites products using newspapers, magazines and home-delivered flyers. Existing agricultural trade shows and exhibitions coupled with the farmer institutions, community leaders and village meetings will be used as grass root channels for marketing the bioplastics and biocomposites and reaching out to potential customers even in remote locations or rural communities (Table 26).

Costs

The costs that arise in the business of recycling biomass into bioplastics and biocomposites shall be incurred and monitored by the producers. The costs will come from the key activities, resources, and the building and maintaining key partnerships that are highly required to engage in the production and marketing of bioplastics and biocomposites. The producers start with the cost related to the initial investment in the infrastructure for the new production facilities, including the cost of production, raw biomass materials, labour and other related operational expenses, as well as the marketing costs. In addition, maintenance costs are incurred to run the business more efficiently and effectively. Nonetheless, the purchase of the biomass

[58] Babich, V. and Tang, C.S., 2012. Managing opportunistic supplier product adulteration: Deferred payments, inspection, and combined mechanisms. Manufacturing & Service Operations Management, 14(2), pp.301-314.

feedstock requires constant investment, which could be significantly reduced through economies of scale when larger quantities of the got per purchase are bought from dedicated suppliers (Table 26).

Revenue streams

Revenue streams from the commercial production of bioplastics and biocomposites shall be generated by selling the products directly to the farmers and other customer segments. Additional revenue will be generated from the expertise and intellectual property accrued by running pilot facilities from which the operators and host entities shall benefit. These extra revenue benefits appear by presenting the best-practice business models to venture capitalists and angel investors whilst providing technical knowledge regarding the novel production facilities to third parties for financial compensation. Lastly, revenue shall be obtained from the sales of marketing services such as logistics, distribution network, product supply and delivery contracts to the dedicated off-takers (Table 26).

Table 26: Social layer of the TLBMC for the bioplastics and biocomposites

Partners	Activities	Value Proposition	Customer Relationship	Customer Segments
Large-scale manufacturer Governments agencies (e.g., ministries of agriculture, water and environment) City councils/ municipality management authorities; NGOs and other (non-profit) associations Private sector partners Product distributors and users, and suppliers of parts Regulatory compliance agencies Biotechnology companies Marketing and distribution partners.	Cultivation or collection of plant biomass as the raw materials; Technology promotion Manufacturing of the final bioplastics and biocomposites products Customized system design and training of staff in production and marketing Bioprocessing process development and optimization Marketing Trade of final bioplastics and biocomposites	Eco-friendly products Better product performance (durability and flexibility) Product recycling for re-use, Better product safety without or with minimal plastic pollution, Improved food safety Eco-friendly use of natural resources Products are better for business	Business to Business (B2B) and Business Customers' sales strategies Competitive feed production and marketing services (e.g., pre-booking systems, aftersales services, attractive and competitive pricing) Direct sales to clients based Flexible trade systems for the customers, Robust product traceability and quality assurance systems	Companies and SMEs such as supermarkets, food traders, retail shops, manufacturing companies NGOs CBOs Academic institutions (e.g., universities, schools and colleges), Public research institutions
	Resources		Channels	
	Physical resources (e.g., land, infrastructure, raw biomass materials and production technology) Financial resources (e.g., own capital, seed funding,		Personal contacts and customer referrals Farmer institutions;	

	equity financing, venture capital, grants, angel investments) Local labour force (e.g., joint venture, staff, partnerships, skilled employees) Intellectual resources (e.g., patents, user rights)		District local government (DLG); Mass media channels (e.g., TVs & Radio); Social media; Agricultural trade exhibitions Farmers, village meetings	
Costs		Revenues		
Investment in infrastructures; raw materials (Biomass), Labour costs Operational expenses Marketing costs Equipment and technology, and maintenance costs.		Direct sale of the bioplastics and biocomposites to the farmers and other customers Intellectual property rights Seed funding from venture capitalists and angel investors Sales of marketing services like the logistics, distribution network and supply)		

ii) Environmental layer of the TLBMC for the Fish Feed Pellets

The environmental aspects of the Triple Layered Business Model Canvas (TLBMC) for bioplastics and biocomposites under the Bio4Africa project focus countries are illustrated in Table 27.

Supplies and out-sourcing

The supplies and out-sourcing depict several cross-cutting materials and productive activities that are important for the operational value but are not considered 'essential' to producer organizations[59]. Thus, within the environmental layer, examples of supplies are water, electricity, raw materials, and production facilities. The primary raw materials (e.g., biomass or feedstock), water, and electricity are locally produced. Therefore, the input supplies are outsourced from dedicated local suppliers ranging from farmers for the biomass feedstock and private institutions and government agencies for the water and electricity supplies (Table 27).

Production

The production component extends the foremost components of the key activities from the economic layer to the environmental layer of the TLBMC and captures the core activities or arrangements in place that the organization should undertake to create value. Production action involves transforming biomass (as the primary raw and unfinished materials) into marketable bioplastics and biocomposite products. The key production aspects involve the administration and management of feed production facilities, personnel, ICT infrastructures, logistics, warehousing, marketing, and trade (Table 27).

[59] Stephan, A., Crawford, R. H. 2014. A multi-scale life-cycle energy and greenhouse gas emissions analysis model for residential buildings. Architectural Science Review, 57(1), 39-48

Functional value

The functional value describes the main points of focus of the products and services output delivered by the business. In this regard, the functional value encompasses the five properties of bioplastics and biocomposites, namely, i) recycling agricultural waste and biomass into high-quality bioplastics and biocomposite products, ii) supply sustainable bioplastics and biocomposite products, iii) promotion of safer food value chains and iv) Eco-friendly production of non-agricultural commodities.

Materials

The materials component biophysical stocks are used by the producers or companies to achieve the functional value of the product and services offered. In other words, the materials component is the environmental extension of the key resources for the business. In the case of bioplastics and biocomposite, the local producers purchase and transform biomass feedstock as the primary input physical materials, and other physical materials like land, building infrastructure, production facilities, machinery, office buildings, furniture, vehicles, and ICT materials (e.g., computers).

Distribution

In the context of the modern TLBMC, distribution involves the transportation of goods or commodities to support primary production. In the case of the producers or firms, the distribution represents the physical means by which the customers access the novel bioplastics and biocomposite products for use and hence, enjoy their functional value. Distribution is the combination of the modes of transport and the distances travelled and weights of products shipped, as well as the key logistics involved in product packaging and delivery of the bioplastics and biocomposite. The modes of transport are based on distances, thus road by train or trucks, and air and water shipment to in-country and in-region markets and off-takers (Table 27).

Use phase

The use phase focuses on the environmental impact of the product or service on the customers or end-users in relation to its functional value. The use phase includes maintenance of the quality and sustainable supply of bioplastics and biocomposites based on the market needs. The novel products are organic bio-products that are envisaged to be low-cost and efficient materials suitable for the local business environment (Table 27).

End of life

End-of-life is when the client opts to end the use of the products or consumption of their functional value. The end-of-life phase often entails matters pertaining to the re-use of materials or secondary by-products such as the re-manufacturing, re-purposing and the options for res-use/ waste recycling, disassembly, incineration and disposal of by-products or supplementary packaging materials. From an environmental perspective, the end-of-life component supports the producers in exploring eco-friendly ways of managing adverse impacts of the bioplastics and biocomposites products on the ecosystems and their impact on ecosystems, e.g., greenhouse gas pollution upon misuse by clients. The detrimental impacts to the ecosystems are averted and/ or minimized through waste recycling strategies that also extend the responsibility of using the feed products and their by-products beyond the conceived value propositions. In this regard, bioplastics and biocomposite products present an unexploited potential for the development of circular bioeconomies beyond environmental protection[60].

Environmental impact

The environmental impact component addresses the environmental costs of the producers based on the product life cycle, estimated by the Life Cycle Assessment (LCA) tool[61]. Besides all financial costs, the Environmental Impact Assessment (EIA) of the production facility further extends to the ecological costs and biophysical indicators[62]. For the novel bioplastics and biocomposites products, the environmental impact indicator metrics are greenhouse gas (GHG) fluxes (thus, CO_2 emissions and carbon footprint), impact on human health, quality of water, air and other ecosystem services.

Environmental benefits

There is a positive correlation relationship between environmental impacts, costs and benefits that extends the value creation of the products and services offered beyond their financial value accrued to the producers, entrepreneurs and/ or promoter firms. The environmental benefits encompass all the ecological value/ advantages the bio-based products or services create through the regenerative positive ecological value or conserving the integrity of the natural ecosystems and its key services. The environmental benefits of feed products shall be estimated using the LCA approach.

Below are the environmental benefits of the bioplastics and biocomposites products: i) saving non-renewable sources of energy through conserving petroleum supplies when the natural biomass sources, including crops, are used as the raw materials in the production process, ii) Climate change mitigation by reducing greenhouse gas pollution when biodegradable plastic is produced to replace conventional plastics; iii) Consumes less energy during the production process as opposed to the polymerization process for the conventional plastic products, iv) provides an eco-friendly solution in the form of materials for packaging products, home-use and construction purposes, v) materials for circular bioeconomy, since the bioplastics and biocomposites products are biodegradable, and also recycled for re-use (Table 8). Table 8 shows a schematic depiction of the Environmental layer of the Triple Layered Business Model Canvas (TLBMC) for the bioplastics and biocomposites products.

Table 27: Environmental layer of the TLBMC for the bioplastics and biocomposites

Supplies and Out-sourcing	Production	Functional Value	End of Life	Use Phase
Importation of machinery and equipment (e.g., production facilities)	Transformation of raw materials into bioplastics and biocomposite products	Recycling agricultural waste and biomass into high-quality bioplastics and biocomposite products		Maintenance of the quality and sustainable supply of bioplastics and biocomposites

[60] Boscolo, M., Lehtonen, P. and Pra, A. 2021. Developing bankable business plans – A learning guide for forest producers and their organizations. Forestry Working Paper No. 24. Rome, FAO. https://doi .org/10. 4060/cb4520en.
[61] De Benedetto, L., Klemes, J., 2009. The Environmental Performance Strategy Map: an integrated LCA approach to support the strategic decision-making process. J. Clean. Prod. Early-Stage Energy Technol. Sustain. Future 17 (10), 900e906.
[62] Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R., 2003. IMPACT 2002þ: a new life cycle impact assessment methodology. Int. J. Life Cycle Assess. 8 (6), 324e330.

Production of raw materials (e.g., crop biomass & feedstock) Supply of the utilities (e.g., water and electricity)	Provision of support services (e.g., ICT, logistics, marketing & trade, warehouse, and administration	Supply of sustainable bioplastics and biocomposite products Promotion of safer food value chains and iv) Eco-friendly production of non-agricultural commodities.		based on the market needs Promote the use of low-cost and efficient materials suitable for the local business environment
	Materials		Distribution	
	Physical materials: land, building infrastructure, production, machinery, office buildings, furniture, vehicles, and ICT materials (e.g., computers).		Modes of transport (e.g., train or trucks, and air & water shipment) Distances travelled	
Environmental Impacts		Environmental Benefits		
Greenhouse gas (GHG) fluxes (e.g., CO_2 emissions and carbon footprint) impact human health, quality of water, air and other ecosystem services.		Saves non-renewable sources of energy through conserving petroleum supplies; ii) Climate change mitigation; Consumes less energy during the production process; Provides an eco-friendly solution for multiple-use products		

ii) Social layer of the TLBMC for the Fish Feed Pellets

The social aspects of the Triple Layered Business Model Canvas (TLBMC) for both the bioplastics and biocomposites are in Table 9. The social layer of the TLBMC is informed by the data obtained through a stakeholder approach that captures the mutual benefits and influences between both the producers and stakeholders. Also, the social layer captures the key social impacts of the feed products derived from the producer and the stakeholder relationships. Employing the bottom-up approach in building the social layer provides a better understanding of primary social impacts and insight for exploring ways to innovate along the production and marketing cycles of the feeds to create social value and improve its potential. By leveraging the new stakeholder approach, the nine components of the social layer of the TLBMC are discussed below.

Communities

Whereas the economic relationships are built between the producer and their business partners, the social relationships are built between the producers, suppliers and the local host communities. In the context of the TLBMC for the bioplastics and biocomposites, stakeholders range from the producers, suppliers, traders and off-takers. The actors constitute the community that influences production and maintains mutually beneficial relationships between producers and stakeholders (Table 28).

Employee

The employee component considers the role of staff and workforce in the production cycle and at the core organizational stakeholder. The employee factors considered are the number, skills and qualifications of the employees, as well as their salient social demographics, such as variations in sex, payments/ salaries, gender, ethnicity, and education levels within the producer organizations. In addition, the employee component also encompasses employee-oriented programs such as primarily tailored capacity-building training, professional development and other support programs that contribute to the viability and success of the feed producer organizations and firms (Table 28).

Social value

The social value speaks to the mission of producers that focuses on creating important benefits for the stakeholders and society in a broader context. For the sustainable production of bioplastics and biocomposites, creating social value is a clear part of the investment plan. The intended social value is interpreted in the context of the bioplastics and biocomposites "roadmap for sustainable growth"[63], as one of the competencies is developing long-term value from the mutually beneficial relationships between the producers, stakeholders and end-users. The social values for both the bioplastics and biocomposites are; i) enhancing the quality of consumers' lives by offering more eco-friendly, safe and healthy food production systems, ii) developing long-term value from the mutually beneficial with the farmers and stakeholders, and iii) safe foods and ecosystems restoration.

Societal culture

The societal culture component recognizes the potential impact of the producers on society and host communities as a whole. In other words, commercial production and trade of bioplastics and biocomposites cannot succeed when the host society fails. Therefore, the social culture component leverages the concept of 'sustainable value'[64] to acknowledge the potential impact of the bioplastics and biocomposites products on host communities and the bioeconomy, and how though bioeconomy positively influences society. Both Non-governmental organizations (NGOs) and Community-Based Organizations (CBOs) also form part of the societal culture space as they carry social agendas through advocacy and influencing societal culture in the business (Table 28).

Governance

The governance component captures the organizational structures and decision-making policies of the producers and firms for the bioplastics and biocomposites. The governance also looks at the key stakeholders such as district local governments (DLG), agro-input dealers, processors, government agencies, farmers and other product off-takers; the producer firms often profile and engage them in scaling commercial production of the bioplastics and biocomposites products.

The main governance aspects for the production of bioplastics and biocomposites are i) the ownership of business firms as cooperative, for profit or not ventures, privately owned for-profit, publicly traded, under the public-private partnership arrangement, ii) internal organizational structures (e.g., the organizational hierarchy, production and functional facilities, product specialization), iii) organigram and decision-making

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[63] Nespresso, 2015. Our Values at Nespresso. Careers at Nespresso, available at: http://www.careersatnespresso.com/working-at-nespresso/our-values/

[64] Laszlo, C., 2008. Sustainable Value: How the World's Leading Companies Are Doing Well by Doing Good. Stanford University Press.

policies (organization policies, transparency, consultation and non-financial criteria), and iv) shareholding and profit sharing arrangements. Each of the factors shall influence how the producers engage stakeholders and external parties in creating social value as an autonomous business unit for the commercial production of bioplastics and biocomposites (Table 28).

Scale of outreach

The scale of outreach describes the depth and breadth of relationships built between the producers or firms and the key stakeholders through their production and marketing activities over time. In this regard, the scale of outreach for bio-based products includes: i) developing long-term and integrative relationships between both the producers or entrepreneurs and stakeholders; ii) outreach of impact of producer-stakeholder relationship across spatial scales and geographically at the local, regional and global focus; iii) the impact of the producer-stakeholder relationship as to whether or how they address societal differences such as locally interpreting core ethical and or cultural actions across different consumer societies and cultures. The deep and diverse outreach will be achieved when creating supplementary social programs such as gender mainstreaming, language education and micro-credit programs for its production, supply and marketing value chains (Table 28).

End users

The end-users are the persons at the end of the product value chain who ultimately use/ consume the value proposition. Under the business model analysis, the end-users component describes how the value proposition of the bio-based products addresses the needs of the end-users by contributing to the quality of life or livelihood. The users with similar needs for the bioplastics and biocomposites products are segmented on the relevant socio-economic and demographic profiles such as spatial location, sex, age, income, ethnicity, education level, effective demand, type of business or industry, among the other cross-cutting factors (Table 28).

Social impacts

The social impacts component addresses the social costs related to the production and marketing of bioplastics and biocomposites products. It also complements and extends both the financial costs of the economic layer and the bio-physical impacts of the environmental layer of the TLBMC (Tables 7 and 8). Based on the commonest social impact metrics of Benoît-Norris[65], the social impact indicators will include working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs), among others.

Social benefits

The social benefits are positive social values created by producing bioplastics and biocomposites products. The social benefit component considers the interpersonal and cultural benefits derived from the new bioplastics and biocomposites products. In this case, the social benefits confirmed for the animal feed products are social costs, capacity building and training opportunities for the farmers and other end-users, business opportunities, and community engagement by the staff and other employees, partnership by

[65] Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., Mazijn, B., 2011. Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. Int. J. Life Cycle Assess. 16 (7), 682e690.

suppliers, and a resilient bioeconomy under the Bio4Africa project host communities (Table 28). Table 28 presents a summary of a social layer of the Triple Layered Business Model Canvas (TLBMC) for animal feeds.

Table 28: Social layer of the TLBMC for the bioplastics and biocomposites

<table>
<tr><th>Local Communities</th><th>Governance</th><th>Social Value</th><th>Societal Culture</th><th>End Users</th></tr>
<tr><td rowspan="3">Stakeholders (e.g., producers, traders and suppliers)
Producers
Suppliers
Host communities</td><td>Stakeholder involvement in the product value chain
Ownership of business firms
Internal organizational structures
Shareholding and profit sharing arrangements</td><td rowspan="3">Enhance the quality of consumer's lives through bioeconomy
Develop long-term value from the mutually beneficial with users or stakeholders
Ecosystem restoration actions</td><td>Sustainable values
Societal and cultural spaces (NGOs and CBOs)
social agendas through advocacy and influencing societal culture in the businesses</td><td rowspan="3">End-user segmentation is based on socio-economic and demographic profiles (e.g., sex, age, income, ethnicity, education level, effective demand, scale and type of firm or industry.</td></tr>
<tr><th>Employees</th><th>Scale of Outreach</th></tr>
<tr><td>Labour force & staff profiles (skills and qualifications of staff)
Salient social demographics of staff</td><td>Long-term and integrative relationships for producers and stakeholders
Outreach and impact of the producer-stakeholder relationships</td></tr>
<tr><th colspan="2">Social Impacts</th><th colspan="3">Social Benefits</th></tr>
<tr><td colspan="2">Social impact metrics such as working hours, cultural heritage, health and safety, fair competition, community engagement, and respect for intellectual property rights (IPRs).</td><td colspan="3">Social costs, capacity-building training opportunities for the farmers and other end-users, agribusiness opportunities, personal development and community engagement by the staff and other employees, partnership by suppliers, and a resilient bioeconomy.</td></tr>
</table>

4. CONCLUSION, WAY FORWARD AND RECOMMENDATIONS

4.1 Conclusion

4.1.1 Summary of the sustainable business models

This report presents sustainable business models for the bio-based products developed under the Bio4Africa project. The sustainable business model provides a framework in the form of the triple layer business model canvas (TLBMC) to enable a triple bottom line perspective to assess or explore the sustainability of economic, environmental and social impact toward large-scale commercial production of biochar. The sustainable TLBMC presents a suitable tool to expand the economic-centred approach of the new biochar business by developing and integrating the environmental and social canvas layers built from lifecycle and stakeholder perspectives into an extended business model canvas. This expanded TLBMC shall definitely support biochar production using a more robust and holistic approach based on the sustainability-oriented business model innovation. As such, the TLBMC will support producers and stakeholders seeking ways to engage in the large-scale commercial production of biochar and/ or transform their producer organizations and firms for sustainability.

4.1.2 Salient observations and findings made

The choice of feedstock is affected by the availability and access to quality biomass resources in all seasons within the communities. Due to the costs related to the collection, transportation and storage of the raw materials, it makes economic sense for the producers to use local biomass and feedstocks. The producers should look at the ecological effects of the locally-sourced materials as a sustainable option. The primary costs and benefits analysis for the BIO4AFRICA project are highlighted below:

Feedstock production and collection: if the feedstock is a waste biomass residue, such as agricultural waste, logging and/ or crop residues, then commercial production becomes less of an economic issue than if the feedstock input is purposely grown for the production of biochar and feed resources.

Use of trade-off: trade-off includes the likelihood of nutrient loss from feedstock during the process of post-harvest handling of raw materials, especially during transportation and storage operations. In the end, low-quality (or less nutritious) biochar and feed resources are produced, and these bio-based products could be rendered less productive than conventional products. In this regard, the end-users may consider trade-offs with the traditional products, but this could vary across the spatial and temporal scales. For example, chicken litter could be valuable in some rural areas as direct manure and fertilizer, while in peri-urban and urban areas, it is treated as waste and attract higher disposal costs.

Feedstock transportation: When waste biomass is found far from the place where the production of biochar and feeds takes place, transportation costs could be high. In this case, producers could resort to densification of the biomass by chipping or pelletizing before transportation to the production facilities.

Feedstock storage and pre-processing: biomass feedstocks need to be dried and processed before Pyrolysis. Depending on the type of biomass or feedstock selected, the drying process could be done passively through careful storage under shade or could attract more drastic interventions such as the use of modern driers that require both energy and labour. The energy for drying biomass could also be obtained from the pyrolysis process of previous batches of the feedstocks.

4.2 Way forward

4.2.1 Operationalization of the sustainable business models

This section discusses how the modern business models shall be operationalized and employed to support the commercial production of biochar and other related innovations toward more sustainable agribusiness enterprises in the BIO4FRICA project target communities. In this regard, the project team shall engage stakeholders and provide a horizontal coherence within each canvas layer of the TLBMC, thereby developing a deeper understanding of the economic, environmental, and social impacts of the bio-based products (thus the biochar) being promoted across the target countries and farming communities. Similarly, vertical coherence will be ensured by providing clear connections between the three layers of the modern TLBMC, and this will ultimately present a more holistic and integrating perspective of creating sustainable-oriented value propositions for biochar as a biofertilizer and soil amendment product.

Moving forward, the stakeholders, including the producers, traders, community leadership, farmers and other off-takers, will be engaged in field testing of the TLBMC for biochar. The data and feedback provided by the stakeholders from the field-testing exercise will be used as user-centric inputs to inform iterations when upgrading or updating the TLBMC for biochar. During the operation phase, the new updated TLBMC are living to reference sustainable business models that shall be employed in scaling commercial production of the biochar for the dedicated off-taker markets through deferred payment and pre-booking systems[66].

4.2.2 Field testing of the sustainable business models

The biochar producers or firms shall engage the stakeholders and actors at the different nodes of the product value chain from input suppliers, agro-input dealers, farmers, traders and consumers in the field testing of the sustainable business models. During the field-testing exercise, an inclusive and participatory approach shall be employed to work closely with the stakeholders and other actors to uncover the “latent dynamics” for production, trade and use of the biochar and, therefore, jointly innovate towards more sustainable solutions and responsive actions. In addition, different Sustainable Business Models that are running under the Accelerator Program shall be included to amplify the prospects of adding more farmers, producers and different sizes of the business Accelerator Program.

The feedback from the product value chain actors at each field-testing cycle will be employed to creatively explores sustainability-oriented business solutions toward scaling the commercial production of biochar. The stakeholders shall have the opportunity to explore the consequences of changing individual elements of sustainable business models by assessing the cascading impacts of such changes within and across the canvas layers of the modern TLBMC tool.

The updated business models will facilitate the creation and a better understanding of innovative and sustainable business ideas and solutions, highlighting interconnections between vital elements within the contextually-relevant TLBMC customized for each bio-based product. The new TLBMC is a validation tool for starting commercial production and trade of bio-based products in Africa. Thus, the sustainable business models strike a balance between the costs and benefits of commercial enterprises in a more holistic manner

[66] Singh, S., 2018. Supermarket Retailing of Agro-Inputs: A Case Study from Uttar Pradesh. In *Institutional Innovations in the Delivery of Farm Services in India* (pp. 71-159). Springer, New Delhi.

with the economic, environmental and social perspectives. It is against this background that field testing and validation of the TLBMC is essential to explore or weigh in, from a broader systems perspective, the potential economic, social and environmental consequences of scaling commercial production of biochar.

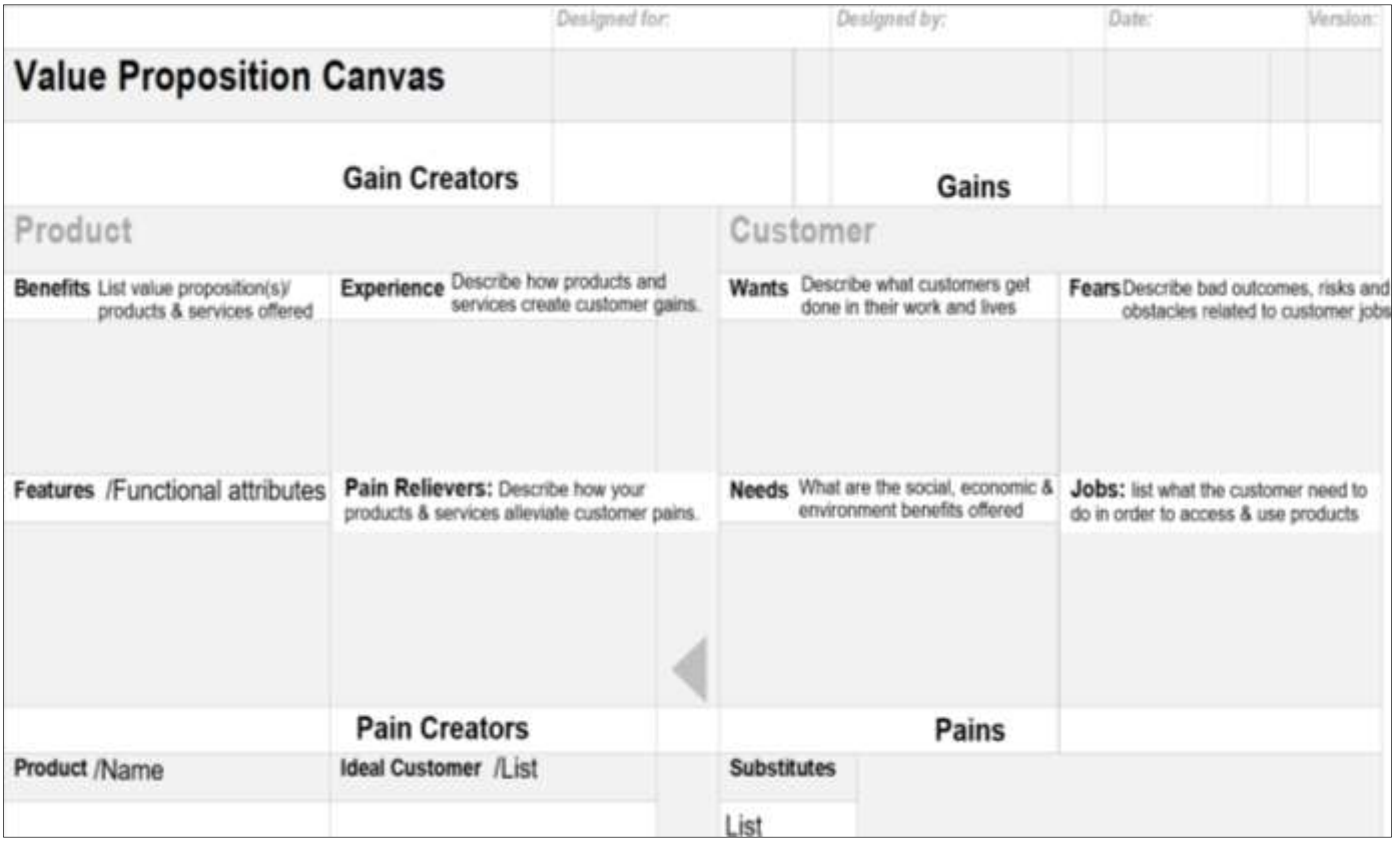
4.3 Recommendations

It is important to assess the aspects of availability and supply of quality raw materials (thus, biomass feedstocks) from the host local communities or other business entities before investing in setting up biochar production and operation facilities. This is because the availability and supply of quality feedstock vary between seasons and within years, courtesy of the subsistence nature of the African traditional agricultural systems that solely depend on natural rains for production. Correspondingly, the seasonal scarcity of biomass could also be caused by the increasing frequencies and severity of adverse climate change vagaries such as dry spells, droughts and erratic rainfall that compromise biomass production across Africa.

Yet in most African communities, biomass feedstocks are often used as energy (heating and cooking fuel). Therefore, biochar production provides an exclusive opportunity for recycling biomass into more eco-friendly products and diversification of sustainable agribusinesses. The biochar produced shall be used on fields to boost soil fertility and potentially increase food production and create more green jobs. In the end, the biochar production will increase incomes, food and nutritional security among the Bio4Africa project communities with cascading impacts on the non-target communities across Africa.

5. LIST OF ANNEXES

5.1 Annexe 1: Template for the Value Proposition Model Canvas used during the workshops to co-design value propositions for the bio-based products



5.2 Annexe 2: Template for the Triple Layered Business Model Canvas (TLBMC) used in the co-designing and development of sustainable business models for the bio-based products

A	Partners	Activities	Value Proposition	Customer Relationship	Customer Segments
Economic Business Model Canvas					
		Resources		Channels	
	Costs		Revenues		

B	Supplies and Out-sourcing	Production	Functional Value	End of Life	Use Phase
Environmental Lifecycle Business Model Canvas					
		Materials		Distribution	
	Environmental Impacts		Environmental Benefits		
C	Local Communities	Governance	Social Value	Societal Culture	End User
Social Stakeholder Business Model Canvas					
		Employees		Scale of Outreach	
	Social Impacts		Social Benefits		

5.3 Annexe 3: Photos for the value proposition workshop in Ghana

5.4 Annexe 4: Photos for the value proposition workshop in Côte d'Ivoire

5.5 Annexe 5: Photos for the value proposition workshop in Senegal

5.6 Annexe 6: Photos for the value proposition workshop in Uganda

6. LIST OF APPENDICES

6.1 Appendix 1: Concept Note for the value proposition design workshop

6.2 Appendix 2: Value proposition workshop reporting template

END

CONCEPT NOTE TO GUIDE THE VALUE PROPOSITION DESIGN WORKSHOP

Workshop Theme:

From Ideas to Action: Designing an all-inclusive, unique, effective and market-centred value proposition to accelerate the commercialization of novel products

Title of the project	Diversifying revenue in rural Africa through circular, sustainable and replicable biobased solutions and business models
Project Acronym	BIO4AFRICA
Under Project Task 5.2	Co-design of inclusive and sustainable business models with farmers and rural communities
Technical Lead	African Forum for Agricultural Advisory Services (AFAAS)
Support Partners	Q-PLAN, SAVANET, iHUB, INP-HB, KRC and UASZ

Prepared by:

African Forum for Agricultural Advisory Services

AFAAS-Uganda

Submission Date: July 11th, 2022

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TABLE OF CONTENTS

SECTION 1: INTRODUCTION

1.1 Background

Food security and climate change are two major development challenges of our time. In Africa, the food system is off track, and the climate is changing profoundly. By 2020, over 35% of the population in Africa faced hunger—more than double the proportion of hungry people in any other region— and about 282 million of Africa's population are undernourished[1]. Yet by 2050, Africa will have more than two billion people to feed whilst coping with adverse environmental, climate and health changes including severe dry spells, droughts, floods, and food-energy poverty among others[2]. Therefore, it is now vital to ensure food security in Africa, and the bioeconomy is set to play a starring role. African agri-food systems can contribute to the continent's food and nutrition security by alleviating poverty and securing food supplies while fostering inclusive, sustainable rural development.

Besides food security, poverty and climate change, other cross-cutting challenges are scarcity of natural resources and sole dependency on environmentally polluting, non-renewable fossil resources such as charcoal, kerosene, and coal for energy. Yet the nature of the bioeconomy in Africa presents an exclusive opportunity to address all the aforesaid inter-connected development challenges.

It is against this background that the BIO4AFRICA project sets off to support the deployment of the bioeconomy in rural Africa through the development of bio-based solutions and value chains with a circular approach to drive the cascading use of local resources and diversify the income of farmers. The BIO4AFRICA is deploying agricultural waste to diversify the income of farmers in Africa by integrating waste into a novel circular bioeconomy and transforming it into high-value products such as animal feed, fertilizer, pollutant absorbents, and cooking fuel etc.

1.2 Brief about the BIO4AFRICA project

The BIO4AFRICA is a 4-year, EU-funded project supported under the prestigious European H2020 Research Innovation Action program. The project is coordinated by the Biomass, wood, energy, products (BioWooEB) research unit at CIRAD, the French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions. The BIO4AFRICA project has 13 African partners (in Senegal, Ivory Coast, Ghana, Uganda and Kenya); and 12 European partners (in France, Greece, Ireland, Spain, and England). The partners are committed to delivering contextually-relevant bioeconomy solutions to increase the incomes, food and nutritional security of farmers whilst propelling agro-industrialisation and green growth in Africa

BIO4Africa will contribute to Africa's food and nutritional security combatting poverty while driving inclusive and sustainable rural development. In other words, the project will support the deployment of the bioeconomy in rural Africa via the development of bio-based solutions and value chains with a circular approach to drive the cascading use of local resources and diversify the income of farmers. The project focus is to transfer novel simple, small-scale, and robust bio-based techs adapted to all

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[1] Holger K., Jenaneshobha S., Braimohpaavo E., Paavo E., Elisteelliot W. Mghenyi. 2022. Adapting Africa's food system to climate change is an imperative; it's time for action. Published on Africa Can End Poverty. https://blogs.worldbank.org/africacan/adapting-africas-food-system-climate-change-imperative-its-time-action

[2] Charles Onyutha., 2021. African food insecurity in a changing climate: The roles of science and policy. Food and Energy Security. https://onlinelibrary.wiley.com/doi/10.1002/fes3.160

the biomass needs and contexts, including the green biorefinery, pyrolysis, hydrothermal carbonisation, and briquetting, pelletising, bio-composites, and bioplastics production. In doing so, the BIO4AFRICA project will empower farmers to sustainably produce a wide variety of higher value and marketable bioproducts and energy, including animal feed, fertilizers, pollutant absorbents, construction materials, packaging, solid fuel for cooking, and ingredients for biogas production, significantly improving the environmental, economic and social performance of their forage agri-food systems.

To this end, BIO4Africa has set up four pilot cases with eight testing sites in Uganda, Ghana, Senegal and Cote d'Ivoire reaching out to and offering more than 300 farmers and farmer groups, including small-scale or subsistence dairies and resource-constrained farmers, women farmer groups and transhumant pastoralists, the opportunity to test them in real production conditions. In total, seven transformation processes are implemented in four pilot zones in Côte d'Ivoire, Ghana, Uganda and Senegal, namely i) green biorefinery, ii) pyrolysis, iii) hydrothermal carbonization, iv) briquetting, v) granulation, vi) bio composites, and vii) bioplastics.

1.3 The context and summary of the bioeconomy model

In developing economies, particularly in Africa, the bioeconomy presents an exclusive opportunity to co-create novel, eco-friendly product lines and demand-driven solutions to fight extreme poverty, acute malnutrition, and food and energy insecurity that affects at least 20% of the population while promoting inclusive rural development. The BIO4AFRICA model is to bring onboard all actors and stakeholders in the bioeconomy to co-create products and solutions with high end-markets.

In March 2022, the first BIO4AFRICA project technology, thus 'a green biorefinery unit' was piloted in Uganda followed by Ghana. At each pilot site, local farmers are profiled and purposively selected to provide essential inputs for the biorefinery, including the residual biomass from the cultivated forage and crop legumes such as alfalfa, manioc bush peas. The biorefinery transforms the green residual biomass into novel products like high nutritious cakes and granules, as the feed of choice for livestock. These foods are very rich in protein making it possible to diversify the diet of livestock.

In Ghana, the granules are easily stored and constitute a useful food for nomadic pastoralists. The biorefinery unit is designed preferably to the size of a container so that it can be easily moved closer to farmers using a flatbed truck. Ultimately, the BIO4AFRICA team aims to increase the production in-take capacity of the residual biomass to over one tonne per hour. But increasing production is also subject to the availability of quality residual biomass, and therefore, dependent on the seasonality of crops (Table 1). Table 1 presents a summary of technologies and bioproducts developed under the BIO4AFRICA project across Uganda, Ghana, Ivory Coast and Senegal.

Another example of a circular bio-recovery process under the BIO4AFRICA project is pyrolysis. Under pyrolysis, the residual biomass is heated to a high temperature without oxygen or under the anaerobic bio-digestion (for biogas production) and is transformed into charcoal and bio-briquettes, respectively. Its products and by-products from pyrolysis provide clean energy for home-cooking thereby saving ecosystem deforestation, bio-fertilizers and biochar for soil fertility and amendment for depolluting and enhancing agriculture productivity (Table 1).

In Côte d'Ivoire, the BIO4AFRICA project has set up pilot water filtration systems that use activated carbon. Equipped with solar pumps, the filtration units could supply at least two villages in the rural areas, not supplied with clean and safe drinking water (Table 1).

Table 1: Summary of Technologies and Bioproducts developed under the BIO4AFRICA project.

Country	Technology & Process	Inputs	Outputs (Bioproducts)	Validation tests
Uganda	- Green biorefinery - HTC - Briquetting	- Protein-rich leguminous plants, Napier(elephant) grasses - Manure, green biorefinery whey	-Animal feed: a) Press cake for ruminants, b) protein concentrate for pigs and poultry, c) whey as animal feed for pigs - Press cake briquettes - Biochar assessed with struvite and manure for soil improvement	- Animal feed trials (cows, pigs, chicken) - Biochar characterization for soil improvement - High-value materials screening in side streams
Ghana	- Green biorefinery - Pyrolysis - Pelletizing	- Various local forage species - Crop residues (corn, yams, cassava, cocoa, sweet potato)	- Animal feed: a) press cake for ruminants, b) protein concentrate for pigs, c) whey for pigs, d) aquaculture protein concentrate - Biochar for soil improvement - Press cake pellets	- Animal feed trials (cows, pigs) - Aquaculture feed trials - Soil experiments (biochar) - High-value materials screening in side streams
Ivory Coast	- Pyrolysis - Pelletizing - Bio-composites/ Bioplastics	- Straw, rice husk, empty cocoa shells, palm seed fibres, palm roundups - Wood processing residues - Cashew nuts, cassava skin, straw, rice husk	- Biomass pellets for animal feed - Biochar granules for adsorption of water pollutants - Bio-composites/ Bioplastics	- Animal feed trials - Tests of water filters using biochar -Bio-composites/ bioplastics tests for their use as packaging
Senegal	- HTC - Briquetting - Pyrolysis - Bio-composites	- Peanut shells, cashew hulls/apples, rice husk, Typha	- Biomass briquettes for solid fuel - Biochar for addition to anaerobic digestion systems (or adsorbent of biogas pollutants) - Bio-composites	-Biochar testing as a solid fuel -Anaerobic digestion tests adding biochar inside the reactor and as pollutants filter -Bio-composites tests to be used as construction materials

Under this overall context, BIO4AFRICA aims to provide rural communities with diverse options for taking up the bio-based solutions into their agri-food systems using bio-based business models that are sustainable. The BIO4AFRICA team will employ analytical and design tools that are well-fit for sustainability-oriented business models and deploy participatory activities to co-design, test and validate these viable models alongside rural community stakeholders, including the farmers, and bio-based experts, extension services, development partners, local authorities, policymakers, among others.

SECTION 2: SCOPE, OBJECTIVES AND IMPLEMENTATION APPROACH

2.1 Scope of the value proposition design workshop

Work Package 5 concerns the development and assessment of circular, replicable and sustainable business models and has a goal to thoroughly assess their potential along with their investment requirements, to use the insights uncovered, and to provide hands-on business support (awareness-raising, business training, mentoring, access to finance support), as well as circular practice guides for rural entrepreneurs to uptake these techs and animate their business models.

In this way task 5.2 aims to co-design all-inclusive and sustainable business models for bio-based technologies transferred and adapted to each BIO4AFRICA project pilot case in Uganda, Ghana, Ivory Coast and Senegal. AFAAS leads the implementation of Task 5.2 and will be supported by partners (Q-PLAN, SAVANET, iHUB, INP-HB, KRC and UASZ) who provide technical backstopping. AFAAS will leverage on the findings of Task 5.1 (gender-sensitive market and value chain analyses) in which case product-specific data was produced principally for the three market analysis themes, namely: 1) market structure analysis (suppliers, buyers, product substitutes, barriers to entry and competitive rivalry); 2) market penetration and socio-economic relationships (vertical and horizontal profiles, behaviour of buyers and consumers (e.g. buying and selling practices, pricing behaviour, price sensitivity etc.,), iii) competitor product market performance analysis (e.g., product size, prices, trends, growth prospects and value addition, gender dimension and socio-economic implications).

AFAAS adopts a gender-responsive, all-inclusive, participatory, bottom-up approach[1]; to inform the co-designing process. This participatory approach will ensure that:

a) All stakeholders (farmers and rural communities) and actors at the different nodes of the product value chain (processors, input dealers, end-users) who understand and address the core problems, and will practically implement the models are broad onboard.
b) The co-designing or co-creation process is market-oriented, people-centred, and uses the activity-centred systems approach
c) There is a smooth transition from product testing and piloting, to pre-testing of the business models and eventually commercialization of the products.
d) There is increased adoption of the products backed by competitive marketing strategies.

AFAAS shall utilize a **Triple-Layered Business Model Canvas**[2] during the co-designing process that will encompass the two foremost operational steps: 1) value proposition designing, and 2) business model designing. In light of the above, the scope of the workshop is limited to designing an all-inclusive, unique, effective and market-centred value proposition that will be deployed to inform the development of business models and also accelerate the commercialization of novel products.

2.2 Rationale and Objective of the value proposition design workshop

The workshop is based on the premise that several bioproducts have been developed under the BIO4AFRICA project and have matured to a ‘minimum viable product (MVP)’ or past ‘proof of

[1] Brem, A., & Wolfram, P. (2014). Research and development from the bottom up-introduction of terminologies for new product development in emerging markets. Journal of Innovation and Entrepreneurship, 3(1), 1-22.

[2] García-Muiña, F.E., Medina-Salgado, M.S., Ferrari, A.M. and Cucchi, M., 2020. Sustainability transition in industry 4.0 and smart manufacturing with the triple-layered business model canvas. Sustainability, 12(6), p.2364.

concept level. They are ready for ready to undergo testing, product-market-fit, business model development, and eventually enter the early adoption and commercialization stage. To support these stages, early and lean validation of the value proposition for the novel bioproducts is needed. Therefore, an all-inclusive, multi-stakeholder workshop will be organised to design a contextually relevant, unique, effective and market-centred value proposition for each of the piloted bioproducts in Uganda, Ghana, Ivory Coast, and Senegal.

2.3 Implementation approach

The workshop will be oriented at the value proposition design process for at least ten bioproducts developed under the BIO4AFRICA project and are being piloted in Uganda, Senegal, Ivory Coast, and Ghana. A 1-2 days' workshop will be designed for the engaged stakeholder and project staff as a multi-disciplinary team to co-create value propositions for each bioproduct through the use of structured design thinking methods and participatory process in co-design the product value propositions, as described in the implementation phases below.

Step 1: Deploy a cross-functional tactic to invite stakeholders and partners

AFAAS will adopt a cross-functional approach in inviting all stakeholder clusters, in which case the value chain actors who are already engaged in the production and piloting phase and know a lot about the bioproducts being promoted and people who don't know anything at all about that specific products and markets will be invited. Similarly, AFAAS will work closely with the Q-PLAN, SAVANET, iHUB, INP-HB, KRC and UASZ to invite all BIO4AFRICA project partners, policymakers, and funders (or their representatives) to the workshop.

Step 2: Presentation of a project pitch

AFAAS will take the lead in coordinating the materials for the partners in convening the workshop. Upon convening, AFAAS technical team will present a pitch for the BIO4AFRICA project in about 5-10 minutes. The initial BIO4AFRICA project pitch presentation will give an overview of when, why and how the project came into being, and why the team thinks that there is value for the communities in Africa. The AFAAS team will describe issues or pains the target population or customers face and how the bioproducts will help address them.

Step 3: Participants' selection of working teams

After the self-introduction and pitch videos, the moderator moderato in each pilot country will lead the process of splitting participants people into 4-5 smaller teams. The moderator will make sure that the groups are balanced based on technical expertise, knowledge of the bioproducts, bioeconomy, market knowledge, and also the gender aspects (age, gender etc.,).

Step 4: Designing the value proposition for products

The team shall brainstorm on the working modalities based on the pre-designed work schedules that will include sessions for working in the individual teams, and converging for the presentation and brainstorming as a whole (all teams or participants).

The first step for each team will be to talk and brainstorm about how they see the idea for their designated bioproducts. All the ideas from each member of the team will be recorded and discussed. The moderator in each pilot country will guide the teams to focus on what kind of customer the bioproducts are targeting, how the products technically work, to what extent they solve challenges of the end-uses and customers, and how will the producers and stakeholders make money out of bioproducts, etc.

SECTION 3: ACTIVITIES FOR THE VALUE PROPOSITION DESIGN WORKSHOP

3.1 Activity 1: Co-designing value propositions for the bioproducts

After a general introduction to all participants, AFAAS technical team will work closely with the project partners, namely Q-PLAN, SAVANET, iHUB, INP-HB, KRC and UASZ to engage all the invited local and international stakeholders in the workshop. The team will moderate the in-person workshops to define the value propositions that will create a market niche for all the BIO4AFRICA bio-product lines and services. The value proposition will reflect a competitive market edge of the bioproducts while considering what the potential consumers and customers want while saving time, money and effort during use.

During the value proposition defining session, the participants will explore the context and co-design value propositions based on the standard value proposition canvas proposed for the bioproducts (**Appendix 1).** The participants will be split into several smaller teams (working groups); where each team will be guided and tasked to start filling in the various areas of the value proposition canvas (Figure 1). Figure 1 presents a schematic summary of the product value proposition canvas for the bioproducts. The proposed product value proposition canvas has two sides, namely the value proposition and customer profile (Figure 1).

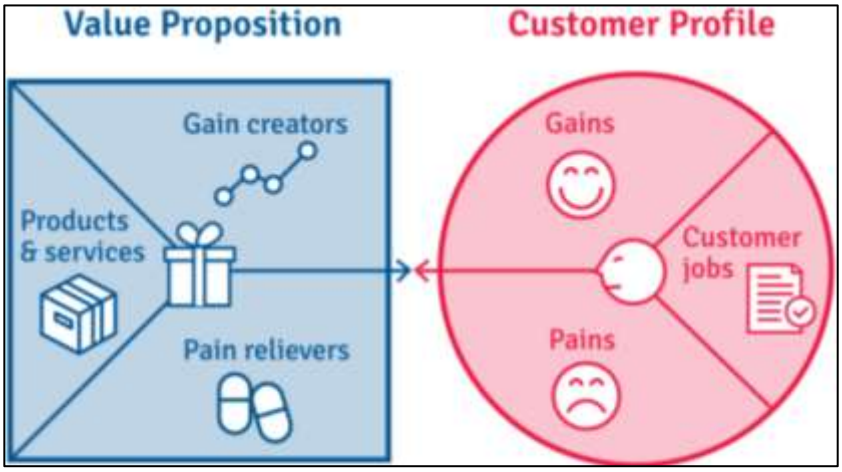


Figure 1: Schematic presentation of the product value proposition canvas proposed for bioproducts

With the Customer Profile, the team shall profile and clarify their understating of customers. The Value Proposition team describes how they intend to create value for the customers.

<u>The customer profile covers</u>:

i) Customer jobs: which may be functional, social, emotional and/ or inherently human;
ii) Customer pains: are negative feelings, high costs, risk factors, challenges and difficulties faced;
iii) Customer gains: referring to savings, dreams, success measures and outcomes achieved once customers complete their jobs.

<u>The value proposition covers</u>:

i) Products and services: what a customer gets when a sale is completed;
ii) Pain relievers: which include functional solution fixes, risk eliminations and "I can finally sleep at night" feelings a customer experiences thanks to your offerings; and

iii) Gain creators: defined by the savings, above-and-beyond outcomes, positive consequences and delights customers can look forward to once receiving your products and services.

The objective of each product is to work towards fitting between the two sides when one meets the other (Figure 1). Therefore, each smaller team will be assigned 1-2 bioproducts to brainstorm and develop product-specific value propositions and fill out the value proposition canvas. They will be guided, begin with, the customer profile on the right of the canvas. Each group will develop a customer profile of their bioproducts, and also brainstorm on how best to collect their socio-economic data mainly regarding; their demography, current customer jobs, incurrent pains, and expected gains.

The teams will be guided on the best way to capture data through posting notes or populating directly on the value proposition canvas. The teams will be supported with complementary trigger questions to help them get started, including those that help trigger a good conversation and knowledge sharing about anticipated product quality and customers, either based on assumptions or real knowledge.

3.1.1 Describing the Customer Pains

Pains describe anything that annoys your customers before, during and after trying to get a job done with the bioproducts. These are some trigger questions the team shall use to come up with product-specific customer pains: What makes your customers feel bad? How are current value propositions underperforming for your customers? Which features are they missing? How do your customers define too costly? Takes a lot of time, costs too much money or requires substantial effort? What risks do your customer fears? What common mistakes do your customers make?

In this regard, examples of customer pains include but are not limited to: the product being expensive, waiting a long time to get the products, confusing requirements, overpaying, waste of time, long queues, lack of aftersales service, short shelf life etc.

3.1.2 Describing the Customer Gains

Gains are the outcomes or benefits customers want for bioproducts. Gains include functional utility, social gains, positive emotions and cost savings. The teams will be guided to use trigger questions: Which savings would make your customers happy? Which savings in terms of time, money, and effort would they have? What would make your customers' jobs or lives easier? What do customers dream about? What are customers looking for the most?

The key examples of customer gains: can apply with confidence, get recognized by the team, applicable ideas, save money, do not have to wait too much, fair price, arrive on time, comfortable, friends' review etc.

3.1.3 Defining the Value Proposition of the products

A product value proposition is the “why” in “why should a potential customer buy a product or from you (the seller) against competitors?”. In other words, it communicates real benefits customers get (or expect) from using your products including a unique selling point -which focuses on speciality claims or guarantees strategically setting the product above the usual products or market competitors. In this context, the value proposition design workshop will connect the benefits of the BIO4AFRICA bioproducts with the problems farmers and end-use customers face.

During this session, it will be time for the teams to think about what bioproducts are going to be offered to the markets. The teams will start by enumerating all the bioproducts and support services their value proposition stands for. Under this component, the teams shall complete their customer profiles including all the known functional, social or emotional jobs.

3.1.4 Describing the Pain relievers

In this session, the team will think about pain relievers and how exactly their bioproducts will alleviate specific customer pains. the key question is: Do bioproducts work efficient and produce savings? Do the bioproducts make your customers feel better? Do the bioproducts address social, economic and environmental concerns? Examples of pain relievers might be: providing healthy meals, enabling direct communication, avoiding confusion, minimising the risk of failure, being practical and visual, purchase everything online.

3.1.5 Describing the Gain creators

The team should describe how the bioproducts create customer gains by bringing the outcomes and benefits. Use the team will this list of trigger key questions to think about them: Could the bioproducts create some kind of saving? Do the bioproducts produce outcomes customers expect and/ or even exceed their expectations? Do the bioproducts make customers' work and/ or life easier? Do the bioproducts create positive social consequences? Do the bioproducts do something specific that the customers are looking for? Do the bioproducts fulfil a desire or social need?

3.2 Activity 2: Developing and Defining 'Fit' and Value Map

Once every team has their product value propositions for the designated bioproducts ready, they will be guided to reflect on their work to see if they achieved 'Fit'. The teams shall achieve Fit when they address important market needs, alleviate extreme pains and create essential gains that customers care about. In this case, customers are the judges, jury and executioners of the value propositions. The teams will be asked to go through pain relievers and gain creators one by one and check to see whether they fit a customer's job/need, pain and/ or gain. Teams shall put a checkmark on each one that does.

AFAAS shall simultaneously employ the three levels of fit to uncover and match the customer needs with the bioproducts' needs, as described below.

i) The ***problem-solution fit***; comes first to identify how the team addresses jobs, pains and gains customers care about.
ii) The ***product-market fit***: shows how the team are providing pain relief and improving the customers' current situation beyond meeting their basic needs.
iii) The ***business model fit***: the conversation the team will have with potential end-users to ensure that the product value proposition fits the bioproduct market demand so that bioproducts are also sustainable, profitable, and scalable businesses.

Upon completing the Fit exercise, the teams will shift focus to the value map for their bioproducts. Here, the teams will capture the complementary and competitor products and services that are part of the current value proposition. The results help the teams to identify all suitable pain relievers and gain creators for customers (Figure 1). In this regard, a prioritization of each area will help the teams finalize and complete the value proposition canvas (Figure 1).

3.3 Activity 3: Co-designing Presentation and review of the product value proposition fit

This will involve workshop sessions to brainstorm solutions and declare assumptions for each of the ten piloted bioproducts. Upon populating and/ or filling the product-specific value proposition canvas, the teams will converge and each team will be given the slot to present to the audience their product-specific value propositions. The completed value proposition canvas for each bioproduct will give the invited audience and stakeholders an exclusive opportunity to review the value propositions for the bioproduct and ascertain if there is a fit between both sides (thus, pain relievers and gain creators for customers).

During the review, the pertinent questions will be: 1) Are products and services addressing essential customer gains and pains? 2) Where are the gaps? 3) Are there opportunities to fill those gaps? And 4) If yes, how? AFAAS envisages this session to be an exciting part of the workshop because the participants and their teams will start brainstorming solutions based on their previous work and the completed map while taking into account the product-specific context, gender-inclusivity, and other cross-cutting socio-economic factors across nations with diverse cultures. The teams will have the opportunity to capture solutions given by the audience, write down their assumptions and afterwards, update their product-specific value propositions. AFAAS will guide the teams on how to rank and/ or sort the assumptions by risk, for purposes of testing the riskiest assumptions first during pre-testing.

3.4 Activity 4: Pre-testing the value proposition for the products

AFAAS will lead the participants in pre-testing sessions for the developed value proposition for each bioproduct. The participants will be convened to test the riskiest assumptions for each bioproduct by formulating a hypothesis and/ or design-related experiments. AFAAS proposes to deploy 'free test cards (**Appendix 1),** as the standard data collection tool that will guide the participants to formulate and test hypotheses, and also define in what way, and by what metrics their hypotheses are to be tested. With the free test cards (Appendix 1), the teams will have the opportunity to train and practice the results and outcomes of their value proposition for each bioproduct. The results and outcomes will guide the teams to rethink and where necessary update the project bioproduct value propositions developed.

3.5 Activity 5: Final team pitch presentations

Every team should now prepare a short pitch presentation stating both the end-user and/ or customer segment they have defined and going through their Value Proposition Canvas. By doing so, AFAAS will the opportunity to identify whether there were one or several customer segments for each of the ten bioproducts piloted.

The AFAAS technical team will coordinate and provide technical backstopping in joining groups in the customer segments. If the bioproduct(s) ends up with only 1-2 customer cluster(s), it will is perfectly okay and normal. With the teams joined, the moderator will ask them to create a final version of the value proposition design which will summarize, complete and improve the ones developed by every team. This is envisaged to create more debate during alignment over the same customer segments and improve the resulting Value Proposition. Finally, the teams shall present their revised pitch, explaining the Fit and receiving feedback from the other teams in the room. At this point, the AFAAS experts will work with the teams to finalise their product-specific value propositions. AFAAS will take the lead in harmonising the value propositions for each bioproduct from teams and compile a final report for the project management unit and funder.

3.6 Activity 6: Reporting and next steps after the workshop

The workshop closes with each team presenting their product-specific value propositions to the rest (all the workshop participants). In the end, AFAAS will ensure knowledge sharing and collaborative agreement on the next steps and follow-ups events between Bbio4africa partners and stakeholders.

After the workshop, the AFAAS technical team will have turned ideas from the stakeholders into a clear value proposition for each bioproduct to customers. However, the Customer Profile and all of its jobs/needs, pains and gains are completely based on assumptions from the potential stakeholders and customers. The assumptions include those, about what they do, why they do it and what they like or do not like among others. However, these assumptions can change over time and across the different geography or target communities because of diverse socio-economic factors and contexts. Therefore, developing the business models for bioproducts involves risk, so the next steps shall be reducing uncertainty by validating assumptions and diminishing risk during the ground-truthing exercise.

SECTION 4: ORGANIZATION OF THE VALUE PROPOSITION DESIGN WORKSHOP

4.1 Composition of the Value Proposition Design Workshop

The BIO4AFRICA Task 5.2 workshop (thus, the Value Proposition Design Workshop) will involve; i) multistakeholder teams of actors who play critical roles at the different nodes of the product value chains, including farmers, suppliers, processors, buyers etc. In addition, multi-disciplinary teams of production and marketing experts from local players, regional, industry and technology perspectives, and the BIO4AFRICA project partners will be invited to discuss critical success factors and/ or limitations of the bioproducts.

Representatives from the local and international agencies, value chain actors, women groups, farmer institutions, policymakers, district local governments, administration, legislative bodies, universities and research institutions, private sector, Civil Society Organisations (CSOs), Non-Governmental Organisations (NGOs), and consumers associations; farmers, environment management bodies (e.g., NEMA); agricultural organisations, agro-technology experts, bio-based process experts, and extension bodies will also be invited (Appendix 3). Appendix 3 presents a detailed list of stakeholders invited list of stakeholders to the Value Proposition Workshop; with 1-3 persons from each sector representing Gender and Youth Inclusion.

4.2 Structure of the Workshops

4.2.1 Invitation process

AFAAS will make preparations in terms of coordinating the value proposition workshops and preparing the tools needed for the product value proposition workshops. Invitation of the expected stakeholders for the workshop shall be the role of the local partners where the pilot studies are being undertaken. The workshop logistics shall then be borne by the local partners organising the value proposition workshops. AFAAS shall communicate the date of the workshop with the work package leaders and the entire consortium of the BIO 4 AFRICA Project.

4.2.2 Supporting material, digital tools and facilitation

AFAAS will engage her technical team to manage the logistics and moderate the workshop. At least three technical staff will be dedicated fully to the workshop activities, and these will be a moderator, a facilitator and a rapporteur:

- **Moderator**: Coordinating the live event, moderating discussions and keeping activities on time.
- **Facilitator**: Facilitating the use of the computers, presentations and digital tools used for keeping notes, ranking, etc.
- **Rapporteur**: Keeping notes during discussions and activities, being responsible for reporting.

Familiarise all people involved in the implementation of the workshop with the flow and tools to be used in its framework. AFAAS shall organise a rehearsal meeting with technical team members from the BIO4AFRICA project in preparation for the workshop to simulate its implementation and ensure that everything works as intended.

If deemed necessary, a broad array of online platforms along with digital collaboration tools will be employed to organise and better run the workshops (Table 1). Table 1 presents some of the key indicative tools suggested.

Table 1: Some of the indicative tools suggested for the workshop

Tools	Description	Link
Miro	Online collaborative whiteboarding, the library of templates, integration with web apps, good for brainstorming, sticky notes, freeform pen, shapes, arrows etc.	https://miro.com/
Mentimeter	Online platform to Build beautiful interactive presentations, Collect polls, data and opinions from participants using smart devices and Get insights on participants with trends and data export	http://www.mentimeter.com/
Mural	Sticky notes, text, shapes and connectors, icons, frameworks, images, gifs, Drawing	https://www.mural.co/

4.3 Proposed action plan

A brief action plan for the organisation, implementation and reporting of the regional workshops are provided in the table which follows.

Table 2: The proposed action plan for the workshop

Description of the Proposed Action	Who	When
1. Draft Concept Note to Guide the Value Proposition Design Workshop	AFAAS	8/7/2022
2. Fix the date of each workshop and invite participants 3. Share the agenda & invitation of the workshop with Task leaders	AFAAS & Project Partners	TBD
Elaboration and sharing of workshop-specific guidelines and reporting	AFAAS	20/07/2022
Organise workshop (including rehearsal meetings beforehand to safeguard successful implementation)	AFAAS & Partners	TBD
Management of the workshop and reporting	AFAAS	TBD
Analysis of workshop results & integration within the deliverable	AFAAS	TBD

4.4 Expected outcome(s)

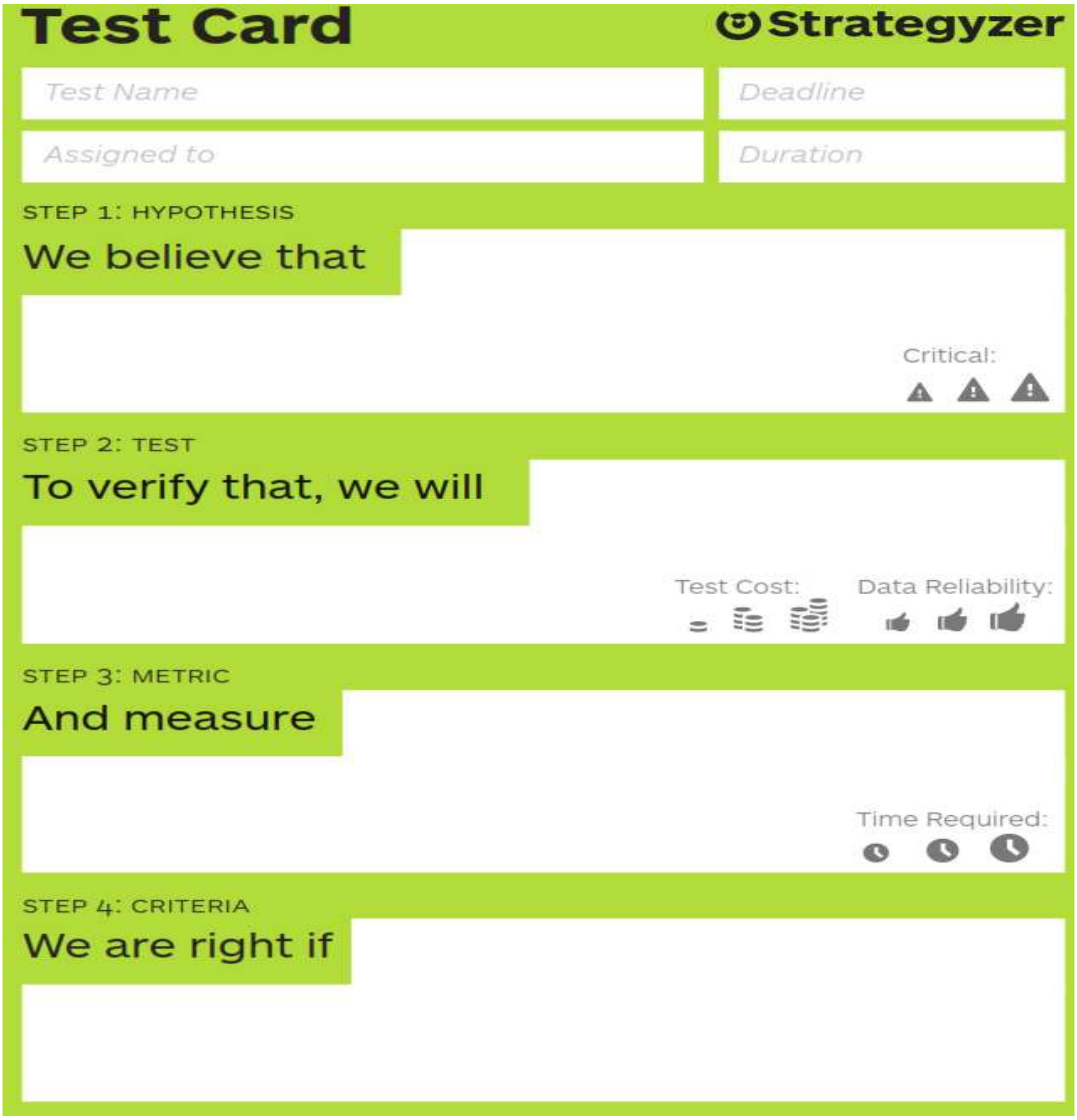
The outcome of the workshop is a comprehensive and completed value proposition canvas for each of the ten bioproducts developed by the BIO4AFRICA project and are being piloted across Uganda, Ghana, Ivory Coast and Senegal. The product value proposition has data on the target customer segment and the internal value map, including product-specific gaps and opportunities for new ideas and solutions. In the end, the value proposition developed will inform designing sustainable, inclusive and climate-smart business models for the bioproducts that will propel the agro-industrialisation, address the food-energy nexus, and drive a green economy in Africa.

APPENDIX 1: THE VALUE PROPOSITION CANVAS PROPOSED FOR THE BIOPRODUCTS

	Designed for:	*Designed by:*	*Date:*	*Version:*
Value Proposition Canvas				

Product			Customer	
Benefits	**Experience**		**Wants**	**Fears**
Features			**Needs**	
Product	**Ideal Customer**		**Substitutes**	

APPENDIX 2: THE VALUE PROPOSITION TEST CARD



Test Card

Strategyzer

Test Name

Deadline

Assigned to

Duration

STEP 1: HYPOTHESIS

We believe that

Critical:

STEP 2: TEST

To verify that, we will

Test Cost:

Data Reliability:

STEP 3: METRIC

And measure

Time Required:

STEP 4: CRITERIA

We are right if

APPENDIX 3: LIST OF STAKEHOLDERS TO BE INVITED TO THE WORKSHOP (EACH SECTOR TO HAVE 1/3 GENDER REPRESENTATION AND YOUTH INCLUSION)

S/N	STAKEHOLDER TYPE	NUMBER	REMARKS
1.	Revenue Authority Representative	1	
2.	Agri entrepreneurs-middle men/processors/aggregators for the feedstock	2	
3.	Farmers cultivating feedstocks to be used for the biotechnology	2	
4.	Livestock keepers-intensive, semi-intensive and pastoralists	2	
5.	Women Cooperative group leaders/ Farmer associations	2	
6.	Policy regulators-quality standard regulator	1	
7.	Officials from Agriculture, livestock and Trade and Industrialisation Department representation	2	
8.	Private agro-dealers for extension	1	
9.	Bio-based / technology experts	2	
10.	Academia	1	
	TOTAL	**17**	

END

VALUE PROPOSITION WORKSHOP REPORT

Title of the project	Diversifying revenue in rural Africa through circular, sustainable, and replicable biobased solutions and business models
Project Acronym	BIO4AFRICA
Under Project Task 5.2	Co-design of inclusive and sustainable business models with farmers and rural communities
Bio-based Products	
Country & Venue	
Host & organizers	
Website	
Email:	
Telephone	

Prepared by:

African Forum for Agricultural Advisory Services

AFAAS-Uganda

Submission Date: ……………………………..

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101000762.

TABLE OF CONTENTS

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1. DESCRIPTION OF THE WORKSHOP

1.1 About the Workshop event

BIO4AFRICA Representatives (Name And Organization)	*Write here*
Event Venue	*Write here*
Date	*Write here*
Lead Organizational Contact (Name)	*Write here*
Work Package	WP5
Task Number	T5.2

1.2 Agenda of the Workshop

(Please insert here the final agenda adopted)

2. WORKSHOP PROCESS: RESULTS AND OUTPUT

2.1 Results and data recorded during the workshop

The team should provide narrative and photos taken when performing the value proposition workshop event and during the co-designing processes described below.

2.1 Co-designing value propositions for the bio-based products

2.1 Developing and Defining 'Fit' and Value Map

2.2 Co-designing Presentation and review of the product value proposition fit

2.3 Pre-testing the value proposition for the products

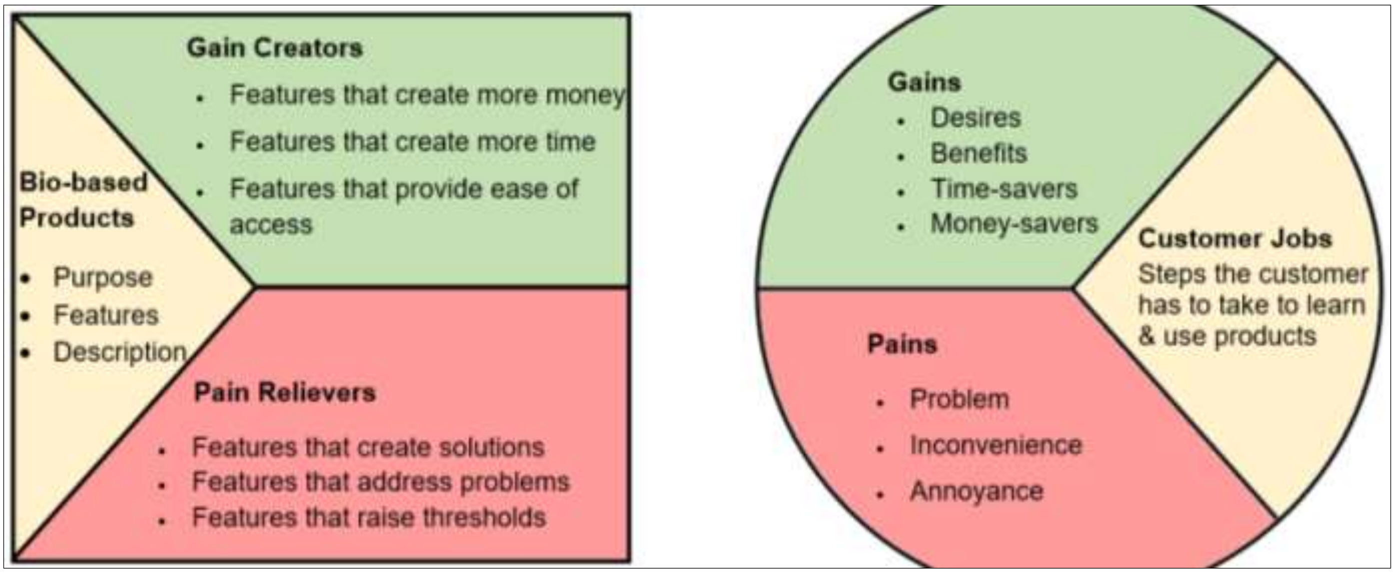
2.4 Final team pitch presentations

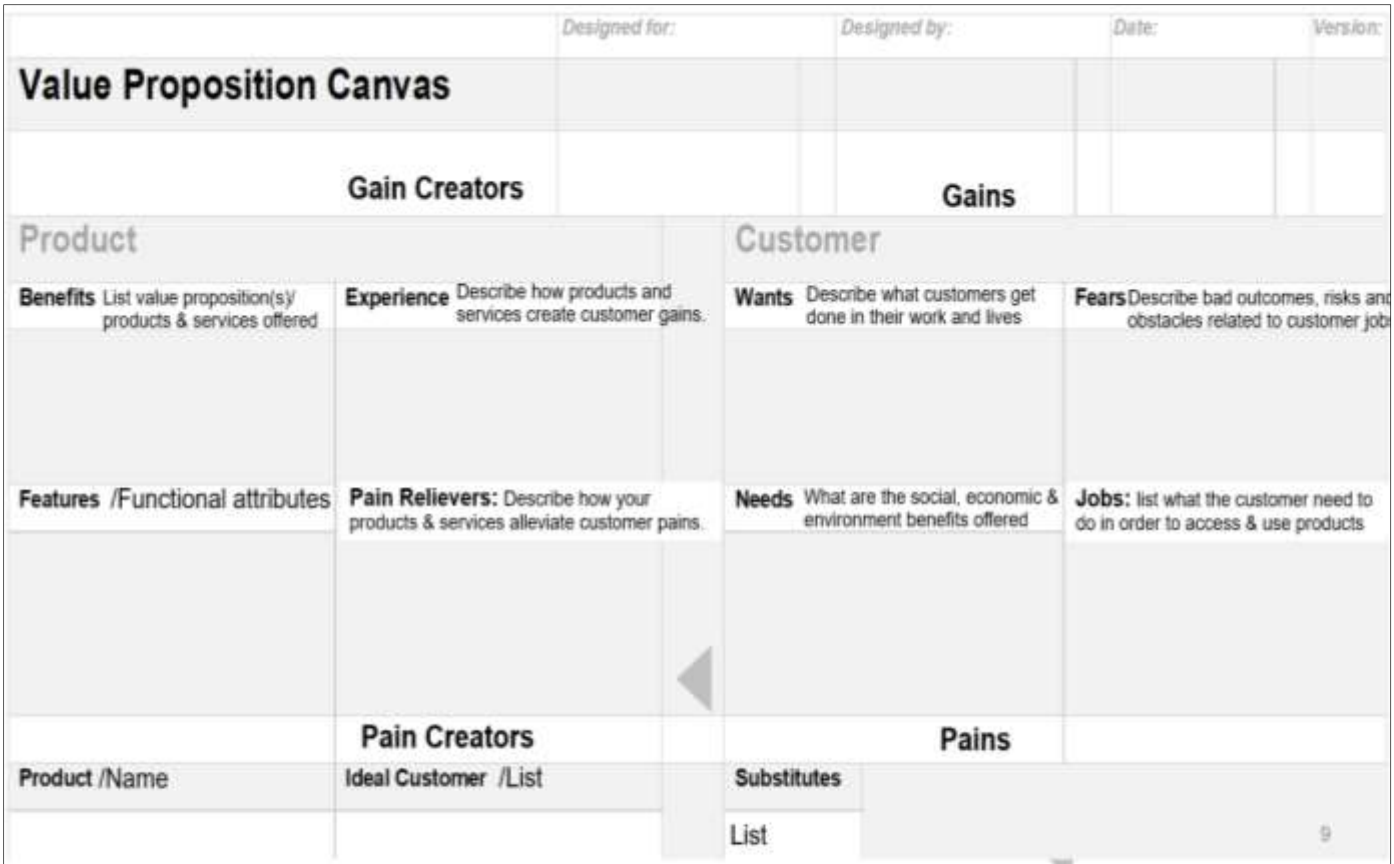
2.5 Workshop evaluations

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101000762.

2.2 The Value Proposition Canvas for each Bio-based Product

Please populate the Value Proposition Canvas by providing product-specific data regarding each component in the value proposition canvas, as described in Figure 1 below.





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2.3 Pertinent perspectives and comments from participants

In addition to the Product-specific Value Proposition Canvas, please provide supplementary data/info from the participants – upon consensus.

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3. PROMOTIONAL AND PUBLICITY MATERIALS

3.1 C&V and publicity materials

-Please share any soft copies of Project C&V materials: T-shirts, brochures, pens, books, umbrellas etc. The online publicity materials are Facebook, YouTube, Twitter, and Instagram, among others.

-Please insert other social media posts made during the workshop: webpages or links shared before or after the meeting, and any photographs from the workshop.

3.2 List of workshop participants and their contacts

The updated list of attendees from different customers and stakeholder clusters, including their local institutions, functions, and email and phone contact information. Add rows if needed and delete the examples in the cells below.

No.	Name	Function	Rep. of Institution	Email & phone
1	….	Farmer	Farmer Group	
2	….	Official	Local Government	
3	…..	Customer/user		
4		Policymaker	Min. of Agriculture	
5		Official		
6				

3.3 Media files for records

- The teams will provide group photos for the participants before, during and after the workshop event.

- The teams will provide short video clips taken during the workshop events. The video clips shall be processed to facilitate the development of video pitches and other media files (e.g., news files) for the bio-based products and the entire BIO4AFRICA project.

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