D4.1
Novel Circular Business Models applied in the value chain of bio-waste valorisation

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List of acronyms

Acronym	Description
AD	Anaerobic Digestion
B2B	Business to Business
B2C	Business to Consumer
BBPs	Bio-based Products
BES	Bioelectrochemical system
BM	Business Model
BMC	Business Model Canvas
BSFL	Black soldier fly
Bt	Bacillus Thuringiensis
CAPEX	Capital expenditures
CBM	Circular Business Model
CE	Circular Economy
EC	European Commission
EIB	European Investment Bank
EIONET	European Environment Information and Observation Network
EMF	Ellen MacArthur Foundation
HORECA	Hotel, Restaurant, Café
OFMSW	Organic fraction of the municipal waste
OPEX	Operating expenses
P3HB	Poly(3-hydroxybutyrate)

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Acronym	Description
PHAs	Polyhydroxyalkanoates
PHBV	Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)
PLA	Polylactic acid
SCP	Single cell protein
SME	Small medium-sized enterprise
TLBM	Tailored Lighthouse Business Model
TRL	Technology readiness level
UWWS	Urban Wastewater sludge
VFAs	Volatile fatty acids
WWTP	Waste Water Treatment Plant

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1. Executive summary

In the framework of WP4 titled “PDA Circular Bio-based Business Models” the aim is to provide PDA in order to support circular bio-based projects in Lighthouse Cities and Regions. In particular, within the actions included in WP4 the development of an integrated Circular Business Model (CBM) typology focused on bio-waste as well as a new circular valuation method will take place. Moreover, tailored Lighthouse Business Model (TLBM) will be provided to Lighthouse Cities and Regions as well as assistance in order to develop the full potential of their solutions for the future implementation of the circular business models. Particularly, in the context of the **Task 4.1 entitled “Screening of the existing innovative circular business models for Urban Circular Bioeconomy”** the aim is to focus on the identification of CBMs for bio-waste valorisation and the development of a CBM typology which will be able to incorporate also other business cases of bio-waste valorization in the future.

In the deliverable the methodological approach for the identification of CBMs for bio-waste is described. Furthermore, the analysis of the CBMs behind 15 successful solutions for bio-waste valorization is presented and a template business canvas for bio-waste valorization is proposed. The examined solutions, followed the work from Task 2.2 and in more specifically they come from H2020 projects, SCALIBUR, Valuewaste and WaysTUP!. Additionally, a new integrated CBM typology focused on bio-waste is developed and presented as well as drivers and barriers related to the implementation of circular business models in bio-waste valorization.

The analysis of the 15 successful solutions for bio-waste valorization revealed significant insights. At first, the concept of adding value is entailed in the examined business cases. Additionally, the examined business models can be characterized resource recovery models. On the other hand, in bio-waste valorization, end-products mainly fall under one of the following categories i.e., nutritional ingredients (e.g. SCP, carotenoids, active peptides, insect), biopolymers (e.g. PHAs, PLA), agricultural components (e.g. biofertilisers, biostimulants, insect frass), chemical ingredients (e.g. biosolvents, VFAs), and are directly consumed for specific applications. Thus, there is an inherent limitation regarding end-product re-use or recycling. Regarding the aspect of the value delivery in the business models it was observed that there are two main types of customers and the respective models i.e. the B2B and B2C.

As for the identification of the new CBMs for bio-waste valorization, the following critical factors were defined and investigated i) Involved parties (types of parties and interconnection between parties) and ii) Product and relevant markets (types of products & relevant markets and value of products). Regarding the types of parties, the three main parties involved in a CBM for bio-waste valorization are the Bio-waste owner, the Solution owner and the Investor. Finally, the new CBM typology includes one core business model category which is related to the interconnection between the involved parties and two sub-business model categories which are related to the extent of participation of the different parties and to the value of the target markets respectively. In particular, in the core business model category which is related to the interconnection between the involved parties three business models are recognized i.e., **joint venture, vertical integrated and individual entrepreneurship**. In the sub-business model category which is related to the participation of the different parties two models are recognized and more specifically **simple collaborative and multi collaborative** and in the sub-business model

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category which is related to the value of the target markets two models are recognized and in particular **high value and medium value**.

Regarding the most important drivers and barriers, the research revealed as the **most significant drivers** the existence of a specific kind of waste (e.g. food waste, garden waste) which needs to be treated as well as the existence of a sufficient market to sell the product. Furthermore, the maturity of the applied technology is a key factor strongly affecting the market acceptance and the economic benefits from the sale of the end-product. On the other hand, the **most important barriers** include at first, the lack or the failure of a separate collection system for specific waste streams. Legislative and regulatory barriers are also very commonly addressed as well as the economic and financial viability of CBMs which are related mainly to the high operational costs. Finally, the higher price of some end-products compared with the conventional ones was recorded as barrier.

2. Introduction

The concept underpinning HOOP is to foster urban circular bioeconomy (UCBE) across Europe by unlocking bio-based investments through a systemic and cross-cutting approach. The project action is deployed by offering Project Development Assistance (PDA) to a group of 8 Lighthouse Cities and Regions and, in later stages, the project will feature the HOOP Urban Circular Bioeconomy Hub (UCBH), an online platform that will provide opportunities to replicate the PDAs of the Lighthouses to other cities and regions across Europe.

2.1. The Circular Economy concept

The European environment policy has been structured upon **8 Environmental Action Plans (EAPs)** until today, under which several strategies and policies were developed and an extended framework of legislation (Directives, Regulations and Decisions) was issued. The ***circular economy (CE) concept*** **is for the first time clearly introduced** in the 7th EAP (2013-2020, In: OJ L 354, 28.12.2013)**.** In the circular economy model value of materials, components and products is maintained for as long as possible. This model is based among others on sharing, reuse, repair and recycling. Moreover, waste minimisation as well as reduction of primary materials' use is achieved.

Although the circular economy concept is considered to be distinctively introduced in the 7th EAP, circular economy in the field of waste management already appears from 2015. More specifically, on December 2015, the European Commission (EC) adopted its first circular economy package, an action plan which aimed to further improve waste management, foster resource efficiency as well as eco-innovation. In addition, the package included four legislative proposals regarding waste, containing specific quantitive targets for recycling, reuse and landfill, which intended to be met by 2030. [1]

On 2018 the EC presented a revised legislative package, which proposed more ambitious targets on waste management. More specifically, the new package included the amendment of 4 Directives regarding waste (Directive 2008/98/EC), landfill (Directive 1999/31/EC), packaging waste (Directive 94/62/EC) and special streams (Directives 2000/53/EC on ELVs, Directive 2006/66/EC on batteries and accumulators, Directive 2012/19/EU on waste electrical and electronic equipment (WEEE)). In the same year, the European strategy for plastics was adopted, followed by the Directive on the reduction of single use plastics.

In 2019 the EU launched also **The European Green Deal** that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use [2]. As defined by the European Green Deal, on March 2020, EC, adopted ***'a new Circular Economy Action Plan on a cleaner and more competitive Europe'*** fostering initiatives throughout the life cycle of products starting from their design, encouraging circular economy processes, promoting sustainable patterns of consumption, and finally struggling to safeguard that the resources used are kept in the EU economy for the longest possible period. The new Circular Economy Action Plan (CEAP) emphasises on the value chains utilizing resources with a high potential for circularity and focuses on the waste sector through the promotion of enhanced waste policy

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to strengthen waste prevention and circularity as well as through the creation of a well-defined secondary raw materials EU market. [3].

2.1.1. CIRCULAR ECONOMY IN BIO-WASTE MANAGEMENT

Regarding the **bioeconomy strategies** in Europe, the European Commission launched in 2012 the initial Bioeconomy Strategy entitled, "Innovating for sustainable growth: a bioeconomy for Europe", to provide a framework on encouraging research and innovation as well as knowledge development on the production of energy and materials derived by the conversion of renewable biological resources. In 2018, an updated bioeconomy strategy was adopted entitled "A sustainable Bioeconomy for Europe – Strengthening the connection between economy, society and the environment, **Updated Bioeconomy Strategy**". The latter includes five main goals and particularly:

i. *ensure food and nutrition security*
ii. *manage natural resources sustainably*
iii. *reduce dependence on non-renewable, unsustainable resources*
iv. *limit and adapt to climate change*
v. *strengthen European competitiveness and create jobs [4]*

In order to support the above objectives 3 important action areas are recognised:

1. *strengthen and scale-up the bio-based sectors, unlock investments and markets*
2. *deploy local bioeconomies across Europe;*
3. *understand the ecological boundaries of the bioeconomy [5]*

The Bioeconomy Strategy contributes to the European Green Deal, as well as the industrial, CE and clean energy innovation strategies. **Sustainability** as well as **circular bioeconomy principles** are commonly highlighted as of great importance in order to achieve the objectives determined by the different strategies.

The HOOP Project, through its planned actions, intends to boost sustainability and bridge the gap between circular economy plans and the investments in bioeconomy sector.

2.2. Objectives

In the framework of **WP4 titled "PDA Circular Bio-based Business Models"** the aim is to provide PDA in order to support circular bio-based projects in Lighthouse Cities and Regions. In particular, within the actions included in WP4 the development of an integrated Circular Business Model (CBM) typology focused on bio-waste as well as a new circular valuation method will take place. Moreover, tailored Lighthouse Business Model (TLBM) will be provided to Lighthouse Cities and Regions as well as assistance in order to develop the full potential of their solutions for the future implementation of the circular business models.

In the context of the **Task 4.1 entitled "Screening of the existing innovative circular business models for Urban Circular Bioeconomy**" the central aim is to focus on the identification of CBMs for bio-waste valorisation

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and the development of a CBM typology which will be able to incorporate also other business cases of bio-waste valorization in the future. **The main objectives of the task include**:

- Identification of existing CBM categorisations and tools proposed by researchers and leading organisations
- Analysis of circular business model for specific valorisation solutions, following the work from T2.2, with the use of the circular business model tool i.e., the business model canvas
- Development of an integrated CBM typology focused on bio-waste
- Investigation of drivers and barriers related to the implementation of circular business models.

The work conducted in the task is included in the present Deliverable 4.1 “Novel Circular Business Models applied in the value chain of bio-waste valorization”.

Under these overarching objectives of the task, some **specific objectives were set for the deliverable**, which are presented below:

- Develop the integrated CBM typology focused on bio-waste by:
    - Evaluating the results from the identification of existing CBM frameworks and the examined circular business model for specific valorisation solutions
    - Defining the characteristics of the new CBMs proposed
- Ensure that a systemic approach is followed throughout the activities performed.

2.2.1. STRUCTURE OF THE DELIVERABLE

The Deliverable 4.1 is organised as follows:

Chapter 1: **Introduction** (the present chapter), the background and the structure of the report is presented.

Chapter 2: **Methodology**, the overall methodology for the identification of CBMs for bio-waste valorisation and the development of the CBM typology.

Chapter 3: **CBM categorization and tools**, presentation of the existing CBM frameworks and tools proposed by researchers and leading organisations.

Chapter 4: **Development of the HOOP CBMs**, analysis of CBMs for specific valorization solutions and first results.

Chapter 5: **CBM identification for bio-waste**, evaluation of the results after the analysis of the HOOP CBMs and development of an integrated CBM typology focused on bio-waste.

Chapter 6: **Drivers and barriers related to the implementation of the CBMs in bio-waste valorisation**, literature review about the already identified barriers hindering the implementation of CBM and primary research, through questionnaire distribution to Lighthouse Cities and Regions and to bio-waste valorization technology providers both participating in the project.

The conclusions are drawn in *Chapter 7* titled **Conclusions**.

References and **Annex** are provided at the end of this deliverable.

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3. Methodological approach for CBM identification for bio-waste

3.1. The 4 level approach

In the following chapter there will be a detailed presentation of the methodology that is applied for the analysis of CBMs in the field of bio-waste. The aim of the analysis is the identification of CBMs focused on bio-waste valorisation and the presentation of a typology which will be able to incorporate also other business cases of bio-waste valorization in the future.

The methodology consists of 4 levels, as summarized below and is further analyzed in the following paragraphs:

I. *1st level of analysis: Literature review.* In this phase, a literature review was conducted focusing on the review of circular business model (CBM) categorisations proposed by researchers and leading organisations. Special focus was additionally on the CBMs proposed for bio-waste valorization. Furthermore, business model tools were presented and more specifically various types of business model canvases. Based on the review conducted a completed *initial business model canvas* for *bio-waste valorization* was completed so as to be used as a framework to further explore the existing solutions of HOOP bio-waste valorization (2nd level of analysis).

II. *2nd level of analysis: Development of the HOOP CBMs.* In the second phase of the analysis, *fifteen (15) business models* were composed by the use of the tool of the business model canvas taking departure from the initial business model canvas that was prepared in the 1st level of analysis. Finally, after the completion of the 15 business model canvases for the respective solutions, the initial business model canvas was validated and a *final template business model canvas for bio-waste* was proposed.

III. *3rd level of analysis: CBM identification for bio-waste.* In this phase, the evaluation of the results of the 2nd level of analysis was conducted. The aim of the first evaluation was to ascertain whether the existing CBM frameworks could describe the business models specifically in the field of bio-waste valorization. New business models were investigated based also on the results of the 2nd level of analysis and the evaluation. Finally, a *new integrated CBM typology focused on bio-waste* and its specificities was proposed.

IV. *4th level of analysis: Investigation of drivers and barriers.* Within this phase, literature review took place in order to collect data about the already identified barriers hindering the implementation of CBM. Following, primary research was conducted aiming to valorise drivers and barriers already identified.

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For this purpose, a questionnaire was sent to Lighthouse Cities and Regions and to bio-waste valorization technology providers, both participating in the HOOP project.

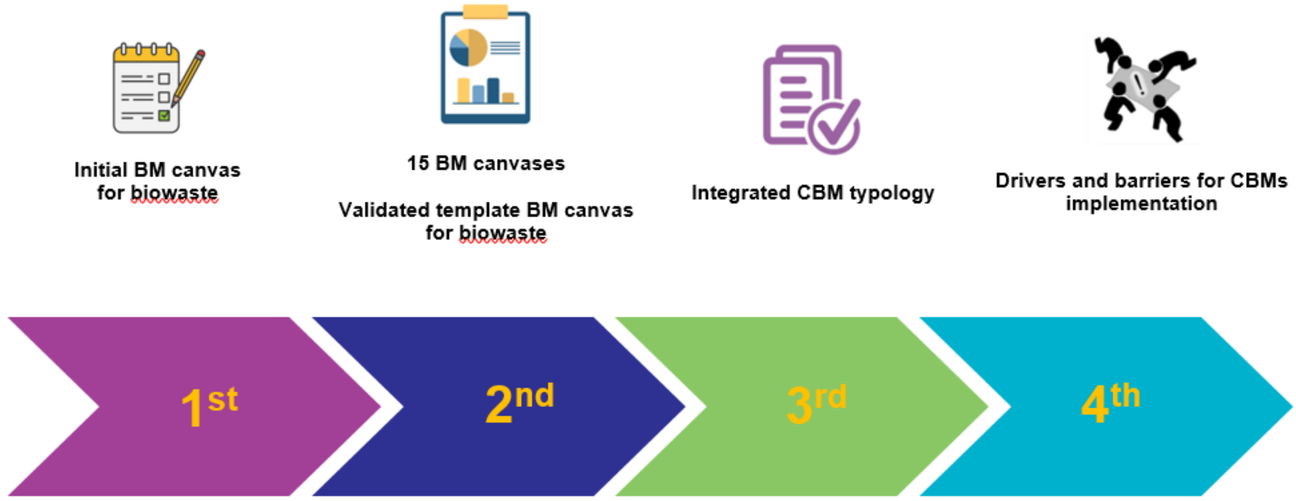

Figure 1. The 4 level methodological approach

3.2. The 1st level of analysis

In this phase, a literature review was conducted both for the CBM frameworks and the business model tools. More specifically, a variety of sources was investigated such as researchers' publications, Leading Organisations' publications and reports in the field of circular economy and bioeconomy and other H2020 Projects. The most representative sources included:

- ✓ *Ellen MacArthur Foundation. Towards a Circular Economy: Business Rationale for an Accelerated Transition. [6]*
- ✓ *European Investment Bank, "The EIB Circular Economy Guide" [7]*
- ✓ *OECD Urban Studies, "The Circular Economy in cities and regions: Synthesis Report [8]*
- ✓ *Eionet Report - ETC/WMGE, "Business Models in a Circular Economy", EEA, European Topic Centre Waste and Materials in a Green Economy [9]*
- ✓ *Achterberg, E., Hinfelaar, J. and Bocken, N. The Value Hill Business Model Tool: identifying gaps and opportunities in a circular network [10]*
- ✓ *Lacy, P. and Rutqvist, J. Waste to wealth: the circular economy advantage [11]*
- ✓ *Van Renswoude, K., Ten Wolde, A., and Jan Joustra, D. Circular Business Models – Part 1: An introduction to IMSA's circular business model scan [12]*

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- ✓ *R2pi project. CIRCULAR BUSINESS MODEL (CEBM) PATTERNS [13]*
- ✓ *WaysTUP! Project. Deliverable 6.2 Business Model Analysis [14]*
- ✓ *NoAW Project. Position paper on Policy recommendations on business and marketing concepts for industrial ecology [15]*
- ✓ *BE-Rural Project. D2.4_Regional_business_models [16]*
- ✓ *Reim et al. Circular Business Models for the Bio-Economy: A Review and New Directions for Future Research [17]*
- ✓ *Ellen MacArthur Foundation website – Learning Hub [18]*
- ✓ *Osterwalder, A. and Pigneur, Y., Business model generation. A handbook for visionaries, game changers, and challengers [19]*
- ✓ *Osterwalder, A., Pigneur, Y. & Tucci, C. Clarifying Business Models: Origins, Present, and Future of the Concept [20]*
- ✓ *Top 20 innovative bio-based products. Conducted for the EC-DG RTD by University of Bologna and Fraunhofer ISI [21]*

Based on the above sources and by the use of the business model canvas, proposed by Osterwalder and Pigneur [19] and adjusted and focused on the circular economy model as described by the Ellen MacArthur Foundation and IDEO [27], a completed initial business model canvas for bio-waste valorization was prepared so as to be used as a framework to further explore the existing solutions of HOOP bio-waste valorization (2nd level of analysis).

3.3. The 2nd level of analysis

In the 2nd level of analysis for the development of the HOOP CBMs, existing solutions/technologies were analysed through the use of the business model canvas as defined in the 1st level of analysis. The examined solutions, followed the work from Task 2.2 and in particular they mainly come from H2020 projects, SCALIBUR, Valuewaste and WaysTUP!. Totally, 17 technologies/solutions were investigated and included in Del 2.2. In the following table the examined solutions are presented.

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Table 1. Solutions investigated in Task 2.2

1	Bioprocess involving methanotrophic bacteria using biomethane arising from the AD of the OFMSW
2	Black soldier fly larvae fed with OFMSW or digestate from AD
3	Nutrients recovered from residual dewatering liquid from AD
4	Microalgae harvesting from bio-waste
5	Fermentation of used cooking oils
6	Volatile fatty acids (VFAs) production from UWWS
7	Cellulosic rejections of wastewater treatment plants to ethyl lactate bio-solvent
8	Polylactic acid (PLA) production from fruits and vegetables waste
9	2,3-Butanediol from OFMSW, garden waste and UWWS
10	Slow pyrolysis
11	Production of functional ingredients from spent coffee grounds
12	Biochemical production of functional ingredients from animal by-products
13	Biochemical conversion of OFMSW to biopolymers
14	Production of biotic pesticides from OFMSW
15	Production of biofertilizers and biostimulants from OFMSW and UWWS
16	Bioconversion of UWWS: CO_2 fermentation with bioelectrochemical systems
17	Bioconversion of UWWS: production of PHBV and other PHAs

Specifically, the technologies described as “Fermentation of used cooking oils” (5), “Biochemical conversion of OFMSW to biopolymers” (13) and the “Bioconversion of UWWS: production of PHBV and other PHAs” (17) all have as an end-product different types of PHAs. Their difference is on the feedstock for the valorization process. Moreover, the technologies “Biochemical conversion of OFMSW to biopolymers” and “Bioconversion of UWWS: production of PHBV and other PHAs” have relatively low TRL (4-5). In the framework of the analysis of their business model it was considered therefore reasonable to examine them as one case under the title “Production

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of P3HB or other PHAs by fermentation". Finally, 15 business model canvases were prepared for 15 technologies/solutions as shown in the table below.

Table 2. Solutions investigated in Del 4.1

1	Bioprocess involving methanotrophic bacteria using biomethane arising from the AD of the OFMSW
2	Black soldier fly larvae fed with OFMSW or digestate from AD
3	Nutrients recovered from residual dewatering liquid from AD
4	Microalgae harvesting from bio-waste
5	Production of P3HB or other PHAs by fermentation
6	Volatile fatty acids (VFAs) production from UWWS
7	Cellulosic rejections of wastewater treatment plants to ethyl lactate bio-solvent
8	Polylactic acid (PLA) production from fruits and vegetables waste
9	2,3-Butanediol from OFMSW, garden waste and UWWS
10	Slow pyrolysis
11	Production of functional ingredients from spent coffee grounds
12	Biochemical production of functional ingredients from animal by-products
13	Production of biotic pesticides from OFMSW
14	Production of biofertilizers and biostimulants from OFMSW and UWWS
15	Bioconversion of UWWS: CO_2 fermentation with bioelectrochemical systems

After the completion of the 15 business model canvases for the respective solutions, the initial business model canvas was validated and a final template business model canvas for bio-waste was proposed.

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3.4. The 3rd level of analysis

In the 3rd level of analysis, the evaluation of the results, previously presented for each one of the 15 solutions, through the completion of 15 business model canvases, will be conducted. The aim of the first evaluation is to ascertain whether the existing CBM frameworks, which were investigated in the 1st level of analysis, could describe the business models specifically in the field of bio-waste valorization. In particular, the CBM frameworks that will be further examined in the context of the bio-waste valorization solutions are:

- *Lacy & Rutqvist [11]*
- *Ellen MacArthur Foundation [6]*
- *Renswoude et al. [12]*
- *Value Hill by Achterberg et al. [7], [10]*
- *Circular business Model patterns identified by R2π project [13]*

According to the analysis conducted it will be realized if the existing frameworks could describe the business models specifically in the field of bio-waste valorization or if there is a need to develop a new integrated CBM typology focused on bio-waste and its specificities.

Finally, a new integrated CBM typology focused on bio-waste which will be able to incorporate also potential business cases of bio-waste valorization will be developed if needed.

3.5. The 4th level of analysis

Within this phase, literature review takes place in order to collect data about the already identified barriers hindering the implementation of CBM. Following, primary research will be conducted aiming to valorise drivers and barriers already identified. For this purpose, a questionnaire will be sent to LH Cities and Regions and to bio-waste valorization technology providers, both participating in the HOOP project.

Questionnaires constitute a traditional mean to carry out primary research. The main goal of conducting the research is to collect primary data from the public authorities and companies responsible for the waste management of cities involved in HOOP project as well as from the technology providers who are also involved in HOOP project, so as to validate the drivers and barriers related to CBM implementation and are recorded.

The development of the questionnaire includes two stages:

1. Preparation of the 1st version of the questionnaire (drafting, structure and features); and
2. Internal validation of the questionnaire with HOOP project partners to conclude to a final version.

Regarding the first step, the barriers that are identified during the literature review as well as important insights from the analysis of the CBM in existing solutions (2nd level of analysis) will be taken into consideration and will be included properly in the questionnaire. It is important also, the questionnaire to be comprehensive, well designed and adjusted to the specific features of the target groups. As mentioned above, two target groups will be addressed and more specifically, the LH Cities and Regions and the technology providers.

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In the case of LH Cities and Regions, the persons that will be asked to fill in the questionnaire are representatives of the LH Cities and Regions involved in the project. The LH Cities and Regions are already implementing circular business models and bio-waste valorization. This fact provides the advantage to identify drivers and barriers already addressed when implementing specific CBM. In the following table, the questions compiled are presented. In the last column of the table, the aim of each question is described.

Table 3. Questionnaire for defining the barriers and drivers for CBM implementation

No	Question	Goal of the question
1	Are you an organization/public authority/company/other (please specify)? Please select	-
2	Do you implement a circular business model in the domain of bio-waste (i.e. valorization of bio-waste and sewage sludge for raw material (compost, protein, bioplastics, etc.) and bioenergy (biogas, etc.) production). Please describe which circular business model you implement.	Define the drivers of selecting this specific CBM
3	Which is the reason you chose this specific circular business model (feedstock availability, economic benefit, demand for a specific end-product deriving from the bio-waste valorization process, weather conditions of the area, etc.)?	Further define the drivers and enablers of selecting this specific CBM
4	What are the most important problems you face regarding the implementation of this circular business model?	Define the barriers of selecting this specific CBM
5	In case you haven't already implemented a circular business model, which is the reason?	Define the barriers of not implementing CBMs
6	In case you are already implementing a circular business model, would you like to implement another one and why?	Define the drivers for implementing this specific CBM

No	Question	Goal of the question
7	From the list below, please select the three most important barriers for the circular business model implementation. • *Supply chain (Absence of "green" suppliers, Sectors with correlated high environmental impact, Provision of accurate evidence related to the benefits of green products, Consumers mindset and misconceptions towards circular economy and green products)* • *Social/cultural (Rigidity of consumer behavior and businesses routines, negative perception of consumers regarding raw materials derived from valorisation of bio-waste and sewage sludge, low dissemination of information for society, consumers, etc.)* • *Economic and financial (Large capital requirements, significant transaction costs, high OPEX costs, high initial CAPEX cost, high maintenance costs, low opportunities of scalability, lack of knowledge or low level of availability regarding financial schemes and funding opportunities, asymmetric information, uncertain return and profit)* • *Institutional/Regulatory (Misaligned incentives, lacking of a conducive legal system, deficient institutional framework, new legislation with high goals and complex and/or misunderstanding of regulatory schemes)* • *Technical and technological (Inappropriate technology, low TRL, low environmental performance of the technology, lag between design and diffusion, lack of technical support and training)* • *Internal environment and procedures (Organizational capabilities necessary for implementing circular business across different organizational functions, efforts in terms of business strategy definition and company structure, need for new organizational competences (e.g., team motivation, organizational culture, participation), Consumers mindset and misconceptions towards circular economy and green products)* • *Lack of information (little understanding and knowledge on Circular Economy)* • *Feedstock availability (Seasonality of biomass versus need of continuous feedstock supply, Logistics: inefficient transport and distribution of biomass)* • *Collaboration in the value chain* • *Lack of separate waste collection system* • *Market: Lacking economic viability of circular business models. Low virgin material prices, low demand of the product, lacking of products standardization.*	Define other barriers for the implementation of CBM
8	Are there any other barriers that are not included in the previous list and you consider them important (e.g. low quality (physicochemical proprieties) of bio-waste and sludge feedstocks)?	Define other barriers hindering the implementation of CBM

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4. CBM categorization and tools – 1st level of analysis

4.1. CBM frameworks

As far as Circular Economy (CE) is concerned, there is not just one definition generally accepted. On the contrary, there are various approaches and perspectives when defining the CE. One of the most popular CE definitions incorporating elements from different disciplines is the one shared by Ellen MacArthur Foundation. More specifically, Ellen MacArthur Foundation defines CE as '*an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models*'. This definition is based upon the principles of cradle-to-cradle and makes a distinction between the technical and biological cycle of materials. [23], [24], [6], [25]

In order to achieve the transition in the new circular economy model new business models should also be considered. There have been various approaches, especially the last 10 years, in the literature in order to establish the new Circular Business Models (CBMs). [26]

In the following paragraphs, a series of different frameworks for circular business models are described, as proposed by researchers and leading organisations. More specifically, the following paragraphs describe the different CBM frameworks as described by:

- *Lacy & Rutqvist [11]*
- *Business model development in the circular economy by EIONET [9]*
- *Renswoude et al. [12]*
- *Value Hill by Achterberg et al. [7], [10]*
- *Circular business Model patterns identified by R2π project [13]*

Moreover, focus was on the case of CBMs in cities and regions and the proposed frameworks that could be considered also by the businesses as well as the public or other nonprofit organisations to achieve transition to circular economy. Particularly:

- *Circular Economy in cities as proposed by the OECD [8] and*
- *Ellen MacArthur Foundation – RESOLVE [6]*

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4.1.1. CIRCULAR BUSINESS MODELS AS SUGGESTED BY LACY & RUTQVIST

In the following paragraphs the CBM framework proposed by Lacy & Rutqvist [11] is presented. In this framework five Circular Business models are suggested. The five Circular Business models were identified when analyzing more than 120 companies which have made improvements in their resource productivity through innovative ways. Through these Business Models, companies are able to reduce the costs of services and ownership, to generate new revenues and lower risk, while at the same time they can reduce their impact regarding resource efficiency.

The five CBM include:

1. **Circular Supply-Chain:** here are cases when the resources demanded by companies could be either scarce or environmentally harmful. Then, the companies have two options: either pay more or search to find alternative resources. The integration of the Circular Supply-Chain indicates the valorization of fully recyclable, renewable and biodegradable materials. These materials could be used in consecutive lifecycles in order to reduce costs and consequently, to increase control and predictability.

2. **Recovery & Recycling:** This model indicates production and consumption systems, where everything that used to be characterized as waste, could be valorized for other uses. There are two ways to implement such a scenario: a) by valorizing end-of-life products in order to recover and reuse valuable materials, energy and components, b) by valorizing waste or/and by-products deriving from a production process**.**

3. **Product Life-Extension:** Products are in many cases discarded by the consumers either because they are broken or because they are out of fashion or not needed any more. However, many of these products still hold a considerable value. The aim of the Product Life-Extension model is to recapture this value. This could be achieved by maintaining and improving products though remanufacturing, repairing and upgrading. Thus, companies could keep them useful for as long as possible.

4. **Sharing Platform:** A very high percentage (~80%) of things stored in a typical home are used only for one time per month. Through the Sharing Platform Model, new business opportunities can arise for companies, consumers and micro-entrepreneurs who are given the possibility to share, rent, swap or lend their own goods. This way, the resources spent for the manufacturing of products that are not frequently used, are reduced and the consumers have a new way to save and earn money (e.g. Airbnb platform).

5. **Product as a Service:** This business model promotes the leasing or paying for products by the use. Consequently, the focus is transferred to the reusability, longevity and reliability of the products and the companies have an opportunity to build new relationships with the consumers.

During the past decade, the five circular business models mentioned above have been adopted increasingly. At first, start-ups were the first ones who adopted the circular business models. At the moment, more and more multinational companies are moving towards circular business model adaptation, according to the study conducted by a joint Accenture and United Nations Global Compact.

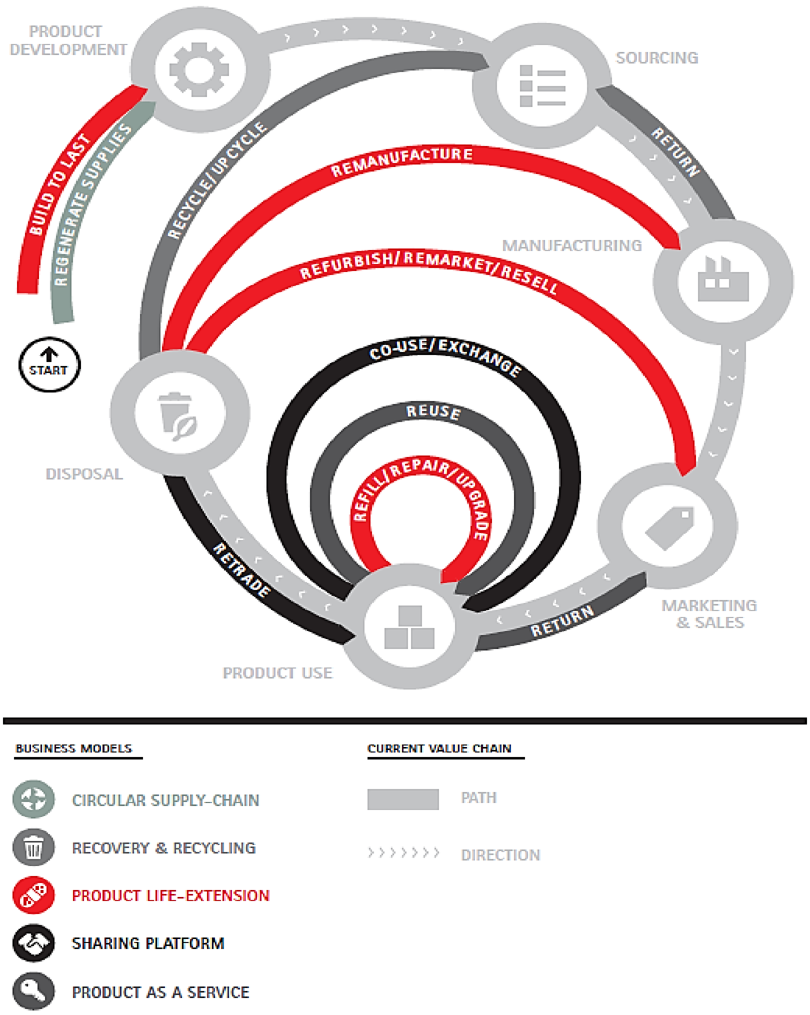

Figure 2. The five circular business models identified by Lacy & Rutqvist [11]

The OECD [26] has also used these Lacy & Rutqvist business models [11] and has summarized key information as presented in table below.

Table 4. Circular business models used by OECD [26]

	Circular supply	Resource recovery	Product life extension	Sharing	Product service system
Key characteristic	Replace traditional material inputs with renewable, bio-based, recovered ones	Produce secondary row materials from waste	Extent product lives	Increase utilization of existing products and assets	Provision of services rather than products. Product ownership remains with supplier
Recourse efficiency driver	Close material loops	Close material loops	Slow material loops	Narrow resource flows	Narrow resource flows
Business model subtypes	Cradle to Cradle	Industrial symbiosis	Classic long life	Co-ownership	Product oriented
		Recycling	Direct reuse	Co-access	User oriented
		Upcycling	Repair		Result oriented
		Downcycling	Refurbishment		
			Remanufacture		
Main sector currently applied in	Diverse consumer product sector	Metals	Automotive	Short term lodging	Transport
		Paper and pulp	Heavy machinery	Transport	Chemicals
		Plastics	Electronics	Machinery	Energy
				Consumer products	

4.1.2. CIRCULAR BUSINESS MODEL PATTERNS IDENTIFIED BY R2Π PROJECT

In the following paragraphs, the seven circular business model patterns that were identified by R2π project [13] are presented. The identified patterns could be grouped according to the life phase of a product. The three life phases of a product are: the production phase, the use phase and the end-of life phase.

Circular business model patterns applied related with PRODUCTION PHASE of a product

1. **Circular sourcing.** Under this model, the renewable and recycled materials can be returned to both the technical and the biological cycle.

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2. **Co-product recovery**. This model indicates that by-products, residual output flows and secondary materials are generated. This can be achieved either by generating these resources by a value chain, or by valorizing the output of a process as an input for another process or/and value chain. Under this model secondary material as well as by-products and residual output flows are generated either by a value chain or by one process becoming input flows for another value chain and/or another process.

3. **Re-condition.** This model is related to the improvement of a product either by fixing the product faults or by upgrading it aesthetically. Thus, product refurbishment and repair can take place. However, an extra warranty of the entire product is not foreseen.

4. **Re-make.** This business model is focused on the end-of cycle extension of the whole product or of a part of the entire product. Contrary to the 'Re-condition' business model, the Re-make business model is aiming at bringing back the product with better or like-new performance, with the relevant warranty.

Circular business model patterns related with the USE PHASE of a product

6. **Access.** This model promotes the approach of "product-as-a-service" by providing access to end users instead of ownership.

7. **Performance.** The aim of this business model is to assure the high level performance of a product because of its high quality technical characteristics and assets. This business model is delivered within the approach of "product-as-a-service".

Circular business model patterns related with the END-OF-CYCLE PHASE of a product

8. **Resource recovery.** This business model is related with the valorization of products or materials at their end-of-cycle. This could be achieved either by the reutilization of the end-of-cycle products and their incorporation into different ones, either by their consumption as feedstock or input flows in another process or value chain.

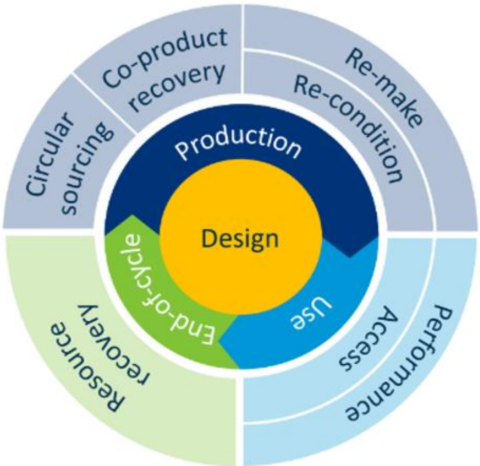

Figure 3. The seven CEBM patterns identified in the R2π project [13]

4.1.3. THE CIRCULAR BUSINESS MODELS AS DEFINED BY EUROPEAN INVESTMENT BANK (EIB)

The European Investment Bank (EIB), under the light of the EU's new Circular Economy Action Plan, has drafted the EIB circular Economy Guide aiming to support the transition to a circular economy, mainly in the European Union, but also in other parts of the world.

According to EIB, the transition to a circular economy requires the companies to reconsider their use of resources, but also to adopt and redesign new business models that rely on refurbishment, remanufacturing, dematerialization, longevity, recycling, capacity sharing and increased reuse.

EIB refers to the business models as defined by Achterberg et al. [7], [10]. More specifically, Achterberg et al. had identified three **phases of a product's life:**

- *the 'before-use' phase,*
- *the 'use' phase,*
- *the 'after-use' phase*

The four Circular Economy Business Models as defined that are based on the phases described above, are the following:

1. **the Circular Design Models** corresponding to the 'before-use' phase**,**
2. **the Optimal Use Models** focusing on the 'use' phase**,**
3. **the Value Recovery Models** targeting the 'after-use' phase of the product, and
4. **the Circular Support Models** relating to all stages. These different business models can be illustrated in what is called a Value Hill, shown in Figure 4**.**

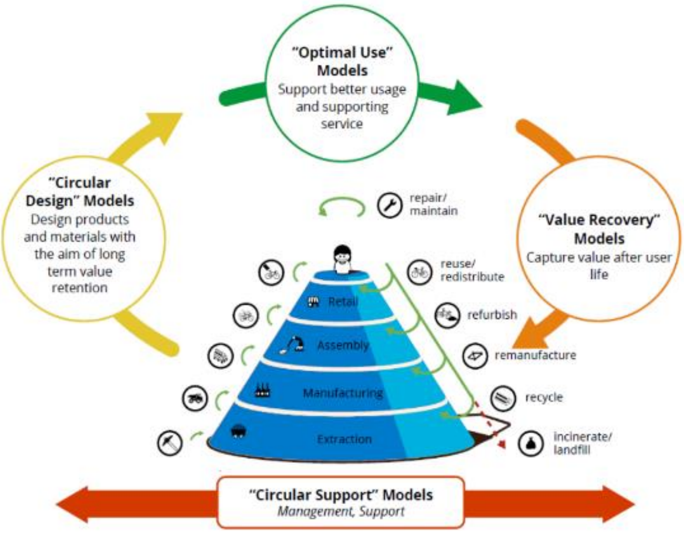

Figure 4. Circular economy business models in the Value Hill, Achterberg et al. [7], [10]

Circular design models. This model focuses on the development of new or existing products or/and processes that aim to increase circularity. The product's design aims to make them last longer, to be easier to maintain, to repair, refurbish, remanufacture, upgrade or recycle. In addition, within this business model, the development of new materials is foreseen, such as bio-based materials, less resource- intensive and/or fully recyclable materials.

Optimal use models. This model category aims to increase the use and the value of products during an extended product life. More specifically, this model promotes the concept of product-to-service e.g. by providing a service instead of selling a product, by taking the responsibility of the product to extend or maintain its useful life. However, the implementation of this kind of model is related to financial implications, such as the changing nature of cash flows, the re-evaluation of residual value etc. In addition, there are challenges regarding legal issues related to the ownership of collateral and its value. These challenges could be difficult to be assessed or valued and consequently this could result in difficulties in financing this kind of projects.

Value recovery models. In this case the focus is on the maximization of products and materials recovery and recycling after their use. The aim is to transform them to useful resources in order to conserve resources and at the same time to reduce waste. Reverse logistics development is considered as very important for this model, for example the return or a product from point of consumption to the point of production. For the implementation of this business model it must be taken into consideration that recycling can lead to the loss of the quality or loss of design, energy and technical inputs. For this reason, a distinction must be made between downcycling (recycling process resulting in losses of quality and functionality) and upcycling (transformation of by-products and waste into new products or materials with higher quality or/and better environmental value.

Circular support models. This business model is related to all stages and they are focused on the management and coordination of circular value networks and resource flows. Also attention is given to incentives optimization and other supporting activities in a circular network. Finally, there is an interaction between circular support models and the others mentioned before: within this model, the development of key technologies is foreseen.

4.1.4. CIRCULAR BUSINESS MODELS AS DESCRIBED BY RENSWOUDE ET AL.

Renswoude et al. (2015) concluded on nineteen Circular Economy Business Models, which are grouped under six categories and in particular:

1. **Short cycle,**
2. **Long cycle,**
3. **Cascades,**

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4. **Pure circles,**
5. **Dematerialised services** and
6. **Produce on Demand**

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The following table summarizes the CBM per category, suggested by Renswoude et al. (2015):

Table 5. Circular business models by Renswoude et al. [12]

1. Sort cycle		
1.	Pay per use	Onetime payment to use product or service
2.	Repair	Product life extension by repair services
3.	Waste reduction	Waste reduction in the production process
4.	Sharing platforms	Products and services are shared among customers
5.	Progressive purchases	Pay periodically small amounts before purchase
2. Long cycle		
6.	Performance based	Long term contract and responsibility with producers
7.	Take back management	Incentive to ensure products gets back to producer
8.	Next life sales	Product gets a next life
9.	Refurbish and resell	Product gets a next life after adjustment
3. Cascades		
10.	Upcycle	Materials are re-used and its value is upgraded
11.	Recycling (Waste handling and repurpose)	Materials are cascaded reused, recycled or disposed
12.	Collaborative production	Cooperation in the production value chain leading to closing the materials loop
4. Pure circles		
13.	Cradle to cradle	Production redesigned to 100% close material loop
14.	Circular sourcing	Only sourcing circular products and materials
5. Dematerialize services		
15.	Physical and virtual	Shifting physical activity to virtual
16.	Subscription based rental	Against, a low periodic fee, customers can use product or services
6. Produce on demand		
17.	Produce on order	Only producing when demand is present
18.	3D printing	Using 3D printing to produce what is needed
19.	Customer vote (design)	Making customers vote which product to make

4.1.5. THE CBM FRAMEWORK AS DESCRIBED BY EIONET

In the report "Business Models in a Circular Economy" drafted by EIONET [9], the analytical framework for the business model development in the circular economy is presented. The framework is based on the following main key points:

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- *As circular goals, can be considered the circular strategies that are related to the useful life extension of products and their remanufacturing, repair, reuse and recycling. These goals have to be achieved through enabling action and innovation.*
- *The business models in a circular economy could be defined as a combination of value proposition, value creation and value capture strategies.*
- *The implementation of the aforementioned business models above could be considered as a means for framing business model innovation.*
- *The business model innovation is built upon social and technical innovation*
- *The appropriate policy, behavioral and educational actions and incentives should be considered as important enablers for circular business model innovation.*

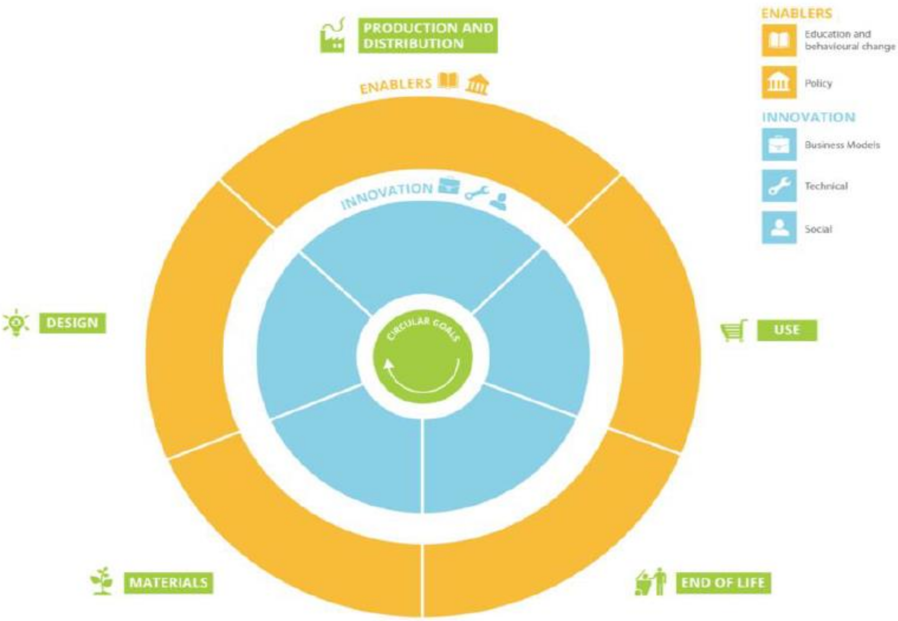

Figure 5. Business Models in Circular Economy [9]

As presented in the figure above, the circular business models are developed taking into consideration the different phases of a product. In particular, these phases are: **1) the raw materials phase, 2) the design phase, 3) the production and distribution phase, 4) the use phase and 5) the end of life phase.**

Regarding the **raw materials phase**, the first circular goal that could be achieved is related to the reduction of resources consumed (e.g. energy, water, land, chemicals, etc.) and the waste reduction as well. The second circular goal that could be achieved during this phase is related to the recycling of materials/waste. Finally, the third circular goal that could be achieved during this phase is the transition from a traditional business model to a model of materials as a service. More specifically, in a model "materials as a service", materials are no longer

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sold to value chain manufacturers, but their functionality is available. For example, in the case of chemical leasing, the chemical company does not sell the processing chemicals to its industrial customers. Instead, the customers buy the service that the chemical company provides, e.g. cleaning dirt and rust from metal parts. Afterwards, they return the chemicals to the supplier of the raw materials, who regenerates or recycles the chemicals for reuse.

During the **product design phase**, the circular design will determine the possibility for reduction, reuse, reconstruction or recycling of materials. The application of circular design is inextricably linked to the available technological solutions.

Within the **production and distribution phase**, the most relevant circular goal to be pursued is to reduce the use of resources. Different ways to achieve lower resource use can be:

- *Increasing the resource efficiency of production and distribution processes*
- *Radically reducing the use of resources in production. Digitizing production*
- *Integrating the use of remanufactured components or new components into the production process*
- *Reducing resources required for the packaging or use of recycled materials*

During the **use phase**, user behavior plays a key role in determining how products are managed during and at the end of use. This means that business model innovation and social innovation are keys in order to increase circularity during the use phase. Reusable product stores as well as product repairs are examples of social innovation that enhances circularity. In addition, a business model for increasing circularity in the use phase is the development practices that focus on the operation or performance of products rather than the product market itself, i.e. access-based models. In the case of these models, users-customers only pay for one (limited) access to the product so the same product can be used by many other users-customers too, either for short periods - rental or sharing - or for longer periods, for example, through lease.

The **end-of-life phase** is particularly important for the ability to reuse and rebuild products. Appropriate incentives are needed to ensure that either products are returned and reused or parts of the products are exploited. Effective return is a challenge, which often requires the cooperation of retailers, and also to ensure that handling goods for reuse or reconstruction during transport does not destroy their value. In this context, the circular objectives that can be set include both recycling and collection for reuse or reconstruction as well as redefining products and materials to create new value.

4.1.6. CIRCULAR ECONOMY IN CITIES

4.1.6.1. THE CBM FRAMEWORK FOR CITIES AS DESCRIBED BY OECD

Finally, according to the recent OECD Composition Report [8], which was based on communication with 300 institutions, the study in 51 cities and OECD regions as well as in-depth case studies and exchanges knowledge with 7 cities and regions, it is reported that in cities and regions the circular economy should ensure:

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- ***Services:*** *efficient use of natural resources as raw materials and optimizing their reuse.*
- ***Economic activities*** *are planned to close, slow down and to limit cycles in value chains.*
- ***Infrastructures*** *designed to avoid the linear model set uses resources inefficiently and intensively.*

In addition, according to the same study CBMs are described which can be applied to cities / regions and which are summarized in the following categories:

1. **Circular supply models**: in these models the traditional inputs are replaced raw materials with secondary materials.
2. **Collaborative consumption**: these models are based on sharing or rental of products between citizens. Corresponding examples are product sharing models, crowdfunding, joint movements etc.
3. **Service system**: the model is about the ability to pay for a service instead of acquiring a product.
4. **Hire or lease of products**: this model aims at extending the life of the products as they are used repeatedly depending on the purpose of their use before proceeding to the phase recycling when possible.

4.1.6.2. THE CBM FRAMEWORK RESOLVE AS DESCRIBED BY ELLEN MACARTHUR FOUNDATION

The CBM framework developed by EMF [6] was based on the 3 principles of circular economy as described by the EMF and in particular:

- Preserving or enhancing the natural resources either by controlling the finite stocks or by valorizing the renewable resource flows.

- Enhancing and optimizing the yields of the resources, by circulating material in use, products and components to the highest degree of utility.
- Fostering the system effectiveness. This could be done by taking into consideration the negative externalities like soil, air and water pollution, the climate change etc., that are related to the use of resources.

The aforementioned three principles were reflected to the following business actions: Regenerate, Share, Optimise, Loop, Virtualise, and Exchange which together formed **the ReSOLVE framework**. In the next paragraphs each element of the framework is further explained.

REgenerate. Moving towards the valorization of renewable energy and materials. The aim of this business action is to maintain and regenerate the ecosystems health and to return biological resources to the biosphere.

Share. The aim in this case is the maximization of the utilization of the products to the greatest extend possible. This can be achieved by reusing the products throughout their technical lifetime, by sharing the products among users, and prolonging the products lifetime through repair, design, maintenance and durability.

Optimise. The aim of the optimization is to increase the performance and the efficiency of the product.

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Loop. According to Ellen McArthur, looping aims to “keep components and materials in closed loops and prioritize inner loops”. In the case of finite materials, looping is translated as remanufacturing of products and components while recycling could be considered as a last resort. On the other hand, in the case of renewable materials this could be translated for example, as the application of anaerobic digestion for biogas production and extraction of bio-chemicals from organic waste.

Virtualize. Through virtualization, the utility is provided virtually, as for example online shopping and virtual offices.

Exchange. Exchanging can be achieved by replacing old materials with advanced non-renewable. In addition, could be achieved by applying new technologies (3D printers) and by choosing new services and products.

Figure 6. The ReSOLVE framework [6]

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4.2. CBM tools

Strategic management tools were considered necessary in order to assess and visualize a specific business idea or concept, in other words to describe a business model [14]. In order to represent different fundamental elements composing a business model and to shed light on the interaction between them, Osterwalder and Pigneur [19] proposed the Business Model Canvas (BMC), a strategic management tool consisting of the following nine building blocks (compositional elements of a business model: (1) the Customer Segments, (2) the Value Propositions, (3) the Channels, (4) the Customer Relationships, (5) the Revenue Streams, (6) the Key Resources, (7) the Key Activities, (8) the Key Partnerships, and (9) the Cost Structure (Osterwalder & Pigneur, 2010). (Kat Valta, WaysTUP).

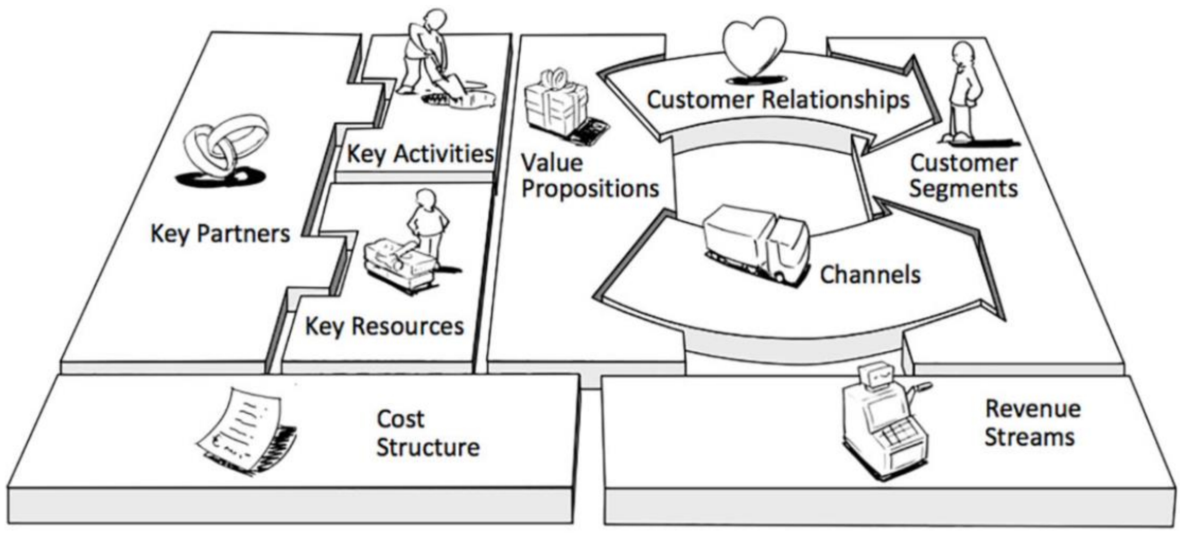

Figure 7. The Business Model Canvas tool and the nine building blocks

The above figure represents the BMC and the nine building blocks as proposed by Osterwalder and Pigneur [19].

More specifically, the nine building blocks “composing” the canvas, are shortly described below:

1. **Customer Segments**: This refers to group/s of people (i.e. the specific target audiences) to which the organization aims to provide their services and products.

2. **Value proposition:** This refers to the products and services provided by an organization in order to meet their customers’ needs and to solve their customers’ problems.

3. **Channels**: This refers to the means through which the products and services are reaching the target audiences. Communication, distribution and sales channels can bring the provided services and products to customers.

4. **Customer relationships:** These are the established relations with the organization's target audience/s and the relations maintenance as well.

5. **Revenue streams:** They refer to the income sources gained by the organization for delivering successfully the value proposition.

6. **Key resources:** These consist of the assets necessary to materialize the value proposition and to reach the specific target audiences.

7. **Key activities:** This includes the activities that an organization must perform to deliver the value proposition successfully.

8. **Key partners:** These are the stakeholders that are necessary to make the whole business model work.

9. **Cost structure:** This refers to the basic costs that must be covered in order to make the business model sustainable.

Furthermore, the Ellen MacArthur Foundation and IDEO [27] developed the Circular Design Guide, which includes a number of tools and methods so as to help organisations to release, define and develop circular innovations. In this context a BMC was developed adjusted and focused on the circular economy model. In the following figure the Circular Business Model Canvas is presented. The canvas apart from the nine building blocks includes also questions and tips relevant to the circular model context.

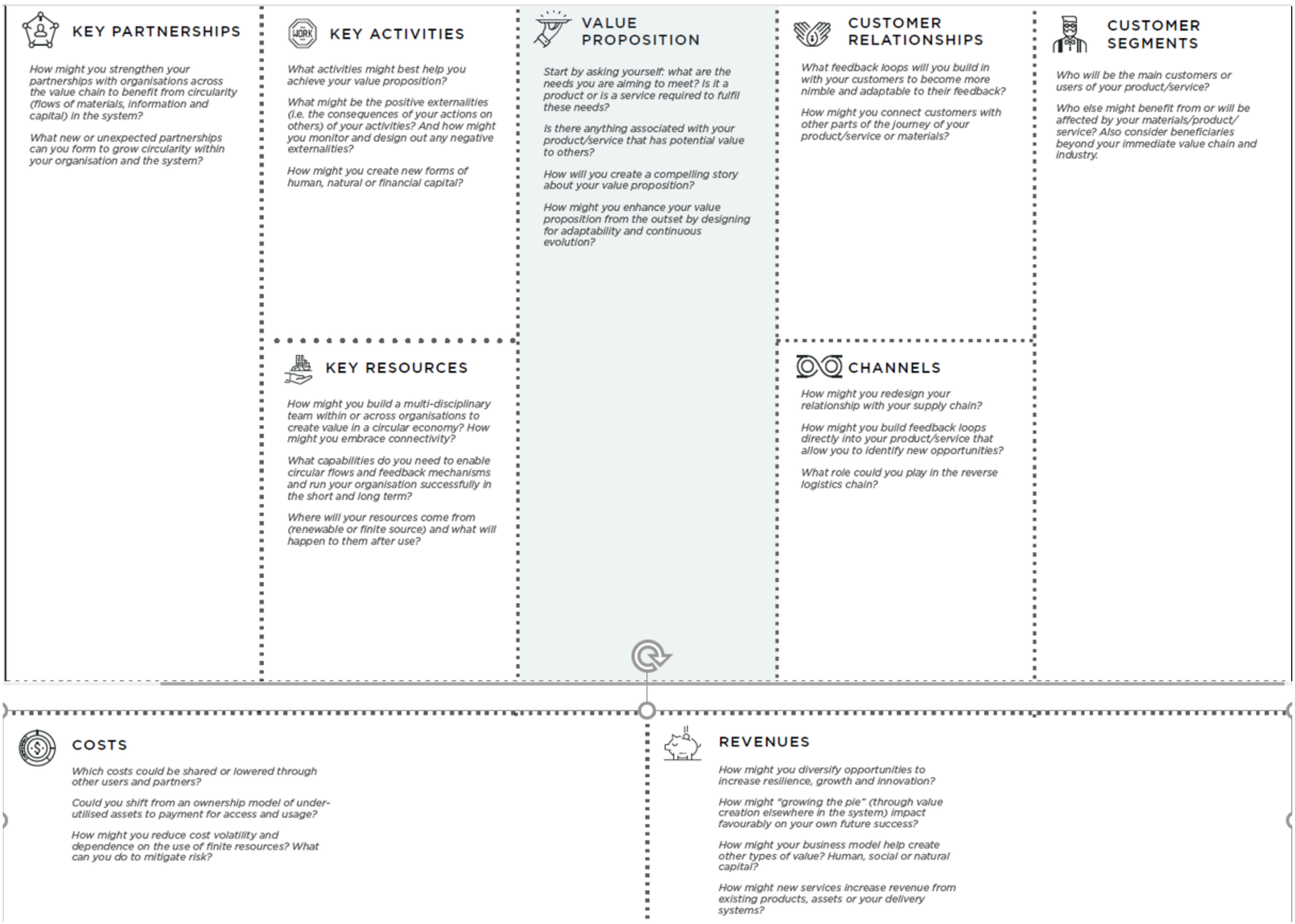

Figure 8. The Business Model Canvas focused on circular business model [27]

4.2.1. BUSINESS MODELS FOR CITIES

The purpose of a company business model differs from the one in the case of a city business model. The aim of a company's business model is to describe how the company captures and delivers value. By the side of a city, a city business model aims to provide guidance to the City Council regarding the implementation of objectives towards a smart and sustainable strategy. [29], [30]

In other words, the Business Models for Cities aim to define how a city can capture and deliver value by developing socially, economically, and environmentally sustainable services. The city's business models take into consideration the interests of both private and public actors with the aim to deliver value to a group of

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different end-users acting in a collaborative context. [29], [30]. A city business model could provide an overview of a strategy on how to create a smart and sustainable city.

The following figure shows the City Model Canvas, as it was developed in the framework of REPLICATE project H2020 [29].

<table>
<tr><td colspan="6">1. Mission statement What is the ultimate goal that the city seeks to achieve?</td></tr>
<tr><td rowspan="2">6. Key Partnerships
Who can help the city deliver the proposed value to the beneficiaries? Who can access key resources that the city council does not have?</td><td>7. Key activities
What must the city council do to create and deliver the proposed value?</td><td colspan="2" rowspan="2">2. Value Proposition
What specific benefits are created and what specific problems does the proposed service solve or alleviate?</td><td>4. Buy-in & support
Whose buy-in is needed in order to deploy the service (legal, policy, procurement, etc.)?</td><td rowspan="2">3. Beneficiaries
Who will directly benefit from the proposed services?</td></tr>
<tr><td>8. Key infrastructure and resources & key regulatory framework
What key resources does the city council have to create and deliver the value? What infrastructure does it need? What is the key regulatory framework required?</td><td>5. Deployment
How will the city solve the problems of the Value proposition specifically?</td></tr>
<tr><td colspan="3">9. Budget cost structure
What costs will the creation and delivery of the proposed services entail?</td><td colspan="3">10. Revenue streams
What sources of revenue for the city do the proposed services provide? What other sources of revenue does the city have?</td></tr>
<tr><td colspan="3">11. Environmental costs
What negative environmental impacts can the proposed services cause?</td><td colspan="3">12. Environmental benefits
What environmental benefits will the proposed services deliver?</td></tr>
<tr><td colspan="3">13. Social risks
What are some of the potential social risks that the proposed service entails? Who is most vulnerable as a result?</td><td colspan="3">14. Social benefits
What social benefits will the proposed services bring about? For whom will these benefits materialize?</td></tr>
</table>

Figure 9. Smart City Model Canvas [29]

The City Business Model Canvas has the following key features:

1. *The City Model Canvas is in the spirit of a mission-driven organization*
2. *It includes not only economic but also social and environmental aspects*
3. *The City Model Canvas is set in such a way, reflecting the goals and the roles of a city municipality.*

All these key features result in a modification of the building blocks. More specifically, instead of nine building blocks, there are in total fourteen. The extra elements included as building blocks in the City Model Canvas are reflecting social and environmental aspects. [14]

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4.3. CBMs for bio-waste valorisation

As mentioned already there is not one common framework for CBMs rather there are various approaches proposed by researchers and leading organisations especially the last 10 years. This deficiency for a generally accepted framework is more profound also in the field of CBMs' framework that particularly investigate the bio-waste valorization. The concept of CBMs focused on bio-waste is still underexplored. In the following paragraphs there is an attempt to present different cases of bio-waste valorization examined as well as the results regarding the CBMs applied.

In the framework of the project NoAW [15], Donner et al. [31] identified and presented six (6) types of BMs that create value specifically from agricultural waste and by-products via cascading and closing loops. More specifically, the six BMs which are suggested include i) biogas plant, ii) upcycling entrepreneurship, iii) environmental biorefinery, iv) agricultural cooperative, v) agropark and vi) support structures. The main difference among the BMs is in their way of creating value and the organisational form suggested. For the determination of the BMs categories, various real cases were examined having the following characteristics i.e., one or more actors were involved geographically close to each other, focus was on agro-waste and by-product valorization particularly via anaerobic digestion. The BM types are presented in the following figure.

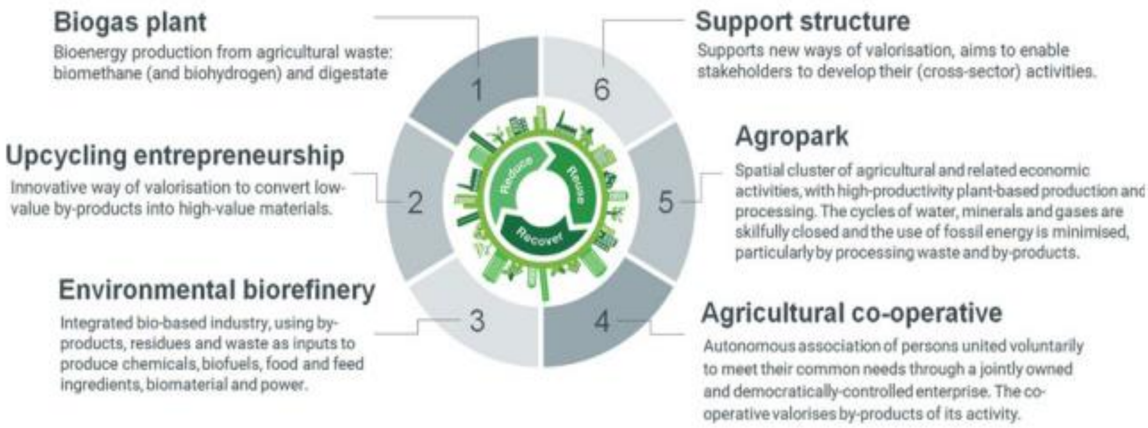

Figure 10. CBM typology for creating value from agrowaste [31]

Moreover, in the framework of BE-Rural Project [16], BMs specifically for small-scale bioeconomy businesses that are suitable for rural areas were analysed with the use of the business model canvas. The project focuses on selected regions in five countries: Bulgaria, Latvia, North Macedonia, Poland and Romania and four exemplary small-scale businesses were selected and analysed. In particular,

1. *Analysis for small-scale pellet producers*
2. *Analysis of a start-up company that offers sustainable packaging and disposable tableware solutions made of agricultural residues*

3. *Analysis of a start-up company developing a technology that turns organic and agroforestry residues into a renewable biocomposite which can be used for the manufacturing of plant pots, construction boards and ornamental vases*
4. *Analysis of an engineering company that offers a transportable plant for protein production from fish waste.*

Indicatively in the following figures the analysis of two of the four cases are presented. The analysis of the business models was made by using the business model canvas.

In the case of organic and agroforestry residues which are converted into a renewable biocomposite (Figure 11), the *value proposition* in this specific business model includes the creation of a sustainable and biodegradable biocomposite which can replace the fossil based alternative materials and can be used for different applications such as the manufacturing of plant pots, construction boards and ornamental vases. Furthermore, income is generated since the agroforestry residues can generate new revenue streams for biomass suppliers. The *customer segment* is the construction industry as well as the tree and plant nurseries and DIY and online stores. Regarding the *key partners,* various partners are important in order to make the business model operational such as technology and the biomass suppliers as well as investors and funders. Additionally, retailers and communication experts are needed for the implementation of the business model. In the *key resources*, the biomass from the surrounding areas are considered essential together with the fungus mycelium which works as a bonding agent to cohere the biomass particles. Moreover, technology, infrastructure and financial resources are required. As for the *cost*s include the investment cost, the technology and operation costs, the feedstock supply costs and the labour and marketing costs. The *revenue streams* will occur mainly from the sale of the end-product.

In the case of the valorization of untapped or disposed fish processing residues for the production of fish proteins (Figure 12), the *value proposition* includes the production of a sustainable product which can substitute less sustainable alternatives in the food & feed, cosmetics and pharma industry. In addition, there is value generation from the untapped or disposed fish residues. The *customer segment* is the food and feed industry, the cosmetics industry and the pharmaceutical industry. Regarding the *key partners,* the fish waste providers and logistics partners for the separate collection of the feedstock as well as the technology providers are crucial. Furthermore, investors need to be acquired. As for the *key resources,* the fish waste and the technology are necessary for the business to run. Moreover, the financial resources are required. As for the *cost*s include the investment cost, the technology and operation costs, the feedstock supply costs and the labour costs. The *revenue streams* will occur mainly from the sale of the end-product, fish-based protein product.

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<table>
<tr>
<td rowspan="2">Key partners
Business incubators
Educational institutions (universities, R&D institutes)
Laboratories
Biomass suppliers (e.g. vineries)
Customers, retailers and online shop providers (promotion of the product)
Social media companies
Logistics partners for the collection of biomass and distribution of products
Investors and funders (e.g. EU)
Technology supplier</td>
<td>Key Activities
Production process and product optimization
Pre-processing (e.g. biomass chipping)
Maintenance of relationships with partners, customers and biomass suppliers
Continuous (online) updates on the products' advantages and success
Sales and marketing</td>
<td rowspan="2">Value Proposition
Sustainable and biodegradable biocomposite for various applications
Replacement of fossil-based materials (decarbonisation)
Extending life cycle of natural resources
Ecological footprint reduction</td>
<td>Customer Relationship
Providing continuously updated content online (social media, blogs)
Sales order (defined by the customer)
Personal contact</td>
<td rowspan="2">Customer Segments
Private persons and households that are aware of environmentally friendly solutions
Tree and plant nurseries
Construction industry
DIY stores
Online shops</td>
</tr>
<tr>
<td>Key Resources
Skilled labour force for product development and marketing
Laboratories for product development
Biomass resources
Production unit
Financial resources (seed capital)
Creative and stimulating environment for start-up establishment</td>
<td>Channels
Newsletters and magazines with focus on sustainability and innovation
Blogs
Social media
Company website
Online shops and DIY stores
Word-of-mouth promotion (e.g. by universities, research institutes partners, investors, etc.)</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Investment costs, biomass supply, marketing, (skilled) labour, rent for laboratories and business incubator spaces, logistics, maintenance of the production facility, energy</td>
<td colspan="2">Revenue Streams
Selling of the biocomposites, showcasing experience as a best practice on different occasions (workshops, fairs, etc) (major awards and prizes)</td>
</tr>
</table>

Figure 11. Business Model Canvas of a start-up company developing a technology that turns organic and agroforestry residues into a renewable biocomposite [16]

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Key partners	**Key Activities**	**Value Proposition**	**Customer Relationship**	**Customer Segments**
Feedstock suppliers (fisheries, fish farms, fish processing industries, fishing vessels, seafood restaurants) Logistics partner for the collection of raw material Technology supplier Hédinn Investors for the business	Fast transport for high-quality products Production process and product optimization Maintenance of relationships with partners, customers and biomass suppliers Procurement of the feedstock Location identification for processing	Creation of natural and sustainable products for the customers Income creation Saving of fish waste disposal costs Valorising untapped and disposed feedstocks Extending life cycle of fish processing waste and bycatch	Personal (on-site) contact On-site sales	Food and feed producers Cosmetics manufactures Pharmaceutical manufacturers
	Key Resources Financial resources (seed capital) Hédinn's protein plant Fish waste and residues Local willingness for implementing new innovative technologies		**Channels** Associations like fishery, healthcare and cosmetic associations (word-of-mouth) Logistics for procurement of feedstock and distribution of the product	

Cost Structure	**Revenue Streams**
Investment costs, feedstock, labour force, logistics, operation and maintenance of the production plant	Selling of fish protein products

Figure 12. Business Model Canvas of an engineering company that offers a transportable plant for protein production from fish waste [16]

Concluding, the analysis of the business models with the use of the business canvas revealed that are aspects that were consistent along the four different cases while simultaneously there are important aspects that are different. The most important factor for the development of a business model seemed to be the technology required as well as the availability of the feedstock and last but not least the investment opportunities.

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In the same context, Reim et al. [17] conducted research focused on the forest sector and the bioeconomy opportunities. Through the review of different sources (scientific articles and book chapters) the need for a holistic perspective about business model activities was revealed. All the information provided in the various sources were examined and related to the different components of the business model canvas. Finally, all business model activities that key actors conduct in order to shift to a CBM in the forest sector, according to literature, were described with the use of the canvas, as presented below.

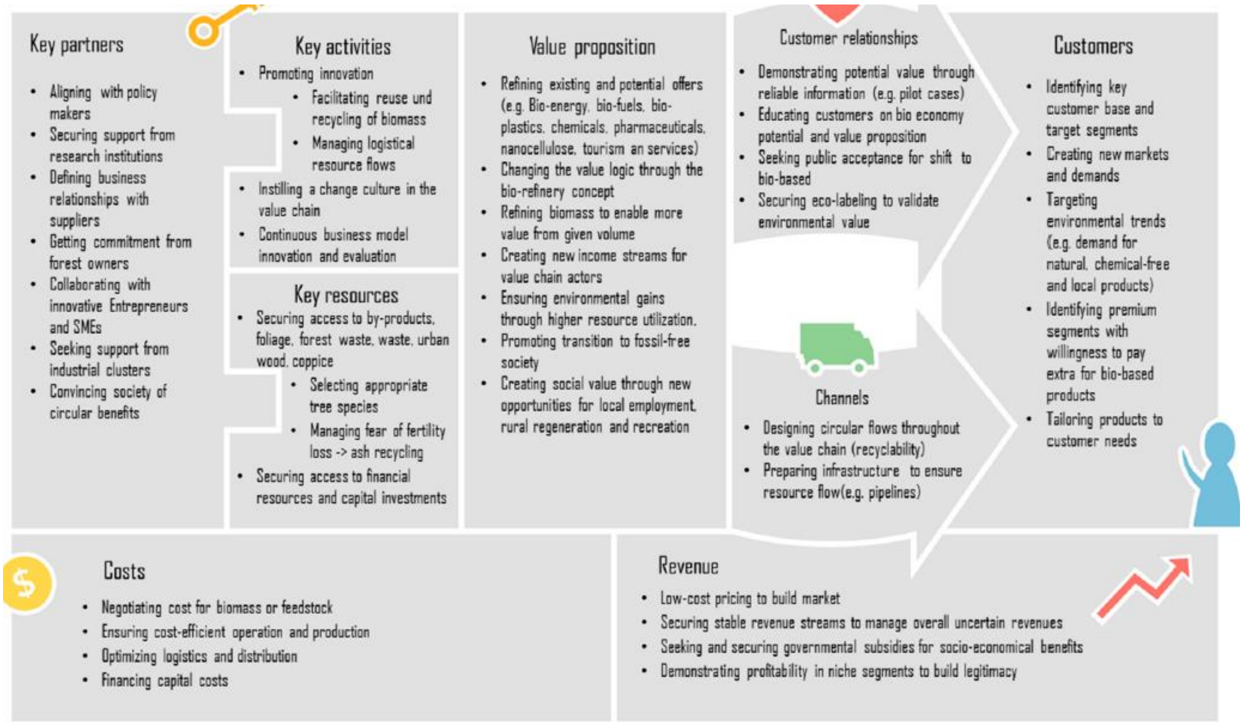

Figure 13. Business model canvas for CBMs in a forest-based bio-economy [17]

Furthermore, in a study that was conducted for the EC-DG RTD in the framework of the BIOSPRI tender "Study on support to R&I policy in the area of bio-based products (BBPs) and services". the most relevant value chains currently under development that derive from biomass components were mapped (Top 20, 2019). Following an assessment that took into consideration the current marketplace, the innovation and the potential in the market, the 20 most innovative BBPs with the greatest potential for commercial deployment within the next 5-10 years were identified. Additionally, case studies were analysed for these 20 products. In the following table the top 20 products as well as their key markets and applications are presented. PHAs from urban wastes as well as Volatile fatty acids (VFAs) mixtures were included in the top 20 BBPs.

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Specifically, Polyhydroxyalkanoates (PHAs) are considered promising biodegradable substitutes for a variety of commodity polymers, such as HDPE, PP etc. PHAs can be obtained from a variety of carbon-rich biomass feedstock, e.g. agricultural wastes, organic fractions of solid municipal wastes and urban wastewater, thus making them attractive for business development. Currently, PHAs based on renewable oils and fats and urban bio-waste (OFMSW and UWW) reach at TRL 6-7. On the other hand, PHAs based on sugars having reached level TRL 9.

Table 6. Selected top 20 BBPs [21]

Biomass category	TOP BBPs under development	Key markets and applications
Natural rubber	Guayule rubber	• Substitute for natural rubber from Hevea Br. in all rubbery goods. Automotive. Biomedical items
Plant fibres	• Lignin biocomposites reinforced with plant fibres • Microfibrillated cellulose • Thermoplastic biopolymers reinforced with plant fibres • Plant fibres reinforced bioresin pre-pregs • Self-binding composite non-woven plant fibres	• Injection molding of plastic items • Rheology modifier, reinforcing filler, emulsions stabilizer, filtering media, biomedical field • Alternative to glass or carbon-fibres reinforced plastics • Alternative to glass or carbon-fibres reinforced pre-pregs • Plastic paper
Renewable oils and fats	• Biolubricants • PHAs • Biobased polyamide 12	• Automotive and industrial field • Biodegradable plastics • Technical plastics

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Biomass category	TOP BBPs under development	Key markets and applications
Lignin	• Lignin-based carbon nanofibres • Bio-BTX aromatics • Lignin bio-oil • Lignin-based phenolic resins • High-purity lignin • Biobased phenol and alkylphenols	• Alternative to PAN-based carbon fibers. Composites • Bio-based raw chemicals • green chemicals and biofuels alternative to phenolic resins • Constructions thermosets. Composites. • Additive for plastics • Aromatic chemicals and monomers
Terpenes	• Limonene-based engineering polymers	• Bio-based polyurethanes, polyamides, polycarbonate
Polyelectro lytes	• Bacterial biosurfactants (sophorolipids and rhamnolipids) • Biotechnological chitosan	• Medical and pharmaceutical formulations, cosmetics, personal care, food industry
Urban bio-wastes	• PHAs from urban wastes • Volatile fatty acids (VFAs) mixtures	• Biodegradable plastics • Raw chemicals to produce esters, solvents, polymers

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Furthermore, for each product the following information was presented:

- *Biomass feedstock*
- *Maximum TRL achieved*
- *Number of active firms*
- *Production facilities (EU / rest of the world)*
- *Leading actors*
- *Estimated market size*
- *Non bio-based or traditional alternatives*
- *Innovation highlights*
- *Applications*
- *Advantages and disadvantages*
- *Value proposition and sustainability*

As for PHAs, while conventional plastics use expensive substrates of nutritional importance, bio-based plastics which use PHAs basically consume agro-waste and surplus material. Additionally, according to the study, PHAs represent a small proportion of total plastic market, although the worldwide demand of bio plastics has grown the last years. Their price is still too high for most applications, however there are supporting factors that make them attractive and promising for the future. In particular, market trends for PHA-based products (e.g. increase in market size for packaging), favoring legislation, special environmental advantages of PHAs (e.g. biodegradability) as well as cheap available feedstock for their production (increase in meat consumption). [21]

From an environmental point of view, PHAs are compostable in aerobic and anaerobic conditions, and additionally biodegrade in open waters (i.e. rivers, oceans, wet lands). As for bio-medical applications, PHAs are suitable for bone-marrow scaffolds, cardiovascular patches, nerve repair devices etc. Currently, Europe is the second producer of PHA, with a capacity of 0.45 million tons for bio-plastic production (18% of global production). [21]

Regarding VFAs, the most significant environmental benefit is its direct substitution of fossil carbon feedstock with more sustainable sources such as waste, which are available in abundance. VFAs are produced through the anaerobic digestion of organic matter. Furthermore, after the anaerobic digestion process, PHAs can be produced as well as other valuable products like biofuels, alcohols, aldehydes or ketones. Amongst the VFAs, the acetic acid is most commercialized product. Currently, the majority of the chemicals produced are fossil based and carbon-containing compounds. However, VFAs and the valorization of the bio-based feedstocks has a great potential for the future. [21]

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4.3.1. INITIAL TEMPLATE BUSINESS CANVAS FOR BIO-WASTE VALORISATION

In the 1st level of analysis for the identification of the CBMs the most representative approaches regarding the CBMs' categorization appearing in the literature were addressed as well as common business model tools, with a focus on the sustainable business model generation tools which take into account also the social and environmental dimension. Additionally, special emphasis was on existing cases of CBMs particularly for various types of bio-waste such as the agro-waste, forest waste etc. as presented in the literature. Finally, taking into consideration the insights from the above review an initial template business model canvas for bio-waste valorization was completed so as to be used as a framework to further explore the existing cases of HOOP bio-waste valorization solutions (2nd level of analysis).

The template business model canvas was based on the 9 elements included in the canvas proposed by Ellen MacArthur Foundation & IDEO (2016). However, the costs and benefits are presented separately as economic costs and revenue streams and social & environmental costs and benefits.

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Table 7. Initial template canvas for bio based solutions

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Circular material supplier Reverse logistics Technology: Partners providing key technologies Storage of materials/products Maintenance services Other partnerships with organisations/clusters etc. across the value chain to strengthen circularity (e.g. sharing infrastructure or other resources mutualisation, public partners, research partners, industrial clusters) Investors	Product design: Design for X (repair, maintenance, disassembly, remanufacturing, recyclability, material substitution etc.) Product quality control Promoting local value chains/markets/materials Reverse Logistics: Executed in-house by organization? Distribution of products Service provision: Product as service, and/or value-added services (e.g. preventative maintenance, asset diagnostics etc.) Actions in order to create new forms of human, natural or financial capital	What are the needs you are aiming to meet? Is it a product or is a service required to fulfil these needs? What is the degree of innovation? Refining biomass to enable more value from given volume Creating new income streams for value chain actors Lower (lifetime) cost: Lower cost of product, or reduced lifetime cost of ownership to an end user. Lower cost: May be priced at a discount to virgin materials on secondary markets.	Long term or recurring? Such as a subscription, part of a long term relationship service etc. Transactional? Single sale, one off transaction How might you connect customers with other parts of the journey of your product/service or materials? Ensuring eco-labeling/standardisation to validate environmental value Public acceptance for shift to bio-based products Informing/education on bio economy potential and value proposition	Basic customer segmentB2B/ B2C? New customer segment: Sale to a different customer segment Vertical customer: Customer outside the main product value chain, beneficiaries beyond your immediate value chain and industry Premium segments willing to pay extra for bio-based products

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<table>
<tr>
<td rowspan="2"></td>
<td>KEY ACTIVITIES

Valorisation process

Change culture in the value chain of bioproducts (increase acceptance of bioproducts)

Maintenance of partnerships with customers, partners and suppliers</td>
<td rowspan="2">VALUE PROPOSITION

Performance: provides outcomes and level of performance corresponding to a customer’s job-to-be-done (equipment up time, output etc.). includes product-service system models.

Access: convenience of on-demand availability, flexibility and greater range of choice. Models include: pay as you go, rental, leasing

Sustainability: Provides a sustainability related outcome that is valued by the customer (environment, social etc.)

Co-value: value provided to a vertical –customer outside the main value chain.</td>
<td></td>
<td rowspan="2"></td>
</tr>
<tr>
<td>KEY RESOURCES

Asset management platform: booking, paying, tracking assets

Specialised production process: Specialised process and facilities (e.g. for recovery processes)

Assets: Assets or product stock available to provide as a service</td>
<td>CHANNELS

Re-sale channel: Distinct sales channel, separate from “new” product sales

Return channel: Collection or return channel for product at end of life

Secondary material market: Markets for sale of recovered materials (co-product, scrap, recycled etc.)

Communication channels</td>
</tr>
</table>

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	KEY RESOURCES Seasonality and variability: ensured feedstock and/or by-products Human and financial resources			

COSTS ○ *Labour: Labour cost (increase or reduction)* ○ *Materials: materials cost (increase or reduction)* ○ *Waste disposal: cost of disposing waste outputs (increase or reduction)* ○ *Financial incentive: to incentivize take – back or return of product* ○ *Financial cost: cost of customer financing (e.g. for leasing solutions)*	REVENUES ○ *Product sale revenue: sale of product, component or material (customer owned)* ○ *Bundled product-service sale revenue: sale of product and service bundle (customer owned)* ○ *Service sale revenue: sale of service only (no ownership)* ○ *Waste as value: revenue stream from waste or co-product being used instead of disposed*
SOCIAL & ENVIRONMENTAL – Potential decrease of jobs in new products or virgin materials sector Potential increase of environmental impacts due to additional transport between value chains.	SOCIAL & ENVIRONMENTAL + Reduced waste to landfill. Reduced waste to incineration Due to lower item cost, access offered on an ad-hoc basis to users unable to afford purchase of asset Increase of jobs in circular materials/repair and refurbishment service, recovery and recycling sector

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5. Development of the HOOP CBMs – 2nd level of analysis

5.1. CBMs for HOOP bio-based solutions

In the 2nd level of analysis for the development of the HOOP CBMs, existing solutions/technologies were analysed through the use of the business model canvas. The examined solutions, followed the work from Task 2.2 and finally 15 cases were examined. In the following table the examined solutions are presented.

Table 8. Solutions investigated in Del 4.1

1	Bioprocess involving methanotrophic bacteria using biomethane arising from the AD of the OFMSW
2	Black soldier fly larvae fed with OFMSW or digestate from AD
3	Nutrients recovered from residual dewatering liquid from AD
4	Microalgae harvesting from bio-waste
5	Production of P3HB or other PHAs by fermentation
6	Volatile fatty acids (VFAs) production from UWWS
7	Cellulosic rejections of wastewater treatment plants to ethyl lactate bio-solvent
8	Polylactic acid (PLA) production from fruits and vegetables waste
9	2,3-Butanediol from OFMSW, garden waste and UWWS
10	Slow pyrolysis
11	Production of functional ingredients from spent coffee grounds

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12	Biochemical production of functional ingredients from animal by-products
13	Production of biotic pesticides from OFMSW
14	Production of biofertilizers and biostimulants from OFMSW and UWWS
15	Bioconversion of UWWS: CO_2 fermentation with bioelectrochemical systems

The 15 technologies were examined regarding their business model through the completion of the business model canvas. In the following section an overview of the analysis of the 15 bio-waste valorization solutions in terms of business model is presented. Thorough presentation of the business model canvas for each solution is presented in the Annex A.

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1. Business model overview for the production of SCP through bioprocess involving methanotrophic bacteria	
Value proposition	
What is the value proposition of the exploitable output?	SCP commercialization which generally contains 50-80% protein on a dry matter and essential amino acids and can be used as alternative protein rich feed. It can also supplement conventional SCP which is produced from natural gas.
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Industries related with animal feed, feed companies, food industry
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	AD plants (biogas as feedstock), Municipalities/Regions, Waste management plants, Local agricultural cooperatives, HORECA, households, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	AD biogas or OFMSW for biogas production, other resources (Water, air, pure oxygen, mineral nutrients, vitamins, energy), human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs (if applicable), waste treatment costs
What are the main revenue streams expected?	Sale of SCP

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2. Business model overview for the Black soldier fly (BSFL)	
Value proposition	
What is the value proposition of the exploitable output?	Commercialize bioproducts such as proteins, lipids and chitin for animal feed. These products can supplement “standard” protein-rich feed and oily products, which may need more land and water for production. Considered novel food. Lower production costs compared to others methods which produce “standard” protein-rich feed and oily products. Thus, cheaper prices and better nutritional properties are expected.
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Industries related with animal feed, aquaculture industries, insect farms, feed companies, agriculture, niche market in Norway
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	Municipalities/Regions, Waste management plants, AD plants, Local agricultural cooperatives, HORECA, households, Insect suppliers, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, collaboration for waste/residue valorization, investors
What are the key resources required to make a functional BM?	Fresh organic matter from the OFMSW, AD digestate and/or UWWS, insects, chemicals and/or enzymes might be required (in case further processing to get chitin and chitosan), energy (Heat/steam), human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs (if applicable), waste treatment costs
What are the main revenue streams expected?	sale of proteins, lipids and chitin for animal feed, sale of by-product (excreta residue)

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3. Business model overview for nutrients recovered from residual dewatering liquid from AD	
Value proposition	
What is the value proposition of the exploitable output?	Commercialisation of struvite and ammonium sulphate, which can supplement conventional fertilisers - inorganic chemical-based fertiliser (phosphorus-based fertilisers and commercial fertiliser ammonium sulphate)
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Agriculture, chemical industry
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	AD plants, Municipalities/Regions, Waste management plant, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	Residual dewatering liquid of anaerobic digestion and/or digestate from AD, magnesium chloride (also possible magnesium hydroxide or magnesium oxide), Sulphuric acid, Sodium hydroxide, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs (if applicable), waste treatment costs
What are the main revenue streams expected?	sale of struvite and ammonium sulphate

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4. Business model overview for Microalgae	
Value proposition	
What is the value proposition of the exploitable output?	Commercialisation of microalgae, which provide an alternative protein source (and other macro and micronutrients such as carbohydrates, lipids, and vitamins). lower price compared to fishmeal. Beneficial from an environmental point of view as they can supplement “standard” protein-rich feed and oily products, which may need more land and water for production
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	aquaculture (fish and mollusks feed), cosmetic industry, pharmaceutical, nutraceutical industries, energy sector (biofuels), - WWTP, farmers, agronomists (nursery gardens), agricultural cooperatives (microalgae biomass as soil conditioner)
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	Local associations of farmers, farmers, households, Municipal Collection Systems/Companies, CO2 might be obtained from residual industrial streams, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	Fruit and vegetable waste, CO2, either enzymes (enzymatic hydrolysis) or steam and high pressure (thermal hydrolysis), human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs (if applicable), waste treatment costs
What are the main revenue streams expected?	sale of microalgae as alternative protein source, revenue stream from by-product (fertilizer)

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5. Business model overview for production of P3HB or other PHAs	
Value proposition	
What is the value proposition of the exploitable output?	Commercialize P3HB or other PHAs, which is known to be biocompatible and biodegradable as well as non-toxic. It can replace synthetic plastics. Industry of PHA's production is competitive and growing
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Plastic industries, cosmetic production industries, pharmaceutical industries (biomedicine), packaging, agriculture (farmers, agricultural associations)
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	HORECA, Households, municipal separate collection system, Municipalities/Regions, WWTPs, AD plant, partnerships to develop separate collection network of UCO, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	UCO or UWWS/OFMSW, bacteria, air, water, mineral nutrients, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs, waste treatment costs
What are the main revenue streams expected?	sale of product (P3HB or other PHAs), revenue stream from residue from fermentation

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6. Business model overview for production of VFAs	
Value proposition	
What is the value proposition of the exploitable output?	Commercialization of acetic acid (or other VFAs), which can supplement conventional VFAs which is produced from natural gas or refined crude oil. Bio-based VFAs have the same properties as petroleum-based ones.
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	WWTP (biological nutrient removal), bioplastics industry, biofuel industry, chemical industries, perfume and cosmetic industries, food industry, animal feed industry
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	WWTP (municipal, industrial, private, public), AD plant, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	UWWS, sludge containing anaerobic bacteria is used as inoculum, sodium hydroxide (NaOH) is added during the process, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs, waste treatment costs
What are the main revenue streams expected?	sale of product (acetic acid or other VFAs), revenue stream from residue from fermentation

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7. Business model overview for production of ethyl lactate	
Value proposition	
What is the value proposition of the exploitable output?	Commercialization of biosolvents for industrial valorization. Ethyl lactate and other acid esters are employed as toxic-free biodegradable bio-solvents.
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Fuel and additive fuel industry (bioethanol), cosmetics, perfumes industry (bioethanol and ethyl lactate), plastics industry, biodiants (paints, varnishes, inks, etc.), food and beverage industry (bioethanol and ethyl lactate as additives in foodstuffs)
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	Municipalities/Regions, Waste management plants, WWTPs, AD plants, HORECA, households, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	Cellulosic rejections UWWS or OFMSW, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs, waste treatment costs
What are the main revenue streams expected?	sale of product (ethyl lactate or bioethanol), revenue stream from co-products that could be sold as compost or biofuel

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8. Business model overview for production of PLA	
Value proposition	
What is the value proposition of the exploitable output?	Commercialization of Polylactic Acid (PLA), a biopolymer that is biocompatible, biodegradable and presents thermoplastic properties similar to PET. It can supplement conventional plastics PLA is the most produced bioplastic globally, with a growing market
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	applications for films, bottles, as agriculture films ,medical and laboratory devices, pharmaceutical industry, food packaging, textile sector
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	HoReCa, household users, farmers, fruit and vegetable market, municipalities/regions, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	Food waste, lactobacillus, enzymes, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs, waste treatment costs
What are the main revenue streams expected?	sale of PLA, revenue stream from residue from fermentation

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9. Business model overview for the production of 2,3 butanediol	
Value proposition	
What is the value proposition of the exploitable output?	Commercialisation of 2,3 butanediol, which can supplement conventional 2,3 butanediol which is produced through chemical methods from fossil sources and it requires high energy intensity and the use of expensive catalysts
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Food industry as food additive, biofuel, chemical industry, polymers and cosmetics industry
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	HoReCa, households, farmers, fruit and vegetable market, municipalities/regions, agriculture cooperatives, partnerships to develop collection network, provider of specialised production process (including for further processing of 2,3 butanediol), expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	Garden waste, vegetables, fruit waste, bacteria, sulphuric acid, enzymes, oxygen, ethanol, acetic acid, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, separate collection costs, waste treatment costs
What are the main revenue streams expected?	Sale of 2,3 butanodiol, revenue stream from residues (e.g. seeds, bagasse and lignocellulosic vegetables for compost)

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10. Business model overview for the production of biochar	
Value proposition	
What is the value proposition of the exploitable output?	Commercialise biochar as soil fertilizer/ biostimulant, which can supplement “standard” chemical fertilisers/biostimulants
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Farmers, agronomists (nursery gardens), agricultural cooperatives, forestry activities, energy sector (biofuels)
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	Municipal WWTPs, Private WWTPs, producers of oil or compost, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	Sewage sludge, olive mill waste water solids can be alternative feedstocks, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, waste treatment costs (off-gas cleaning system)
What are the main revenue streams expected?	Sale of biochar, revenue stream from waste or co-product being used instead of disposed (gas)

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11. Business model overview for the production of functional ingredients from spent coffee grounds (SCGs)	
Value proposition	
What is the value proposition of the exploitable output?	Commercialization of aromatic flavor components, coffee oil and/or carotenoids which can replace oils and flavors with harmful chemical components
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	food industry, animal food industry, cosmetic industry, pharmaceutical, nutraceutical industries
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	HoReCa and potentially household users, hotels, restaurants, coffee shops and coffee companies, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	SCGs, hexane and ethanol for the extraction, enzymes, sulphuric acid, $(NH_4)_2SO_4$, KH_2PO_4, $MgSO_4$, glucose for carotenoids production, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, waste treatment costs
What are the main revenue streams expected?	Sale of aromatic flavor components, coffee oil and/or carotenoids, revenue stream from waste being used instead of disposed (solid waste from fermentation process)

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12. Business model overview for the production of functional ingredients from animal by-products	
Value proposition	
What is the value proposition of the exploitable output?	Commercialization of gelatine or hydrolysed collagen which can replace collagen hydrolysate produced by the ovine and pig by products
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	animal feed companies, cosmetic industry, pharmaceutical industry
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	HoReCa, Markets ((i.e., butcheries, fisheries), households, aquaculture industries, slaughterhouses and food processing industries, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	products coming from fish/meat waste treatment, biomass, fltration grounds, water (decalcified), enzymes (commercial), sulphuric acid, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, waste treatment costs
What are the main revenue streams expected?	Sale of gelatine or hydrolysed collagen, revenue stream from waste being used instead of disposed (organic waste that can be valorised (AD, compost))

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13. Business model overview for the production of biopesticides	
Value proposition	
What is the value proposition of the exploitable output?	Commercialization of the bacteria Bacillus Thuringiensis (Bt) (biological pesticide) which can supplement conventional chemical pesticides
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Farmers, agronomists (nursery gardens), agricultural cooperatives
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	Municipalities/Regions, Waste management plants, AD plants, local agricultural cooperatives, HORECA, farmers, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	Food waste, Bacillus thuringiensis, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, waste treatment costs
What are the main revenue streams expected?	Sale of bacteria Bacillus Thuringiensis (Bt), revenue stream from waste being used instead of disposed (residue as fertiliser)

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14. Business model overview for the production of biostimulants and biofertilizers	
Value proposition	
What is the value proposition of the exploitable output?	Commercialization of biofertilisers and biostimulants which can improve the productivity per unit area in a relatively short time. Consequently, they can reduce the use costs compared to chemical fertilisers
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	Farmers, agronomists (nursery gardens), agricultural cooperatives
Business readiness element	
Who are the key partners, partnerships and synergies required to optimize the BM, acquire resources and reduce risk?	Municipalities/Regions, Waste management plants, AD plants, local agricultural cooperatives, HORECA, farmers, WWTPs, partnerships to develop collection network, provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	OFMSW or UWWS, enzymes, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, waste treatment costs
What are the main revenue streams expected?	Sale of biofertilisers and biostimulants, revenue stream from waste being used instead of disposed (residue as fertiliser)

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15. Business model overview for the production of biomethane and organic compounds with the bioelectrochemical system process	
Value proposition	
What is the value proposition of the exploitable output?	Commercialization of biomethane and other organic compounds which can supplement conventional acetate, other energy sources (in case of biomethane) direct CO2 sequestration from the technology
Type of Exploitation (e.g. commercial, scientific, other).	Commercial
Market readiness element	
What are the main target markets?	pharmaceutical industry, textile industry, paints, plastics industry, fuels, energy
Business readiness element	
Who are the key partners, pertherships and synergies required to optimize the BM, acquire resources and reduce risk?	Municipalities/Regions, AD plants, (UWWS and biogas from AD plant), provider of specialised production process, expert for maintenance of equipment, investors
What are the key resources required to make a functional BM?	UWWS and biogas from AD plant to provide CO2, enriched homoacetogens, human & financial resources, infrastructure
What are the main costs incurred to make the BM operational?	Infrastructure & operational costs, labour costs, materials costs, waste treatment costs
What are the main revenue streams expected?	Sale of product (biomethane, organic compounds)

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By comparing the results of the business models for the 15 valorisation solutions significant insights can be obtained. At first, the examined solutions use bio-waste and convert them into value added products, such as feed products, chemical and/or polymers while at the same time enhance the resource efficiency of the respective processes by reducing the use of fossil carbon. Additionally, renewable carbon sources from biomass, agriculture and/or forestry, including byproducts and wastes streams, are used. Hence, the above solutions comply with the circular bioeconomy principles which promote the resource efficiency, the valorisation of waste, the reduction of the demand of fossil carbon and the elimination of the GHG emissions [32]. Moreover, it is evident that in all examined valorization solutions the end product is of higher value than the feedstock used, which is bio-waste streams. Furthermore, as mentioned by Aschemann-Witzel and Stangherlin [33], in circular bioeconomy the concept of adding value is entailed. Consequently, all examined business models can be characterized resource recovery models.

On the other hand, all the end products, which fall under one of the following categories i.e., nutritional ingredients (e.g. SCP, carotenoids, active peptides, insect), biopolymers (e.g. PHAs, PLA), agricultural components (e.g. biofertilisers, biostimulants, insect frass), chemical ingredients (e.g. biosolvents, VFAs), are directly consumed for specific applications and there is an inherent limitation regarding end-product re-use or recycling. Therefore, the business models based on recycling or remanufacturing of the end product are not suitable for bio-waste valorization cases.

Regarding the aspect of the value delivery in the business models it was observed that there are two main types of customers and the respective channels to contact them i.e. the wholesale customers which include the industry sector such as the chemical industry, the food and feed industry, the packaging industry etc. and on the other hand the individual customers which may include basically farmers, agronomists and the pet market. In the first case the business model could be characterized B2B, while in the second case B2C. it should be noted here that in all analysed business models the channel was B2B while only in some business models the channel was additionally B2C. Both B2B and B2C were suitable when the end product targeted the agricultural sector or the feed companies.

Finally, from the point of view of the required partnerships and collaborations which impact the value creation of the business model, it was observed that for some of the examined valorization solutions, the existence of AD or WWT was necessary. The feedstock for the examined technology was either the AD biogas or the AD digestate or the UWWS and not directly the OFMSW or the special streams of organic waste.

5.1.1. PROPOSAL OF TEMPLATE BUSINESS CANVAS FOR BIO-WASTE VALORISATION

After the completion of the 15 business model canvases for the respective solutions, the initial business model canvas, proposed in the 1st level of analysis, was validated and a final template business model canvas for bio-waste was proposed and is presented below.

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Table 9. Template business canvas for bio based solutions

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers Technology: Partners providing key technologies Experts for maintenance services Other partnerships with organisations/clusters etc. across the value chain to strengthen circularity (e.g. sharing infrastructure or other resources mutualisation, public partners, research partners, industrial clusters)	Product design: Design for X (biodegradability, recyclability, material substitution etc.) Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/material s Collection and/or storage of feedstock Production of the bioproduct (pretreatment, core process, post-treatment) Product quality control – product certification	Valorise bio-waste to enable more value from given volume and from waste Creating new income streams for value chain actors Lower (lifetime) cost: Lower cost of product, or reduced lifetime cost of ownership to an end user. Lower cost: May be priced at a discount to virgin materials on secondary markets. Access: convenience of on-demand availability, flexibility and greater range of choice.	Ensuring eco-labeling/standardisation to validate environmental value Long term or recurring, such as a subscription, part of a long term relationship service etc. Transactional. Single sale, one off transaction B2B Personal contact with wholesale customers (e.g. food industry, feed industry, feed companies) Sales according to customer's order	Basic customer segment B2B, B2C? New customer segment: Sale to a different customer segment Vertical customer: Customer outside the main product value chain, beneficiaries beyond your immediate value chain and industry Premium segments willing to pay extra for bio-based products

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KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Partnerships to develop collection network *certified transport company for raw material and/or product company for the bio-waste collection equipment (e.g. bins).* Partnerships for packaging and distribution of product Reverse logistics- collaboration for waste/residue treatment Public/private financing Partnerships that may have positive impact in society and/or environment	Reverse Logistics: collaboration for waste/residue treatment Packaging and distribution of products Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers Service provision if possible: Recovery of product Change culture in the value chain of bioproducts (increase acceptance of bioproducts) Explore new market segments if exist	Sustainability: Provides a sustainability related outcome that is valued by the customer (environmental, social etc.) Co-value: value provided to a vertical – customer outside the main value chain. Innovation product	Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs) B2C Personal contact with customers or relative networks (e.g. farmers) Sales according to customers' order Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs) Informing/educating on bio economy potential and value proposition	Bio-products main customer segments: 1. Food industry (e.g. flavoring in food and beverage products, food preservation) 2. Feed industry (Industries related with animal feed (aquaculture, poultry and swine species, mollusks) 3. Feed companies, pets market 4. Chemical industry (e.g. biosolvents, paints) 5. Plastic, Packaging industry 6. Cosmetics 7. Pharmaceutical industry 8. Agriculture 9. Energy sector (biofuels)

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KEY PARTERNSHIPS	KEY RESOURCES		CHANNELS	CUSTOMER SEGMENTS
Engineers to conduct a study for a plant (if new) and the necessary permission documents.	Specialised production process: Specialised process and facilities (e.g. for recovery processes) Ensured feedstock and/or by-products (Seasonality and variability) Other resources (e.g. water, air, energy, enzymes) Assets: Assets or product stock available to provide as a service Human and financial resources		Re-sale channel: Distinct sales channel, separate from “new” product sales Return channel: Collection or return channel for product at end of life Secondary material market: Markets for sale of recovered materials (co-product, scrap, recycled etc.) Communication channels Promotion through the relative networks, local associations of farmers, agronomists etc. Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc.)	Bio-products main customer segments (continued): 10. Microelectronics (bioethanol) 11. Textile industry (PLA)

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CHANNELS

Participation in relevant campaigns, local events (for raising awareness and demonstrating the products)

Sales through Company

Website, online shops, on-site (if exists)

Word-of- mouth

COSTS

- Labour: Labour cost
- Materials: materials cost (feedstock, other additional materials)
- Infrastructure cost/ maintenance cost
- Separate collection cost
- Waste treatment cost incl. waste disposal (cost of disposing waste outputs)
- Operational costs
- Communication, dissemination costs
- Financial incentive: to incentivize take – back or return of product

REVENUES

- Product sale revenue: sale of product, component or material (customer owned)
- Bundled product-service sale revenue: sale of product and service bundle (customer owned)
- Service sale revenue: sale of service only (no ownership)
- Waste as value: revenue stream from waste or co-product being used instead of disposed

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SOCIAL & ENVIRONMENTAL –	SOCIAL & ENVIRONMENTAL +
Environmental issues such as increased energy consumption, additional transport between value chains, odor pollution, chemicals for the production process etc. High production costs of bio-product. Low TRL. Technologies of bio-waste valorization under development and therefore the economic costs are not fully estimated. Higher price than the conventional product Medical issues (e.g. allergy symptoms, toxicity threshold) Lack of social acceptance. Lack of information regarding the benefits of the bio-product. Lack of targeted legislation	Environmental benefits such as ○ reduced waste to landfill, reduced waste to incineration ○ more efficient use of resources through bio-waste valorization ○ bio-products can supplement other conventional products (e.g. fossil based products, protein-rich and oily products, chemical for agriculture etc.) ○ reduced emissions ○ carbon negative bio-product (e.g. biochar) Better performance of the bio-product compared with the conventional product Lower production cost and/or price than the conventional product Positive impact to food scarcity. Use of bio-products in food industry, which may contribute to the human food supply and security in the future Social acceptance Promotion of EU legislation (e.g. Regulation 2009/1069/EC for protein recovery and recycling process of animal by-products)

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6. CBM identification for bio-waste – 3rd level of analysis

6.1. First evaluation of the results

In the 3rd level of analysis, the evaluation of the results, previously presented for each one of the 15 solutions, will be conducted. The aim of the first evaluation is to ascertain whether the existing CBM frameworks, which were presented in detail in Chapter 3, could describe the business models specifically in the field of bio-waste valorization. In the following table each of the examined solutions is matched with a corresponding CBM category according to five frameworks analysed previously (Section 3.1), and in particular:

- *Lacy & Rutqvist [11]*
- *Ellen MacArthur Foundation [6]*
- *Renswoude et al. [12]*
- *Value Hill by Achterberg et al. [7] [10]*
- *Circular business Model patterns identified by R2π project [13]*

The matching that took place indicates that according to the Value Hill categorization [7] [10] the more suitable business models are the "Value Recovery Models" which target the 'after-use' phase of the product. In these business models the aim is to transform products at the end of their life to useful resources in order to conserve resources and at the same time to reduce waste.

Similarly, according to Lacy & Rutqvist [11] and the R2π Project [13] the business model categories that explains better the bio-waste valorization are "Recovery & Recycling" and "Resource recovery" respectively, which refer to the end-of-life of a product and its potential utilization as feedstock for another value chain and/or another process.

Additionally, according to Renswood et al. [12] the more suitable business models are the "Cascades" where materials are reused and their value is upgraded. Furthermore, in this category waste handling and repurposing is included where waste is reused and recycled and finally collaborative production model is included which aims at closing the materials loop through the collaboration between the different stakeholders in the production value chain.

Last but not least, the RESOLVE framework [6] describes a similar business model category, "Loop", in which AD as well as the extraction of biochemicals from organic waste are included. In this category, the aim is to

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keep the components and materials in closed loops and prioritize the inner loops. The emphasis is on remanufacturing, recycling of products and components as well as recovery.

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Table 10. Matching of business models of examined solutions with the existing CBM frameworks

	Technology	Value Hill by Achterberg et al. (2016)	Renswoude et al. (2015)	Lacy & Rutqvist (2015)	R2π project, (2019)	ReSOLVE (EMF, 2015)
1	Bioprocess involving methanotrophic bacteria using biomethane arising from the AD of the OFMSW	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
2	Black soldier fly larvae fed with OFMSW or digestate from AD	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
3	Nutrients recovered from residual dewatering liquid from AD	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
4	Microalgae harvesting from bio-waste	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
5	Fermentation of used cooking oils	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
6	Volatile fatty acids (VFAs) production from UWWS	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop

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	Technology	Value Hill by Achterberg et al. (2016)	Renswoude et al. (2015)	Lacy & Rutqvist (2015)	R2π project, (2019)	ReSOLVE (EMF, 2015)
7	Cellulosic rejections of wastewater treatment plants to ethyl lactate bio-solvent	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
8	Polylactic acid (PLA) production from fruits and vegetables waste	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
9	2,3-Butanediol from OFMSW, garden waste and UWWS	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
10	Slow pyrolysis	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
11	Production of functional ingredients from spent coffee grounds	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
12	Biochemical production of functional ingredients from animal by-products	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
13	Production of biotic pesticides from OFMSW	Value Recovery Models	Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop

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	Technology	Value Hill by Achterberg et al. (2016)	Renswoude et al. (2015)	Lacy & Rutqvist (2015)	R2π project, (2019)	ReSOLVE (EMF, 2015)
14	Production of biofertilizers and biostimulants from OFMSW and UWWS	Value Models	Recovery Cascades	Recovery & Recycling Circular Supply Chain	Recourse recovery	Loop
16	Bioconversion of UWWS: CO_2 fermentation with bioelectrochemical systems	Value Models	Recovery Cascades	Recovery and Recycling Circular Supply Chain	Recourse recovery	Loop

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The above analysis revealed that the examined solutions do not differentiate between each other, regarding their business model, in the context of each one of the existing frameworks, meaning that all examined solutions fall under the same category of business model in each framework. Moreover, all corresponding business model categories (for the examined solution) among the different frameworks have as main focus the reutilization of the waste as feedstock in other value chains or processes or the recovery of certain materials for further use. Thus, the latter consists of a one-dimensional approach regarding the business models which is related solely with the reusability of the waste. In this concept no other aspects that could differentiate a business model in the field of bio-waste valorisation are described through the existing CBM categories. Such aspects could be the different end users and the targeted markets of bio-based products, the key partnerships in bio-waste value chain, the revenue streams, bio-waste availability etc. Hence, taking into consideration the existing frameworks and the incorporated categorisations it is evident that are not able to depict different bio-waste valorization business models. Concluding, **there is a need to develop a new integrated CBM typology focused on bio-waste which will be able to incorporate also potential business cases of bio-waste valorization.**

The development of the new CBM typology will be presented in the next section.

6.2. Development of the CBMs typology

Following the results from the first evaluation previously presented, different aspects were examined in order to determine those critical factors that could impact and differentiate the type of business models in the case of bio-waste valorization. From the completion of the business canvases which describe the business model of each case as well as the literature review specifically for bio-waste business models, the most important aspects include the partnerships which are relevant for the successful operation of the business model, the bio-waste availability as well as the maturity of the technologies applied. The latter may affect the efficiency of the process as well as the costs and environmental issues. Furthermore, essential factor is the legal and regulatory implications regarding the uses of the end - product as well as the value of the final product and the targeted markets. Therefore, the most important factors for the successful operation of a business model in bio-waste valorisation include:

- *Involved parties*
    - *Types of parties*
    - *Interconnection between parties*
- *Bio-waste availability*
- *Maturity of bio-waste valorization technologies*
- *Product and relevant markets*
    - *Types of products and relevant markets*
    - *Value of products*
- *Legal and regulatory implications regarding the uses of the end - product*

Regarding the value of the end – product and the targeted market, the biobased value pyramid was taken into consideration, as described various researchers i.e., Lange et al [34], Bosman & Rotmans [35] and Stegmann

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et al [36]. Moving from the upper part of the bio-based value pyramid to the lower part goes along with decreasing value of the end – product. More specifically, the end – products which are used in the pharmaceutical industry as well as the food and feed industry are of **high value** and are expected to create high revenue streams.

Moreover, the produced bioprlastics and biopolymers which target the plastic industry and the bulk chemicals and fuels as well as feltilisers are of **medium value** and are expected to create medium revenue streams. Finally, the end – products which target the energy sector are considered to have **lower value** compared with the others. However, it should be noted here, that applications on the lower parts of the pyramid might still be preferable is some cases mainly from an economic perspective, since they have higher technological maturity and/or efficiency.

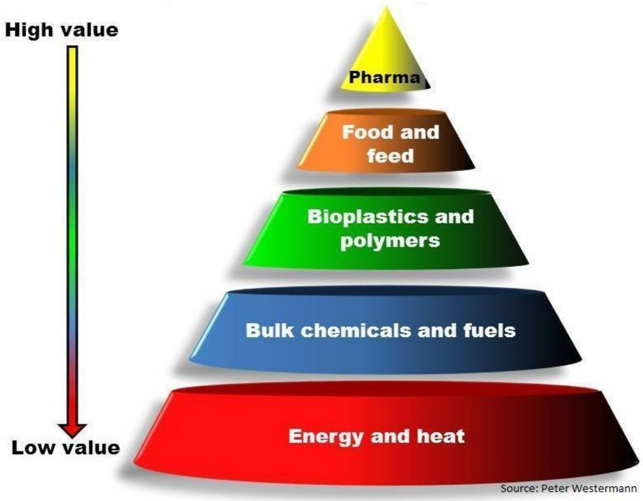

Figure 14. Biobased value-pyramid [37]

The availability of the bio-waste as feedstock as well as the existence of a mature valorization technology are fundamental factors for the implementation of any business related to bio-waste valorization. The absence of any of the two (feedstock, technology) implies the failure to develop and operate a business. Furthermore, the legal and regulatory aspects should be favorable so as to be able to finally distribute a product on the market.

As for the involved parties is essential to recognize the important players in the development of a business model for bio-waste valorisation. Taking into consideration the analysis of the business models in Chapter 4 as well as the literature review in Chapter 3, the most important parties include the Bio-waste owner, the Solution owner and the Investor. All three parties are equally important and the absence of any of them leads to the non-implementation of the business model. The definition of each one of the parties is presented below:

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- **Bio-waste owner**: A public or private organization or association which is responsible for the management of the bio-waste produced in a specific geographical territory of its responsibility. Indicative examples of Bio-waste owners could be a Municipality or other Local Authority, an Agricultural Association, Hotels Association etc.
- **Solution owner**: A public or private organization or other entity which owns or owns and operates a specific treatment technology for bio-waste valorisation. Indicative example of a Solution owner is technical entities providing bio-waste treatment technologies.
- **Investor**: Any natural person or other entity (such as a firm or mutual fund) or public organisation who commits capital with the expectation of receiving financial or other returns. An investor could be a person or a firm as well as a Municipality (or other public body) which has the necessary funds to invest in a project.

Concluding, the **critical factors that could create potential diversification of the business models for the valorization of bio-waste are**:

- ***Involved parties***
    - *Types of parties*
    - *Interconnection between parties*
- ***Product and relevant markets***
    - *Types of products and relevant markets*
    - *Value of products*

In the following paragraphs the aforementioned factors will be analysed and finally the new CBMs and their typology will be presented.

As mentioned above the three main parties involved in a CBM for bio-waste valorization are **the Bio-waste owner, the Solution owner and the Investor**. The interconnections between these parties may lead to different business models. In the following figures all different interconnections are illustrated. The interconnections are examined taking departure from one party every time and the possible ways it can make business and more specifically valorize bio-waste and take advantage of the end - product or benefits.

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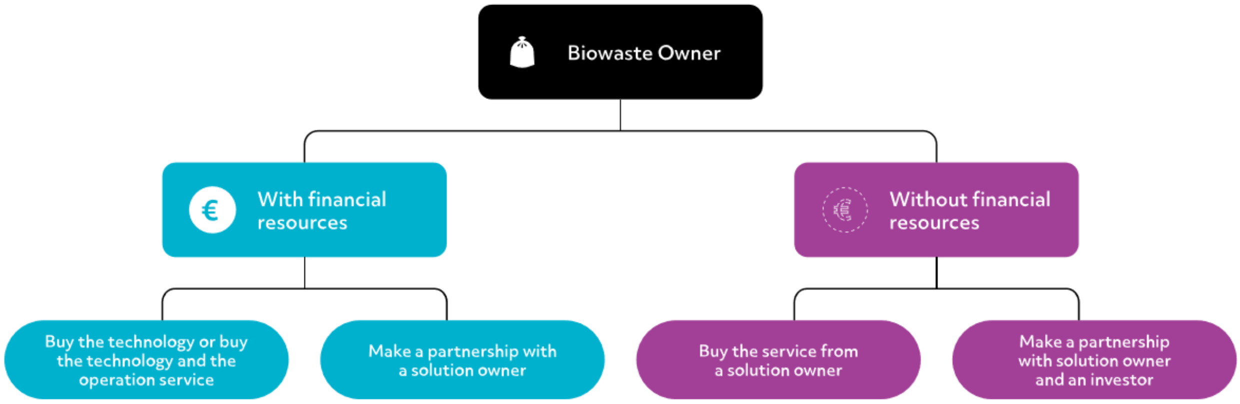

Figure 15. Connections between the Bio-waste owner and the other two parties (Solution owner, Investor)

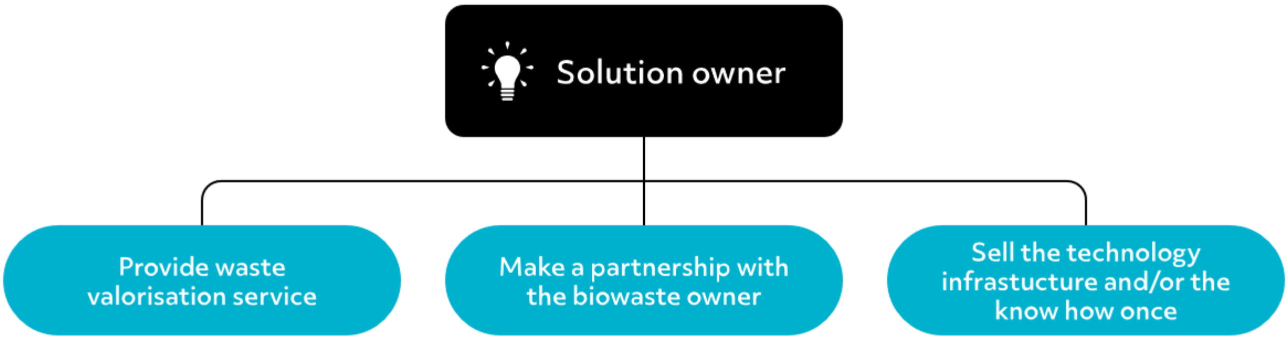

Figure 16. Connections between the Solution owner and the other two parties (Bio-waste owner, Investor)

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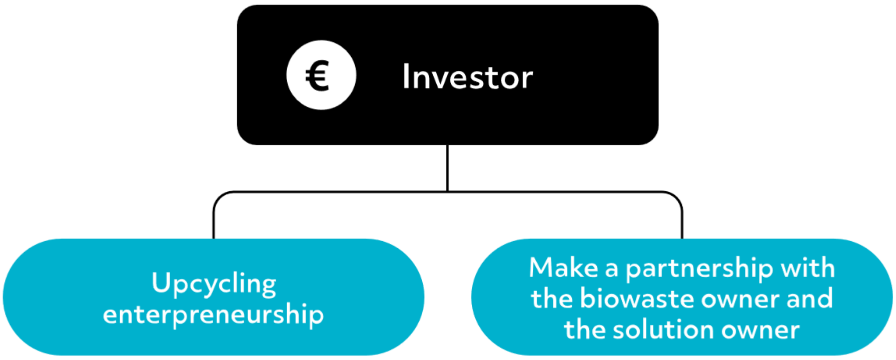

Figure 17. Connections between the Investor and the other two parties (Bio-waste owner, Solution owner)

Having analysed the critical factors which may play a significant role for the business models implemented for the bio-waste valorization the following categories are proposed and more specifically one core business model category which is related to the interconnection between the involved parties and two sub-business categories which are related to the extent of participation of the different parties and to the value of the target markets respectively.

In the core business model category which is related to the interconnection between the involved parties three (3) business models are recognized and in particular:

1. ***Joint venture*** *is a business model where the involved parties are related with a legal relationship that is most often formed by a written agreement between two or more among the bio-waste owner, the solution owner and/or the investor. The partners invest their assets (bio-waste, solution, money) in the business, and each partner benefits from any profits and sustains part of any losses.*
2. ***Vertical integrated*** *is a business model where only one of the parties (the bio-waste owner or the solution owner or the investor) consolidates multiple steps in the valorization process. In a vertically integrated business model the party performs all tasks commonly carried out by the other parties, instead of acting solely as bio-waste owner or solution owner or investor.*
3. ***Individual entrepreneurship*** *is a business model where one type of party (the bio-waste owner or the solution owner or the investor) utilizes its asset/product/service and all costs and revenues will always be assumed by the entrepreneur and not by third parties.*

In the sub-model category which is related to the participation of the different parties two (2) sub-models are recognized and in particular:

i. ***Simple collaborative*** *is a sub-business model where there is one participant from the same type of parties (one bio-waste owner and one solution owner) who is involved in the core business model.*

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ii. ***Multi collaborative*** *is a sub-business model where there is more than one participant from the same type of parties (e.g. two bio-waste owners or/and three solution owners) who are involved in the core business model.*

In the sub-model category which is related to the value of the target markets two (2) sub-models are recognized and in particular:

i. ***High value*** *is a sub-business model where the market targeted is expected to create high value for the product owner. According to the pyramid of bio-waste valorization, the Pharma and the Food and Feed market are considered of high value.*
ii. ***Medium value*** *is a sub-business model where the market targeted is expected to create medium value for the product owner. According to the pyramid of bio-waste valorization, the Bioplastics & polymers and the Bulk chemical & fuels market are considered of medium value.*

The sub-models identified can be combined with the core business models and the potential alternatives are presented in the following table.

Table 11. Core business model and sub-model categories for bio-waste valorisation

Core business model category	Sub-model category related to parties	Sub-model category related to markets
Joint venture	Simple collaborative	High value
	Multi collaborative	Medium value
Vertical integrated	Simple collaborative	High value
	Multi collaborative	Medium value
Individual entrepreneurship	-	High value
	-	Medium value

In the table below indicative cases of CBMs focused on the bio-waste valorisation are presented based on the suggested CBM typology.

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Table 12. Indicative CBM examples for bio-waste valorization

	Joint venture	**Vertical integrated**	**Individual entrepreneurship**
Simple collaborative	A Municipality who has the feedstock (*Bio-waste owner*) collaborates with a technical private company who grows microalgae (*Solution owner*) and a private entity (*Investor*) who commits capital, in order to treat bio-waste and all have benefits from the end-product or any other benefit. For example, the Municipality saves money for the disposal of the MSW, the Solution owner and the Investor earn from the sales of the end-product.	A Municipality who has the feedstock (*Bio-waste owner*), with its own financial resources (also *Investor*), invests in a technology (e.g. production of biofertilisers), thus it is also the *Solution owner*. The Municipality is responsible to operate the treatment technology and also benefits from the end product. For example, the Municipality uses the biofertiliser in the public green areas and/or sales biofertiliser to farmers, agricultural associations etc.	Not applicable
Multi collaborative	An Agricultural Association who has the feedstock (*Bio-waste owner*) collaborates with more than one technical private companies (*Solution owners*), one that owns and operates an AD plant and one that produces SCP, and a private entity (*Investor*) in order to treat bio-waste and all have benefits from the sales of the end-product(s).	More than one Municipalities in a region who have the feedstock (*Bio-waste owners*) are collaborating and with their own financial resources (*Investors also*), invest in a technology (e.g. production of biofertilisers), thus they are also the *Solution owners*. The Municipalities are responsible to operate the treatment technology and also benefit from the end product. For	Not applicable

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	Joint venture	Vertical integrated	Individual entrepreneurship
		example, the Municipalities use the biofertiliser in the public green areas and/or sales biofertiliser to farmers, agricultural associations etc.	
High value	A Municipality who has the feedstock (*Bio-waste owner*) collaborates with a technical private company who produces functional ingredients from SCGs (*Solution owner*) and a private entity (*Investor*) in order to treat bio-waste and the final product is functional ingredients (e.g. aromatic flavor components, coffee oil). All have benefits from the end-product or any other benefit.	A Municipality who has the feedstock (*Bio-waste owner*), with its own financial resources (*Investor also*), invests in a technology (e.g. artificial insect rearing), thus it is also the *Solution owner*. The Municipality is responsible to operate the treatment technology and also benefits from the end product which is proteins, lipids and chitin for animal feed.	A Hotel Association in a region who has the feedstock (*Bio-waste owner*) provides the bio-waste in a technical private company (*Solution owner*). The Solution owner may buy or not the feedstock, treats the bio-waste and benefits from the sale of the product (e.g. nutrients recovered from SCGs). The Hotel Association and the Solution owner act independently regarding their costs and revenues.
Medium value	A Municipality who has the feedstock (*Bio-waste owner*) collaborates with a technical private company who produces P3HB and a private entity (*Investor*) in order to treat bio-waste and the final product is bioplastics.	A Municipality who has the feedstock (*Bio-waste owner*), with its own financial resources (*Investor also*), invests in a technology (e.g. production of biofertilisers), thus it is also the *Solution owner*. The Municipality is responsible to operate the treatment technology and also benefits from the end product which is biofertiliser.	A Hotel Association in a region who has the feedstock (*Bio-waste owner*) provides the bio-waste in a technical private company (*Solution owner*). The Solution owner may buy or not the feedstock, treats the bio-waste and benefits from the sale of the product (e.g. PLA). The Hotel Association and the Solution owner act independently regarding their costs and revenues.

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7. Drivers and barriers related to the implementation of the CBMs in bio-waste valorization – 4th level of analysis

7.1. Barriers categorization according to literature

7.1.1. BARRIERS CATEGORIZATION ACCORDING TO DIFFERENT RESEARCHERS

In this section, the barriers as identified by different researchers are presented. These researchers investigated the barriers focusing on different target groups such as small and medium-sized enterprises (SMEs), policy-makers and product-oriented manufacturing firms. The summary of the literature review presented below was first conducted in the context of the D7.5: Policy baseline analysis (final) in the framework of the WaysTUP! Project [50] and is here further processed.

According to the research conducted by Rizos et al. [38], seven broad barrier categories were identified. These barriers are responsible for preventing small and medium-sized enterprises (SMEs) from adopting circular economy business models (CEBMs). On the other hand, according to Ritzén and Sandström [39] the barriers for the transition towards Circular Economy can be grouped in five broad categories. Their study was focused on the organizational barriers that the product-oriented manufacturing firms are facing, when moving from a linear to a circular economy. The research conducted by de Jesus and Mendonça [40] was focused on the identification of barriers following an "eco-innovation" perspective. They concluded in four main barrier categories that hinder the development of a circular economy, namely "Technical", "Economic", "Institutional" and "Social". According to a higher level categorization, these barriers could be identified as hard barriers ("Technical" and "Economic") and soft barriers ("Institutional" and "Social"). Taking into consideration the de

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Jesus's and Mendonça's categorisation of barriers, but not their further categorization in hard and soft ones, Kirchherr et al. [41] conducted literature review and survey addressing on a large sample of policy-makers and businesses. Their research resulted in four barrier categories. Finally, Bianchini et al. [42] have identified several barriers that constrain the practical implementation of Circular Business Models (CBMs), both internal and external, and have organized these under five broad categories. In the following table, the barriers identified by different researchers are presented.

Table 13. Barriers categorization according to Rizos et al. [38], Ritzén and Sandström [39], De Jesus and Mendonça [40], Kirchherr et al. [41], Bianchini et al. [42]

Researchers	Barriers identified
Rizos et al. [38]	Lack of support from the supply and the demand network Lack of capital Lack of government support/effective legislation Administrative burden Lack of technical and technological know-how Lack of information Company environmental culture
Ritzén and Sandström [39]	Attitudinal Operational: Infrastructure/ Supply chain management Structural Financial Technological
De Jesus and Mendonça [40]	Economic/Financial/Market Technical Institutional/Regulatory Social/Cultural: Rigidity of consumer behavior and businesses routines

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Researchers	Barriers identified
Kirchherr et al. [41]	Cultural: Lacking awareness and/or willingness to engage with CE Market: Lacking economic viability of circular business models Regulatory: Lacking policies in support of a CE transition Technological: Lacking (proven) technologies to implement CE
Bianchini et al. [42]	Internal Process Technical Market Institutional, regulatory and social Economic and financial

Within the present report, the barriers mentioned above were taken into consideration with the aim to compile the information and suggest wider and common barrier categories that correspond to the researchers' analysis and recommendations. Thus, the barrier categories finally proposed are: supply chain, social/cultural, economic & financial viability, institutional and regulatory framework, technical and technological, internal environment and procedures, lack of information. The following table presents the correspondence of the proposed common barriers categories with the researchers' barrier recommendations. The aim of the table is to reveal the most commonly addressed barriers according to researchers.

Table 14. Correspondence of the proposed common barriers categories with the researchers' barrier recommendations

	Rizos et al. [38]	Ritzén and Sandström [39]	De Jesus and Mendonça [40]	Kirchherr et al. [41]	Bianchini et al. [42]
Supply chain	X	X			X
Social/culture	X	X	X	X	X
Economic and financial	X	X	X	X	X
Institutional/Regulatory framework	X		X	X	X

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	Rizos et al. [38]	Ritzén and Sandström [39]	De Jesus and Mendonça [40]	Kirchherr et al. [41]	Bianchini et al. [42]
Technical and technological	X	X	X	X	X
Internal environment and procedures	X	X	X		X
Lack of information	X				

As presented in the table, social/cultural, technical/technological, and economic/financial barriers were mentioned by all researchers. Moreover, most researchers (four out of five) identified barriers related to the institutional/regulatory framework as well as to internal environment and procedures. Lack of information, regarding circular economy opportunities, is mentioned by only one researcher.

7.1.2. BARRIERS CATEGORIZATION ACCORDING TO DIFFERENT EU PROJECTS

In this section, the barriers as identified in the framework of different projects are presented. Within these projects, the barriers in adopting circular economy business models (focusing on bio-based products) were investigated. The summary of the literature review presented below was first conducted in the context of the D7.5: Policy baseline analysis (final) in the framework of the WaysTUP! Project [50] and is here further processed.

The BIO-TIC project "The bioeconomy enabled: A roadmap to a thriving industrial biotechnology sector in Europe" [43] was focused on the identification of the hurdles hindering Industrial Biotechnology's (IB) potential. The results were based on the analysis of five business cases and finally the barriers identified were falling in four thematic areas. In the framework of BIOWAYS project "Promoting the potential of the bioeconomy by raising the awareness of bio-based products and applications and their benefits to society" [44,45], the focus was given in the barriers related to the sustainable production and market exploitation of bio-based products. In addition, the focus was given to the public's perception regarding the barriers that hinder the wider use of bio-based products. Regarding BioBase4SME project "Bio-Innovation Support for Entrepreneurs throughout NWE Regions" [46], the aim was to support SMEs and Start-ups to transfer their innovation to market, by helping them overcome both technological and non-technological barriers. In this context, different SMEs were asked to rate barriers that were grouped in 9 main categories. Within the R2π project "The route to circular economy project" [47], the barriers that arose from the examined case studies were organized under three broad categories. Within the RoadToBio project – "Roadmap for the Chemical Industry in Europe towards a Bioeconomy" [48], the focus is given on the barriers that prevent the chemical and material industry from utilizing bio-based resources. In particular, this is related to the EU chemical industry's role in the bioeconomy. Finally, in the context of POWER4BIO project "emPOWERing regional stakeholders for realizing the full potential of

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European BIOeconomy" [49] the focus was given on barriers related to the application of regional policies aiming to support a bio-based economy. In the following table, the barriers identified within the aforementioned projects are presented:

Table 15: Barriers identified within BIO-TIC, BIOWAYS, BioBase4SME, R2π, RoadToBio and POWER4BIO projects

Project	Barriers identified
BIO-TIC [43]	Feedstock availability Technology: Bioconversion and downstream Processing Markets: Lower cost -competitiveness versus fossil products, Investment barriers and financial hurdles/capital requirements, Definition of bio-product unclear, Poor public perception Innovation system: Investment barriers and financial hurdles/capital requirements, Human resources, Inefficient collaboration, IPR, sustainability barrier
BIOWAYS [44,45]	Feedstock related Industry related: Low technology readiness level and commercialization status, lack of cooperation between the stakeholders in the relevant value chains, hurdles in establishing partnerships between academia and industry, limited financial support partnerships between academia and industry, limited financial support for new production facilities, lack of a trained workforce
BioBase4SME [46]	Demand-side policy barriers Stakeholder perception barriers Investment barriers Regulatory barriers Intellectual property related hurdles Human resource barriers Hurdles for efficient collaboration Feedstock related barriers

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Project	Barriers identified
R2π [47]	Internal Economic: cost issues, customer issues Contextual: Sectoral issues, Infrastructure, Technology and dynamic aspects Finance Policy: Obstructive Policy & bureaucracy, Externalities, Missing Regulation, EU Policy
RoadToBio [48]	Access to feedstock Competition with established fossil industry Policy and Regulatory framework Public perception and societal challenges Markets, Finance and Investment Research and Development
POWER4BIO [49]	Barriers for the bio-based economy (BBE) development: Biomass availability, Lack of public acceptance and awareness, Lack of supporting market mechanisms Barriers for the bio-based economy (BBE) policy: Vague goals and no operationalization, Timeframe of policy is uncertain

Within the present report, the barriers identified by the above mentioned projects were taken into consideration with the aim to compile the information and suggest wider and common barrier categories that correspond to the projects' recommendations. Thus, the barrier categories proposed are: social/culture, economic & financial viability, institutional and regulatory framework, technical and technological, feedstock availability and collaboration in the value chain. The following table presents the correspondence of the proposed common barriers categories with the projects' barrier recommendations. The aim of the table is to reveal the most commonly addressed barriers according to the projects.

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Table 16. Correspondence of the proposed common barriers categories with the projects' barrier recommendations

	BIO-TIC [43]	BIOWAYS [44, 45]	BioBase4SME [46]	R2π [47]	RoadToBio [48]	POWER4BIO [49]
Social/cultural	X	X	X		X	X
Economic and financial	X	X	X	X	X	X
Institutional/Regulatory framework	X		X	X	X	X
Technical and technological	X	X	X	X	X	
Feedstock availability	X	X	X		X	X
Collaboration in the value chain	X	X	X			

As a general comment, all projects have reported almost the same barriers. In particular, all projects recorded economic/financial barriers. In addition, most of the researchers (five out of six) identified barriers related to the institutional/ regulatory framework, to the technical and technological readiness availability as well as to the society/culture. Finally, the collaboration in the value chain was reported from three out of six projects.

7.2. Barriers categorization according to literature analysis and CBM canvases

In previous chapter (see Chapter 4), the business canvases were completed for the technologies falling under the interest of HOOP project. During this process, different aspects were taken into consideration like: key partnerships, key activities, value proposition, costs, revenues, social and environmental benefits. The analysis of the technologies highlighted significant factors that could affect the successful implementation of the business models. The most important factors are the lack of separate collection system, low demand of the product, lack of products standardization, lower price of the conventional product compared with the bio-based one, economic viability of circular business models which may act as barriers in the implementation of the CBMs.

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In the next step, the proposed common categories corresponding to the literature review (researchers and projects recommendations) as well as the barriers identified from the CBM analysis of the examined solutions, as mentioned above, are summarised in the following table. The identified barriers were included in the questionnaire (Question 7) in order to be valorized by the HOOP partners.

Table 17. Barriers categories based on barriers identified during the canvases development process and the barriers as identified by researchers and projects.

Barrier Category	Description of the category
Supply chain	Absence of "green" suppliers, Sectors with correlated high environmental impact, Provision of accurate evidence related to the benefits of green products, Consumers mindset and misconceptions towards circular economy and green products
Social/cultural	Rigidity of consumer behavior and business routines, negative perception of consumers regarding raw materials derived from valorisation of bio-waste and sewage sludge, low dissemination of information for society, consumers, etc.
Economic and financial	Large capital requirements, significant transaction costs, high OPEX costs, high initial CAPEX cost, high maintenance costs, low opportunities of scalability, lack of knowledge or low level of availability regarding financial schemes and funding opportunities , asymmetric information, uncertain return and profit
Institutional/ Regulatory	Misaligned incentives, lacking of a conducive legal system, deficient institutional framework, new legislation with high goals and complex and/or misunderstanding of regulatory schemes
Technical and technological	Inappropriate technology, low TRL, low environmental performance of the technology, lag between design and diffusion, lack of technical support and training

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Barrier Category	Description of the category
Internal environment and procedures	Organizational capabilities necessary for implementing circular business across different organizational functions, efforts in terms of business strategy definition and company structure, need for new organizational competences (e.g., team motivation, organizational culture, participation) Consumers mindset and misconceptions towards circular economy and green products)
Lack of information	Little understanding and knowledge on Circular Economy
Feedstock availability	Seasonality of biomass versus need of continuous feedstock supply, Logistics: inefficient transport and distribution of biomass
Collaboration in the value chain	Lack of cooperation between the stakeholders in the relevant value chains, hurdles in establishing partnerships between academia and industry
Lack of separate waste collection system	No separate collection system available or failure of the separate waste collection system.
Market	Low demand of the product, lack of product standardization, lower price of the conventional product compared with the bio-based one.

7.3. Questionnaire Results

Within the conducted primary research, questionnaires were prepared and sent to Lighthouse Cities and Regions and technology providers involved in HOOP project, to fill them in with their input, according to their experience in CBM implementation. All Lighthouse Cities and Regions answered the questionnaire as well as the technical partners except ITENE which is a Technological Research Center and does not collect or treat bio-waste directly. Regarding the Lighthouse Cities and Regions, most of them are already implementing a CBM either on their own or with the collaboration with organizations or/and companies (subcontracting). As presented in the Table 18, the majority of the Lighthouse Cities and Regions are valorizing or are planning to valorize their organic fraction of their municipal solid waste and waste water treatment sludge, either for biogas or compost

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and fertilizer production. The focus here is not to emphasize the already applied technologies (biogas and compost production), but to investigate the drivers and enablers that played a key role in their implementation. The information presented in Table 18, Table 19, Table 20 and Table 21, is based on the answers provided by the Lighthouse Cities and Regions and technology providers.

Table 18. Already applied circular business models by Lighthouse Cities and Regions and technology providers involved in HOOP project (information provided from the answers in Questions 1 and 2).

Light House City & Regions and technology providers participating in the HOOP project	Already applied Circular Business Model
LHC 1 Public authority	Valorization of household bio-waste for biogas production (anaerobic digestion) & subsequent biogas combustion for electricity generation. Valorization of bio-waste for compost (green waste composting & compost made of a combination of green waste and digestate).
LHC 2 Group of companies	In LHC 2, a circular strategy for bio-waste already exists, a circular business model is implemented yet as LHC 2 does not treat the bio-waste in house. A biogas plant is planned, but not yet decided. LHC 2 also collaborates with startup companies that have implemented a circular business model to upgrade bio-waste to high quality protein and fertilizer.
LHC 3 Cluster of entities established as a Non-Profit Company.	LHC 3 does not implement a circular business model but the organization with which they collaborate, (a linked third party in the HOOP Project (and a member of LHC 2) implement a bio-waste valorization procedure producing compost.
LHC 4 Public authority	Valorisation of (giant) hogweed and other urban greenery into compound granules (bio composite). Valorisation of wood fibres as an addition to (green) concrete. Torrefaction of pruning wood and leaf and grass waste

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Light House City & Regions and technology providers participating in the HOOP project	Already applied Circular Business Model
LHC 5 Public authority representing the interest of the 378 municipalities	A municipal composting plant is about to be introduced which will reduce the disposal costs of the organic fraction.
LHC 6 Public authority. Municipality	Compost is the typical bioproduct coming from bio-waste treatment and has application in agriculture. LHC 6 has a very important agricultural sector and low levels of soil organic matter.
LHC 7 Association of municipalities – public entity	Bio-waste is currently valorized to produce compost in a tunnel composting plant.
LHC 8 Public owned Ltd.	Private companies are subcontracted by the local waste management authority to collect and transport the bio-waste to a private biogas processing plant.
TP 1 Waste management company	TP1 has historically composted the organic fraction from the municipal waste. At this moment, TP1 recycles as much as possible. The collected RSU is composted. The sub products from municipal origin such as pruning, meat and fish, coffee or carob are valorized. And finally TP1 is now running an enzymatic recycling process of plastics, in order to produce bioplastics.
TP2 SME – Small and medium-sized enterprise	TP2 valorizes bio-waste in the form of used cooking oil, coffee ground and brewer's grain for the production of biopolymer PHA, coffee oil and other products with high value such as cosmetic products and compounds containing coffee ground.
TP3 Research center (public-private partnership)	Valorization of urban bio-waste and sewage sludge as volatile fatty acids for the chemical industry.

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The following table summarizes the drivers and enablers for the already applied CBM related to bio-waste valorization technologies as came out from the filled in questionnaires.

Table 19: Drivers and enablers for the already applied bio-waste valorization technologies as came out from the filled in questionnaires (information provided from the answers in Questions 2 and 3).

Technology already implemented	Drivers and enablers
Composting	Necessity of treating bio-waste from separate collection especially garden waste Possibility of producing a compost with a high quality – to introduce in a market Maturity of the technology Presence of a very important agricultural sector and low levels of soil organic matter. Reduce the disposal costs of the organic fraction Collaboration with associations of representation and assistance of agriculture) for the valorization of compost produced. Economic benefit (i.e. composting of digestate is cheaper and more climate friendly than incineration)
Biogas production	Necessity to treat bio-waste consisting mostly of food waste Maturity of technology Possibility of producing a renewable gas – possibility of having a great impact in the gas grid, which is currently only of fossil origin Process is better suited for treating only food waste than composting
Valorisation of (giant) hogweed and other urban greenery into compound granules (bio composite)	Feedstock availability This type of plant waste is abundant, invasive and toxic
Valorisation of wood fibres as an addition to (green) concrete.	Feedstock availability

Taking into account the above mentioned collected information, the drivers and enablers leading a city/region to adopt a circular business model could be categorized in the following general groups:

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1. *Necessity to treat a specific kind of waste (e.g. food waste, garden waste).* This factor depends a lot on the local characteristics of the region/city examined. For example, in the case of Almere, the presence of the toxic and invasive plant (giant) hogweed, makes it waste and thus, a considerable necessity of managing this waste is aroused.

2. *Existence of a market or field ready to receive the produced bio based products.* This factor could also be dependent on local characteristics as in the case of LHC 6 which has a very important agricultural sector and low levels of soil organic matter and thus, the compost coming from bio-waste treatment is applied in this sector.

3. *High demand for the produced bio product.* For example, as mentioned in the table above, the biogas production from bio-waste could have a great impact on the gas grid.

4. *Economic benefits.* Economic benefits could be achieved from the bio-waste product sales or/and from the resources saved due to the reduction of the disposal costs of the organic fraction.

5. *Maturity of the applied technology.* It is about a key factor which can strongly affect some of the above mentioned ones (2, 3 and 4). In particular, the maturity of the applied technologies can be determinant regarding the quality (technical specifications) of the produced bio-based products and thus the acceptance of the bio-based products by the market. In addition, the maturity of a technology is responsible for providing the possibility to treat large amounts of waste corresponding to city/region level.

Regarding the barriers for the implementation of CBM, these are separated in two categories in the following table, taking into consideration the questionnaire structure: (1) the barriers already met during the implementation of existing CBM and (2) the barriers hindering the future implementation of new business models.

According to the answers collected, the barriers identified are presented below:

Table 20. Barriers addressed by LHC and technology providers during the implementation of already applied CBM and barriers hindering future CBM application (information provided from the answers in Questions 4,5 and 6).

Barriers	Already Existing CBM/ Future CBM
<u>Low quality of the separate collection system</u> (e.g. high percentage of impurities in the bio-waste fraction before and after the sorting process due to non-optimal separation behavior of the citizens). Difficulty in changing the behavior of the citizens in order to separate their food wastes	Already existing (LHC 1) Already existing (LHC 3) Already existing (LHC 6) Already existing (LHC 7) Already existing (LHC 8)
<u>Unstable quantity and quality of waste produced</u> Composting of digestate is dependent on structural material such as green waste. Bottlenecks can occur depending on the season (i.e. lack of green waste in winter).	Already existing (LHC 1)

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Barriers	Already Existing CBM/ Future CBM
Seasonality of waste.	Already existing (LHC 4)
Variability of waste through the year.	Already existing (LHC 7)
Legislation/regulation framework barriers.	
Areas of application for compost products are becoming increasingly limited in Germany due to an increasing focus on groundwater protection	Already existing (LHC 1)
In the case of bio-waste to protein: regulatory barriers and the production scale is not at a commercial level yet.	Future CBM (LHC 2)
There are some legal restrictions on the end-of-waste-status. The moment the plant waste is regarded as waste the possibilities of recycling are limited.	Already existing (LHC 4)
There are some legal restrictions with the invasive plants. A permanent exemption is needed to structurally collect, transport, store and treat these plants.	Already existing (LHC 4)
There are some legal restrictions with ownership of waste. The plant waste is to be found in different areas, with different owners. It is not straightforward that the collector has access to the area or is allowed to collect the waste (the collector needs to be appointed by the appropriate authority).	Already existing (LHC 4)
Regional bureaucratic barriers to implement anaerobic digestion for organic waste treatment	Future CBM (LHC 5)
Bioproducts from Black soldier fly larvae find barriers due to food and feed European legislation, together with social acceptance reticence towards the consumption of products from insects.	Future CBM (LHC 6)
Legal barriers (end of waste criteria).	Already existing (TP2)
Market barriers	
The final product can be used only under specific circumstances	Already existing (LHC 3)
Lack of mature demand market. There is no steady market demand.	Already existing (LHC 4)
Lack of separate waste collection system	

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Barriers	Already Existing CBM/ Future CBM
Lack of separate waste collection system only in regard to the juridical boundaries that occurs with the different locations of waste, and thereby different owners of the waste.	Already existing (LHC 4)
Necessity to introduce a new collection process for future organic bioplastics. These materials do not have the same composting times as the organic fraction and must be treated separately. The days required for composting these materials are different from the composting days foreseen for food residues and it is not suitable for composting plants according to current legislation. This material cannot therefore be introduced into the current collection system for paper. If this material increases, it could prove to be a critical issue for the paper supply chain. It is necessary to adapt the legislation for the composting cycle of composters.	Future CBM (LHC 5)
In the case of compost, limited acceptability by the farmers due to the potential presence of non-organic materials. Biostabilized organic fraction from mixed municipal waste has limited applicability as compost due to Spanish legislation.	Already existing (LHC 6)
In the case of struvite, the relevant technology is still under development [TRL 7]. Its use has not been implemented in the local agriculture due to legal barriers (according to the EU legislation, struvite recovered from waste streams will be applicable to soils from summer 2022). Potential problems are related to competence with traditional fertilisers.	Future CBM (LHC 6)
Lack of social acceptance	
Bioproducts from Black soldier fly larvae find barriers due to food and feed European legislation, together with social acceptance reticence towards the consumption of products from insects.	Future CBM (LHC 6)
General lack of information	
Lack of data and access to it which makes it difficult to implement strategic, coordinated and symbiotic initiatives	Future CBM (LHC 6)
Low quality of the produced bio-products	
In the case of compost, limited acceptability by the farmers due to the potential presence of non-organic materials. Bio Stabilized organic fraction from mixed municipal waste has limited applicability as compost due to Spanish legislation.	Already existing (LHC 6)

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Barriers	Already Existing CBM/ Future CBM
Economic/financial viability	
Higher operational costs than the revenue obtained with selling the products of biowaste valorization.	Already existing (LHC 7)
For anaerobic digestion – lack of economically viable routes to effectively valorize the digestate into products for agriculture	Already existing (LHC 7)
The main problems are the high cost of the end product compared to processes from non-waste materials, due to longer and more expensive processes;	Already existing (TP1)
Low TRLs for some valorization technologies	Future CBM (TP1) Future CBM (TP3)
Competition between bio-waste valorization technologies	Already existing (TP1)
Feedstock is being undervalued in other routes competing the CBM applied	
Logistics	Future CBM (TP3)

Following the results presented above some remarks could be made. Barriers related to the lack or the failure of the separate collection system are the most commonly addressed (seven out of eight Lighthouse Cities & Regions mentioned this barrier) and affect the availability and the quality of the demanded bio-waste feedstock. In addition, legislation and regulatory framework barriers are also very commonly addressed and hinder the implementation of innovative products (five out of eight Lighthouse Cities and one out of three technology providers mentioned this barrier). These barriers are mainly related to the legal restrictions regarding the application of the bio products in different domains, to the legal restrictions for the end-of-waste-criteria that hinder the process of recycling and to the bureaucratic barriers hindering the implementation of different organic waste treatment technologies. Barriers in the market are also considerable and are related to the non-steady demand of the produced bio-based product, or to the limited market acceptance for the bio-based products. Barriers related to the economic and financial viability of CBM are of high consideration and are related mainly to the high operational costs which are not balanced by the revenues deriving from the products sales. In addition, the high costs of the products due to the high operational costs are not able to compete with the cheaper conventional products.

In addition, both Lighthouse Cities and Regions and technology providers were asked to select from a list the **three most important barriers for the circular business model implementation.** The list provided to both Lighthouse Cities and Regions and technology providers, was compiled during the previous step (please see 6.1.3 section) and was based on categorization and sub categorization of barriers taking into consideration the barriers identified during the canvases development process and the barriers as identified by researchers and projects.
The results are presented below:

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Table 21. Selection of the most important barriers for the circular business models implementation, per LHC and technology provider (Question 7)

	LHC1	LHC2	LHC3	LHC4	LHC5	LHC6	LHC7	LHC8	TP1	TP2	TP3
Supply chain (Absence of “green” suppliers, Sectors with correlated high environmental impact, Provision of accurate evidence related to the benefits of green products, Consumers mindset and misconceptions towards circular economy and green products)					✓						
Social/cultural (Rigidity of onsumer behavior and businesses routines, negative perception of consumers regarding raw materials derived from valorisation of bio-waste and sewage sludge, low dissemination of information for society, consumers, etc.)			✓		✓						
Economic and financial (Large capital requirements, significant transaction costs, high OPEX costs, high initial CAPEX cost, high maintenance costs, low opportunities of scalability, lack of knowledge or low level of availability regarding financial schemes and funding opportunities , asymmetric information, uncertain return and profit)		✓				✓	✓		✓	✓	✓
Institutional/Regulatory (Misaligned incentives, lacking of a conducive legal system, deficient institutional framework, new legislation with high goals and complex and/or misunderstanding of regulatory schemes)	✓	✓	✓		✓		✓	✓		✓	✓
Technical and technological (Inappropriate technology, low TRL, low environmental performance of the technology,	✓	✓				✓			✓	✓	✓

	LHC1	LHC2	LHC3	LHC4	LHC5	LHC6	LHC7	LHC8	TP1	TP2	TP3
lag between design and diffusion, lack of technical support and training)											
Internal environment and procedures (Organizational capabilities necessary for implementing circular business across different organizational functions, efforts in terms of business strategy definition and company structure, need for new organizational competences (e.g., team motivation, organizational culture, participation) Consumers mindset and misconceptions towards circular economy and green products)				✓							
Lack of information (little understanding and knowledge on Circular Economy)			✓		✓	✓					
Feedstock availability (Seasonality of biomass versus need of continuous feedstock supply, Logistics: inefficient transport and distribution of biomass)								✓			
Collaboration in the value chain											
Lack of separate waste collection system				✓							
Market: Lacking economic viability of circular business models. Low virgin material prices, low demand of the product, lack of product standardization.	✓			✓			✓	✓	✓		

Finally, based on the results deriving from the primary research summarized in both **Table 19 and Table 20,** the following barrier categories and subcategories are identified:

1. Separate collection system. The barriers related to the separate collection system could be further categorized as follows:

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-Failure of the separate collection system. This is strongly related to citizens' awareness as citizens are the key actor defining the separate collection system success.

-Lack of separate collection system to support the separation level demanded. It has to be mentioned, that different technologies demand different levels of "waste stream separation". For example, in the case of black soldier fly larvae production, the feedstock required is organic matter from the OFMSW. On the other hand, for algae production technology a very specific fraction of municipal solid waste organic fraction is required (only residues from fruits and vegetables).

-Lack of separate collection system necessary for the separation of the waste deriving from the future organic bio products. Necessity to introduce a new collection process for future organic bioplastics, like in the case of PHAs production. This material does not have the same composting time as the organic fraction and must be treated separately.

2. Unstable quantity and quality of waste produced. The barriers related to the instability of the quantity and quality of waste produced could be further categorized as follows:

-Seasonality of waste.

-Variability of waste through the year

3.Legislation/regulatory framework barriers. The barriers related to the Legislation/regulatory framework could be further categorized as follows:

-Legislation barriers for the application of the bio products in different domains (e.g. Black soldier fly larvae find barriers due to food and feed European legislation)

-Legal restrictions on the end-of-waste-status, hindering the process of recycling

-Legal restrictions related to the ownership of waste, hindering the establishment of a waste collection system.

-Regional bureaucratic barriers to implement specific technologies for organic waste treatment

-Legal barriers related to the end of waste criteria

4. Lack of social acceptance. For example, there is social acceptance reticence towards the consumption of products from insects, hindering the implementation of the CBM related to the production of the Black Soldier Fly Larvae.

5.Market barriers. The barriers related to the market could be further categorized as follows:

The final product can be used only under specific circumstances

Lack of mature demand market. There is no steady market demand.

Competence with traditional products. Preferences for the conventional products instead of the bioproducts

6.Low quality of the produced bioproducts

For example, in the case of compost, there is limited acceptability by the farmers due to the potential presence of non-organic materials. Bio stabilized organic fraction from mixed municipal waste has limited applicability as compost due to Spanish legislation

7.Economic/financial viability. The barriers related to the economic/financial viability could be further categorized as follows:

Higher operational costs than the revenue obtained with selling the products of bio-waste valorization.

High cost of the end product compared to processes from non-waste materials, due to longer and more expensive processes;

8.General lack of information

Lack of data and access to it, makes it difficult to implement strategic, coordinated and symbiotic initiatives

9. Low TRLs for bio-waste valorization technologies

The low maturity of the applied technologies can negatively affect the quality of the produced bio-based products. In addition, the low maturity of a technology is a barrier to treat large amounts of waste corresponding to city/region level.

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8. Conclusions

The present deliverable focuses on the identification of CBMs for bio-waste valorisation and the development of a CBM typology which will be able to incorporate also other business cases of bio-waste valorization in the future. In the deliverable the methodological approach for the identification of CBMs for bio-waste is described. Furthermore, the analysis of the CBMs behind 15 successful solutions for bio-waste valorization is presented and a template business canvas for bio-waste valorization is proposed. The examined solutions, followed the work from Task 2.2 and in particular they mainly come from H2020 projects, SCALIBUR, Valuewaste and WaysTUP!. Additionally, a new integrated CBM typology focused on bio-waste is developed and presented as well as drivers and barriers related to the implementation of circular business models in bio-waste valorization.

Concerning the applied methodology, it was based on 4 levels and more specifically at first, a literature review focusing on CBM frameworks proposed by researchers and leading organisations with emphasis also on CBMs focused on bio-waste was conducted (1st level). Furthermore, the analysis of 15 business models for bio-waste valorization solutions followed with the use of the business model canvas tool (2nd level) and resulted in the development of the new CBM typology (3rd level). Finally, the investigation of drivers and barriers related to the implementation of CBMs in bio-waste valorization took place (4th level).

The analysis of the 15 successful solutions for bio-waste valorization revealed significant insights. At first, the examined solutions use bio-waste and convert them into value added products, such as feed products, chemical and/or polymers while at the same time enhance the resource efficiency of the respective processes by reducing the use of fossil carbon. Additionally, renewable carbon sources from biomass, agriculture and/or forestry, including byproducts and wastes streams, are used. Hence, the above solutions comply with the circular bioeconomy principles which promote the resource efficiency, the valorisation of waste, the reduction of the demand of fossil carbon and the elimination of the GHG emissions [32]. Moreover, **the concept of adding value** is entailed in all examined business case. Additionally, all examined business models can be characterized **resource recovery models**. On the other hand, in bio-waste valorization end-products mainly fall under one of the following categories i.e., nutritional ingredients (e.g. SCP, carotenoids, active peptides, insect), biopolymers (e.g. PHAs, PLA), agricultural components (e.g. biofertilisers, biostimulants, insect frass), chemical ingredients (e.g. biosolvents, VFAs), and are directly consumed for specific applications. Thus, there is an inherent limitation regarding re-use or recycling of the end-product. Therefore, the **business models based on end-product recycling or remanufacturing are not suitable for bio-waste valorization cases**. Regarding the aspect of the value delivery in the business models it was observed that there are **two main types of customers and the respective channels** to contact them i.e. the wholesale customers which include the industry sector such as the chemical industry, the food and feed industry, the packaging industry etc. and on the other hand the individual customers which may include basically farmers, agronomists and the pet market.

Moreover, regarding the existing CBM frameworks and how they could integrate the bio-waste valorization business models it was highlighted that the existing CBM frameworks are related solely with the reusability of

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the waste. More specifically, examined bio-waste valorization solutions fall under the same category of business model in each framework i.e. “Value Recovery Models” in the Value Hill by Achterberg et al. [7] [10], “Recovery & Recycling” according to Lacy & Rutqvist [11], “Resource recovery” according to the R2π Project [13] and “Loop” business model category in the RESOLVE framework by EMF [6]. In this concept no other aspects that could differentiate a business model in the field of bio-waste valorization such as the different end users and the targeted markets of bio-based products, the key partnerships in bio-waste value chain and the bio-waste availability are described through the existing CBM categories. Hence, **a need to develop a new integrated CBM typology focused on bio-waste was revealed**.

Different aspects were examined in order to determine those critical factors that could impact and differentiate the type of business models in the case of bio-waste valorization. As a result, the following critical factors were defined i) Involved parties (types of parties and interconnection between parties) and ii) Product and relevant markets (types of products & relevant markets and value of products). Regarding the types of parties, the three main parties involved in a CBM for bio-waste valorization are **the Bio-waste owner, the Solution owner and the Investor**.

The new CBM typology includes one core business model category which is related to the interconnection between the involved parties and two sub-business model categories which are related to the extent of participation of the different parties and to the value of the target markets respectively are proposed. In particular, in the core business model category which is related to the interconnection between the involved parties three business models are recognized i.e., **joint venture, vertical integrated and individual entrepreneurship**. In the sub- business model category which is related to the participation of the different parties two models are recognized and more specifically **simple collaborative and multi collaborative** and in the sub- business model category which is related to the value of the target markets two models are recognized and in particular **high value and medium value**.

Finally, one of the main factors acting as **driver** for the implementation of CBM is the **necessity to treat a specific kind of waste** (e.g. food waste, garden waste). In addition, the presence of a **market demand** for the produced bio based product is significant, as this way, the commercialization of the produced bio-based products will be assured. Additionally, **economic benefits** will be created for the product owner. Last but not least, the **maturity of the applied technology** is a key factor strongly affecting the market acceptance and the economic benefits from the sale of the end-product. In particular, the maturity of the applied technology is crucial for the achieved quality of the end-products.

Barriers related to the **lack or the failure of the separate collection system** are the most commonly addressed and affect the availability and quality of the required bio-waste feedstock. In addition, **legislative and regulatory barriers** are also very commonly addressed and hinder the implementation of CBMs for the production of innovative products. These barriers are mainly related to the legal restrictions concerning the application of the bio-based products in different domains and the legal restrictions on the end-of-waste-status which hinder the process of recycling. **Barriers in the market** are also highlighted and are related to the non-steady demand of the produced bio-based product, or related to the low market acceptance of the bio-based products. Barriers related to the **economic and financial viability of CBMs** are of high consideration and are related mainly to the high operational costs which are not balanced by the revenues deriving from the products selling. In addition, the high price of some bio-based products is not able to compete with the cheaper conventional products.

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10. ANNEX - Business Model Canvases for HOOP Technologies

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10.1. Production of SCP through bioprocess involving methanotrophic bacteria using biomethane (from the AD of the OFMSW)

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers: -AD plant (biogas as feedstock) -other materials Provider of specialised production process (fermentation, fractionation/ removal of nucleic acids, fractionation/obtain other products). Collaboration to conduct the study for a plant (if new) and the necessary permission documents. Expert for maintenance of equipment	Collaboration with feedstock suppliers Promoting local value chains/markets/materials Collection and storage of feedstock Bioproduct production (fermentation, fractionation) Product quality control. Product certification (e.g. ISO). Reverse Logistics: collaboration for waste/residue treatment	Commercialize SCP (generally contains 50-80 % protein on a dry matter and essential amino acids) Considered novel food (potential new market segments) The use of SCP from biogas is beneficial from an environmental point of view as it can supplement conventional SCP which is produced from natural gas.	B to B Personal contact with wholesale customers (eg food industry, feed industry, feed companies) - Sales according to customer's order - Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• Feed companies • Industries related with animal feed (aqua/mariculture and livestock feed industries. The protein is approved by the European Union for use in protein nutritional feeds for salmon and livestock (e.g., pigs, poultry and cattle) • Food industry, it is used as flavour enhancer, aroma carriers, vitamin carriers, emulsifying aids and to improve the nutritive value of baked products in soups, in ready-to-serve meals and in recipes (In the case of fractionation this could be used theoretically as food ingredient)

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<table>
<tr>
<td rowspan="2">KEY PARTERNSHIPS

Municipalities/Regions, Waste management plants, AD plants, Local agricultural cooperatives, HORECA, households (separate collection of biowaste network needed).

Partnerships to develop collection network
• certified transport company for raw material and/or product
• company for the biowaste collection equipment (e.g. bins)

Packaging and distribution of SCP

Collaboration for waste/residue treatment (salts-rich liquid effluent). It can be treated in the a waste treatment plant or partially reintroduced in the fermenter</td>
<td>KEY ACTIVITIES

Packaging and distribution of the bioproduct

Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers

Change culture in the value chain (increase acceptance of bioproducts)

Explore new segments – food industry</td>
<td rowspan="2"></td>
<td></td>
<td rowspan="2">CUSTOMER SEGMENTS

• Technical field, it is used in paper processing, leather processing and as foam stabilisers</td>
</tr>
<tr>
<td>KEY RESOURCES

• Infrastructure and equipment. The fermenter should be coupled with anaerobic digestion
• Feedstock: AD biogas (OFMSW for biogas production)</td>
<td>CHANNELS

Promotion through the relative networks, local associations of farmers, agronomists etc</td>
</tr>
</table>

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KEY PARTERNSHIPS	KEY RESOURCES		CHANNELS	
Public/private financing	• Other resources: Water, air, pure oxygen, mineral nutrients, vitamins, energy • Personnel • Financial resources		Advertising, communication and dissemination activities (Newsletters, Blogs etc) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists)	

COSTS	REVENUES
• Labour: Labour cost • Materials: materials cost (feedstock, other additional materials) • Infrastructure cost/ maintenance cost • Separate collection cost (if applicable) • Waste treatment cost) • Operational costs • Communication, dissemination costs	• Product sale revenue: sale of SCP • Waste as value: revenue stream from waste or co-product being used instead of disposed

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SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +
• Lack of information regarding the benefits of SCP • Uncertainty among costumers about the safety of SCP to be used in feed • Not suitable for human consumption until now because of the high content of nucleic acids (N-rich diets cause nephritic stress). Concerns related to SCP consumption are the RNA content, toxins produced by microbes, potential allergy symptoms, and harmful substances derived from the feedstock such as heavy metals	• New jobs related to circular economy concepts • More efficient (decreased) use of resources (here natural gas) through biowaste valorisation • The process uses the CH_4 into material valorisation, decreasing the CO_2 emission associated with burning the biogas. • Increasing interest in SCP for the use in healthy diets and novel food, what may contribute to the human food supply and security in the future

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10.2. Black soldier fly (BSFL)

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers (fresh organic matter from the OFMSW, AD digestate and/or UWWS) Insect suppliers (European Union has already approved the use of 5 species, including H. Illucens) Provider of specialised production process (pretreatment, insect rearing, fractionation). Collaboration to conduct the study for a plant (if new) and the necessary permission documents. Maintenance of equipment	Collaboration with feedstock suppliers Promoting local value chains/markets/materials Collection of feedstock from local suppliers (fresh organic matter from the OFMSW, AD digestate and/or UWWS) - **vegetal, egg and dairy by-products** Storage of feedstock in order to feed the larvae (only biowaste or mixed with other components to improve the mixture)	Commercialize bioproducts such as proteins, lipids and chitin for animal feed Artificial insect rearing. Commercialization of the insects Considered novel food Lower production costs compared to others methods which produce “standard” protein-rich feed and oily products. Thus, cheaper prices and better nutritional properties are expected.	B to B Personal contact with wholesale customers or relative networks (eg Agricultural cooperatives) Sales according to customers’ order Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs) Informing/educating on bio economy potential and value proposition	• feed companies, • Industries related with animal feed. Insect-derived lipids can be added to the feed of poultry and swine species • aquaculture industry (aquaculture species can be fed with insect-derived processed animal proteins) • agriculture • Insect farms: commercialization of the insects – (selling larvae to other insect farms) • Pets market niche market in Norway

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KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION		
Municipalities/Regions, Waste management plants, AD plants, Local agricultural cooperatives, HORECA, households (separate collection of biowaste network needed). Partnerships to develop collection network • certified transport company for raw material and/or product • company for the biowaste collection equipment (e.g. bins). Partnerships for packaging and distribution of product (either animal feed or the insect itself)	Pretreatment/modification of feedstock. Particle size reduction and omogenization of biowaste. Water content adjustment and biowaste distributed on specific trays for larval growth evenly Rearing of insects (to produce larvae and killing laves before they become pupae) Bioproducts production (Fractionation: The cleaned and stabilised larvae might be separated into different bioproducts like proteins, lauric acid-rich lipids, and chitin)	The use of this bio products is beneficial from an environmental point of view as they can supplement “standard” protein-rich feed and oily products, which may need more land and water for production		

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KEY PARTERNSHIPS	KEY ACTIVITIES			
Collaboration for waste/residue valorization (Compost/frass. BSFL treatment process generates a by-product, the excreta residue. Possible use is its application in agriculture, similar to compost or its subsequent processing in a biogas facility) Public/private financing	Residue treatment. • Residue must undergo a maturation process before it can be used as a soil amendment, because the microbial activity in the material is very high • Chitin enriched compost. Chitin is a growth enhancer for plants. Value-added compost can be obtained by grinding dead and stabilised larvae in their frass. Reverse logistics: collaboration with AD plant to further treat the excreta residue. Application of residue in agriculture (compost or Chitin enriched compost) Product quality control – product certification			

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	KEY ACTIVITIES Packaging and distribution of the bioproducts Communication and dissemination activities awareness programs, including field demonstrations, are suggested to communicate the benefits of these bioproducts Maintenance of partnerships with customers, partners and suppliers Explore new segments – food industry			
	KEY RESOURCES • Infrastructure and equipment • Feedstock & insects • In case further processing to get chitin and chitosan, chemicals and/or enzymes might be required • Energy (Heat/steam)		CHANNELS Promotion through the relative networks Advertising, communication and dissemination activities (Newsletters, Blogs,	

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	KEY RESOURCES • Personnel • Financial resources		CHANNELS Social media, tv/radio etc) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists) Promotion (e.g. by universities, research institutes partners, investors,	

COSTS • Labour: Labour cost • Materials: materials cost (feedstock, other additional materials) • Infrastructure cost/ maintenance cost • Separate collection cost • Waste treatment cost incl. waste disposal (cost of disposing waste outputs) • Operational costs • Communication, dissemination costs	REVENUES • Product sale revenue: sale bioproducts such as proteins, lipids and chitin for animal feed • revenue stream from by-product produced (compost)

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SOCIAL & ENVIRONMENTAL –	SOCIAL & ENVIRONMENTAL +
• The acceptance of insects as food is complex and includes factors such as disgust, neophobia and familiarity. Need for change of culture • Currently, there are legal restrictions for the use of insects for human nutrition because of the lack of certification as “safe food” required by the European Regulation 2015/2283. • Possible medical issues, allergies	Reduced waste to landfill. Reduced waste to incineration Increase of jobs in circular materials/repair and refurbishment service, recovery and recycling sector Reduce the use of other agricultural resources providing “standard” protein-rich feed and oily products, which may need more land and water for production Positive impact to food scarcity – insect protein in the sustainable food cycle • this valorisation route is the least sensitive to the presence of improper waste (plastic, glass, metal), as the larvae just do not eat them. • low environmental foot print requiring substantially less land and water for production • Sustainability benefits: insects have a high food conversion rate • If separated collection of Biowaste (OFMSW) is already implemented, no further actions by citizens is required

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10.3. Nutrients recovered from residual dewatering liquid from AD (ammonium sulphate ((NH4)2SO4) and struvite (NH4MgPO4·6H2O))

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers: • AD plant (residual dewatering liquid of anaerobic digestion and/or digestate from AD) Provider of specialized production process Collaboration to conduct the study for a plant (if new) and the necessary permission documents.	Collaboration with feedstock suppliers and technology providers Collection and/or storage of feedstock Production of struvite and ammonium sulfate (decarbonation, P-cristallyzation, stripping, N-cristallyzation) Packaging and distribution of products Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers	Commercialization of: bioproduct is struvite, the first phosphorus-based fertiliser obtained from renewable resources (waste water) and bioproduct ammonium sulphate, which is a widely known and used fertiliser The use of this bioproduct is beneficial from an environmental point of view as it can supplement conventional fertilisers - inorganic chemical-based fertiliser (phosphorus-based fertilisers and commercial fertiliser ammonium sulphate).	B to B Personal contact with wholesale customers (eg food industry, feed industry, feed companies) Sales according to customer's order Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• Agriculture • Chemical industry producing ammonium sulfate or struvite

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<table>
<tr>
<td rowspan="2">KEY PARTERNSHIPS

Expert for maintenance of equipment

Packaging and distribution of biofertilisers

Partnerships to develop collection network
• certified transport company for raw material and/or product
• company for the biowaste collection equipment.

Collaboration for residue management which is wastewater.

Public/private financing</td>
<td>KEY ACTIVITIES

Product (struvite and ammonium sulfate) quality control – product certification

Change culture in the value chain of bioproducts (increase acceptance of bioproducts)
Promoting local value chains/markets/materials

Reverse Logistics: collaboration for waste/residue treatment
This residue could be used to water agriculture crops. Otherwise, the residue is diverged to a wastewater treatment plant for urban wastewater (no industrial treatment requires, no concern about toxic additives, metals, etc.).</td>
<td rowspan="2"></td>
<td>CUSTOMER RELATIONSHIPS

B to C
• Personal contact with customers or relative networks (e.g. farmers)
• Sales according to customers' order
• Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)

Public acceptance for shift to bio-based products

Informing/educating on bio economy potential and value proposition</td>
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<tr>
<td>KEY RESOURCES

• Infrastructure and equipment.</td>
<td>CHANNELS

Secondary material market: Markets for sale of recovered materials (co-product, scrap, recycled etc)</td>
</tr>
</table>

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	KEY RESOURCES		CHANNELS	
	• Residual dewatering liquid of anaerobic digestion and/or digestate from AD. Waste from meat processing are excluded from AD in this case except when pasteurised up front. • Other resources: Magnesium chloride (also possible magnesium hydroxide or magnesium oxide). Sulphuric acid. Sodium hydroxide. Air • Personnel • Financial resources		<u>Communication</u> Promotion through the relative networks Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists)	

COSTS	REVENUES
• Labour: Labour cost • Materials: materials cost (feedstock, other additional materials) • Infrastructure cost/ maintenance cost • Separate collection cost • Waste treatment cost incl. waste disposal (cost of disposing waste outputs)	Product sale revenue: sale of struvite and ammonium sulphate

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COSTS	
• Operational costs • Communication, dissemination costs	
SOCIAL & ENVIRONMENTAL –	SOCIAL & ENVIRONMENTAL +
• Limitations related to nutrient recovery from AD systems are the electricity consumption, the chemical requirements and the eventually low concentration of nutrient in the AD liquor, which may result in economically unviable processes • More awareness programs, including field demonstrations, are suggested to communicate the benefits of biofertilisers to farmers	• New jobs • More efficient (decreased) use of resources (Struvite replaces phosphorus-based fertilisers, Ammonium sulphate is equivalent to the commercial fertiliser ammonium sulphate) through biowaste valorisation • struvite, the first phosphorus-based fertiliser obtained from renewable resources • ammonium sulphate, which is a widely known and used fertiliser • Struvite has not been approved as fertiliser for Organic agriculture (Bio) but the process is ongoing (recently got the end-of-waste status for the EU 2003/2003 fertiliser validation). • N-based bioproducts of this technology are already existing and marketable fertilisers.

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10.4. Microalgae harvesting from biowaste

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers (Fruit and vegetable waste) • Local associations of farmers, farmers, households, Municipal Collection Systems/Companies • It is required CO2 and light for the growth of microalgae (autotrophic). CO2 might be obtained from residual industrial streams. Partners providing specialised technologies – (Hydrolysis, Fermentation, Photo Biorreactor)	Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Collection and/or storage of feedstock Production of the bioproduct microalgae (hydrolysis, cultivation of microalgae, harvesting, separation) Product quality control – product certification Packaging and distribution of products	Production of alternative protein source (and other macro and micronutrients such as carbohydrates, lipids, and vitamins) low price compared to fishmeal High-value products, such as carotenoids and oils high in omega-3 fatty acids (high added-value products have applications in cosmetic, pharmaceutical and nutraceutical industry)	B to B Personal contact with wholesale customers (eg food industry, feed industry, feed companies) Sales according to customer's order Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• aquaculture (fish and mollusks feed), • cosmetic industry, • pharmaceutical, • nutraceutical industries • the energy sector (biofuels) • wastewater treatment plants • farmers, Agronomists (nursery gardens), Agricultural cooperatives (microalgae biomass as soil conditioner)

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KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	
Experts for maintenance services Partnerships for packaging and distribution of product Collaboration for the residue exploitation. Partnerships to develop collection network • certified transport company for raw material and/or product • company for the biowaste collection equipment (e.g. bins). Collaboration to conduct the study for a plant (if new) and the necessary permission documents.	Reverse Logistics: collaboration for waste/residue treatment • The residue from hydrolysis might be used as feedstock for further processes, as for instance insect breeding. • This residue might be also used as organic fertiliser. • It is required CO_2 and light for the growth of microalgae (autotrophic). CO_2 might be obtained from residual industrial streams. Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers Change culture in the value chain of bioproducts (increase acceptance of bioproducts)	The use of this bioproducts is beneficial from an environmental point of view as they can supplement “standard” protein-rich feed and oily products, which may need more land and water for production	B to C • Personal contact with customers or relative networks (e.g. farmers) • Sales according to customers' order • Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs) Informing/educating on bio economy potential and value proposition	

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KEY PARTERNSHIPS	KEY RESOURCES		CHANNELS	
Public/private financing	Infrastructure and equipment. Feedstock (Fruit and vegetable waste) Other resources: CO_2, either enzymes (enzymatic hydrolysis) or steam and high pressure (thermal hydrolysis) Personnel Financial resources		Promotion through the relative networks Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists)	

COSTS	REVENUES
• Labour: Labour cost • Materials: materials cost (feedstock, other additional materials) • Infrastructure cost/ maintenance cost • Separate collection cost • Waste treatment cost incl. waste disposal (cost of disposing waste outputs) • Operational costs • Communication, dissemination costs	• Product sale revenue: sale of microalgae as alternative protein source • Waste as value: revenue stream from by-product (fertilizer)

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SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +
• Energy consumption for the production of microalgae • The lack of targeted legislation presents a barrier to the widespread adoption of microalgae-based technologies, including those relevant for the production of biofuels (from their lipidic fraction) and nutrition application • It is not possible yet to estimate the amount of CO_2 captured by microalgae.	• It is required CO_2 and light for the growth of microalgae (autotrophic). CO_2 might be obtained from residual industrial streams. Saving in emissions by using CO_2 for microalgae cultivation and avoidance of landfilling emissions. • The use of this bioproducts is beneficial from an environmental point of view as they can supplement “standard” protein-rich feed and oily products, which may need more land and water for production

10.5. Production of P3HB and other PHAs by fermentation

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers UCOs as feedstock -HORECA -Households -Municipal separate collection system UWWS/OFMSW as feedstock • Municipalities/Regions, WWTPs AD plant for residue exploitation Partners providing key technologies (fermentation, biomass isolation procedure, post treatment to modify the properties of P3HB)	Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Collection and Storage of feedstock Production of the bioproduct P3HB (or other PHAs) (fermentation, polymer isolation) Product quality control – product certification Packaging and distribution of products	Commercialize P3HB. P3HB is known to be biocompatible and biodegradable as well as non-toxic P3HB can replace synthetic plastics and its use is beneficial from an environmental point of view as it can supplement conventional plastics derived from fossil resources. It can replace also PHAs made from first generation feedstock (e.g. virgin oil, carbohydrate rich plants, corn, potatoes or sugar cane) that could instead be used to human or animal nutrition. High profit expected.	Eco-labeling /standardisation (product purity, biodegradability in different media e.g. soil, seawater etc) to validate environmental value B to B Personal contact with wholesale customers (eg cosmetic, chemical, plastic industry etc.) Sales according to customer's order Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• Plastic industries • Cosmetic production industries • Pharmaceutical industries (biomedicine) • Packaging • Agriculture (farmers, agricultural associations)

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<table>
<tr>
<td rowspan="2">KEY PARTERNSHIPS

Experts for maintenance services

Partnerships for packaging and distribution of product P3HB

Public/private financing

Partnerships to develop collection network
• certified transport company for raw material and/or product
• company for the biowaste collection equipment (e.g. special bins).

Collaboration to conduct the study for a plant (if new) and the necessary permission documents</td>
<td>KEY ACTIVITIES

Reverse Logistics: collaboration for waste/residue treatment
The biomass residue from fermentation can be sent to anaerobic digestion for biogas production.

Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers</td>
<td rowspan="2">VALUE PROPOSITION

Industry of PHA’s production is competitive and growing.

The use of waste materials as carbon sources represents a valuable option to reduce both environmental impact and the production costs of PHA.</td>
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<td>KEY RESOURCES

• Infrastructure and equipment.
• Feedstock UCO
• Other resources: bacteria, air, water, mineral nutrients
• Personnel
• Financial resources</td>
<td>CHANNELS

Promotion through the relative networks (eg plastic industry associations)

Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc)</td>
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			CHANNELS Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists)	

COSTS • Labour: Labour cost • Materials: materials cost (feedstock, Air, water and mineral nutrients) • Infrastructure cost/ maintenance cost • Separate collection cost • Waste treatment cost incl. waste disposal (cost of disposing waste outputs) • Operation cost • Communication, dissemination costs	REVENUES • Product sale revenue: sale of product (P3HB or other PHAs) • Waste as value: revenue stream from waste or co-product being used instead of disposed (residue from fermentation)

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SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +
Acceptance of the bioproduct from biowaste. Wide production, commercialization, and thus application of PHAs as a biodegradable alternative to conventional plastics is still limited due to high production cost., The technologies of bioconversion of UWWS into PHBV are under development and therefore the economic costs are not fully estimated and the TRL is still low.	No harmful organic solvents are used in comparison with the production of the fossil-derived plastics. PHAs are biodegradable and biocompatible, being a sustainable substitute to conventional plastics derived from fossil resources. Several studies have shown the biodegradability of P3HB also in soil, compost, seawater and under anaerobic conditions. In general, the biodegradability of PHAs is similar to the biodegradability of cellulose. PH3B has also no or low toxicity. Generally, the PHA production plants can be easily designed as a side stream process of WWTPs. PHA production in a WWTP has the potential to reduce the amount of sludge that needs to be finally disposed. The waste expected can be managed together with primary and secondary sludge from WWTP.

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10.6. Volatile fatty acids (VFAs) production from UWWS

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers: WWTP (municipal, industrial, private, public) Provider of specialised production process (pretreatment, acidogenic fermentation, AD plant). Expert for maintenance of equipment Partnerships for packaging and distribution of VFAs	Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Collection and/or storage of feedstock Bioproduct production (pretreatment, fermentation, VFAs recovery, AD plant) Residue treatment : solid fraction of the fermentation is considered a residue waste AD plant biogas, fertiliser Product quality control – product certification	Commercialize acetic acid (or other VFAs) The use of this bioproduct is beneficial from an environmental point of view as it can supplement conventional VFAs which is produced from natural gas or refined crude oil Bio-based VFAs have the same properties as petroleum-based one and can therefore be directly used as raw materials in the same industries.	B to B Personal contact with wholesale customers (eg food industry, feed industry, feed companies) Sales according to customer's order Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• WWTP (biological nutrient removal), • bioplastics industry, • biofuel industry • chemical industries • perfume and cosmetic industries • food industry: flavouring in food and beverage products as well as for food preservation approved bio-based butyric acid as food additive, demand in this industry has increased considerably • animal feed industry

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KEY PARTERNSHIPS Collaboration for waste/residue valorization: solid fraction of fermentation biogas, fertiliser Public/private financing Collaboration to conduct the study for a plant (if new) and the necessary permission documents.	KEY ACTIVITIES Packaging and distribution of the bioproduct Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers			
	KEY RESOURCES • Infrastructure and equipment. • Feedstock sewage sludge • Other resources: sludge containing anaerobic bacteria is used as inoculum. In addition, sodium hydroxide (NaOH) is added during the process. • Personnel • Financial resources		CHANNELS Promotion through the relative networks Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists)	

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<table>
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COSTS

Labour: Labour cost
Materials: materials cost (feedstock, other additional materials, use of chemicals).
Infrastructure cost/ maintenance cost
Separate collection cost

Waste treatment cost incl. waste disposal (cost of disposing waste outputs)
Operational costs

Communication, dissemination costs

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REVENUES

Product sale revenue: sale of acetic acid (or other VFAs)
Waste as value: Sales from Fertilizer and/or biogas

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SOCIAL & ENVIRONMENTAL −

Use of chemicals for the production process. One of the VFAs disadvantages is mostly related with the actual production costs relative to with the use of chemicals. Presently, the bottleneck for an economically sustainable VFAs industrial production is represented by the costs associated to the separation/purification downstream processes.

Acceptability challenges
Odour pollution-Bio-based VFAs have an unpleasant sour odour
In case of utilizing the presented bioproducts (VFAs) for the food or cosmetic industry, purity and toxicity threshold must be respected, depending on the legislation in force.
</td>
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SOCIAL & ENVIRONMENTAL +
Prevent landfilling/incineration of biowaste
Bio-based VFAs have the same properties as petroleum-based one and can therefore be directly used as raw materials in the same industries.
More efficient (decreased) use of resources (petrochemical based (refined crude oil and natural gas as a feedstock) through biowaste valorization. Additionally, VFA production from biowaste avoids the production of hazardous wastes such as heavy metals and organic solvents as well as produces emission of greenhouse gasses.
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</table>

10.7. Production of ethyl lactate

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock providers: municipalities/Regions, Waste management plants, WWTPs, AD plants, HORECA, households (separate collection of biowaste network needed) Technology providers of specialised production process (pretreatment, production of bioethanol, production of ethyl lactate). Experts for maintenance services	Collection and/or storage of feedstock Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Pre-treatment (separation of cellulose, hemicellulose and lignin, making the polysaccharides available for the following process steps) Production of bioethanol Production of ethyl lactate	Commercialization of biosolvents for industrial valorization. Replacement of conventional products that require the use of primary resources. Ethyl lactate and other acid esters are employed as toxic-free biodegradable bio-solvents and they had been proven to be suitable as additives in foodstuffs.	B to B - Personal contact with wholesale customers (eg food industry, feed industry, feed companies) - Sales according to customer's order - Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• Fuel and additive fuel industry (bioethanol) • Cosmetics, perfumes, etc. industry (bioethanol and ethyl lactate) • Plastics industry (ethylene) (bioethanol and ethyl lactate) • Biodiants (paints, varnishes, inks, etc.) • Food and beverage industry (bioethanol and ethyl lactate as additives in foodstuffs) • Microelectronics

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KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION		
Other partnerships with organisations/clusters etc. across the value chain to strengthen circularity (e.g. sharing infrastructure or other resources mutualisation, public partners, research partners, industrial clusters Company for packaging of the final product Partnerships to develop collection network • certified transport company for raw material and/or product • company for the biowaste collection equipment (e.g. bins). Reverse logistics- Collaboration for waste/residue valorization (AD plant, compost plant, waste to energy)	Extra dehydration whether the desired final product is high-purity ethyl lactate Product quality control – product certification Reverse Logistics: collaboration for waste/residue treatment. Residue (from fermentation (ethanol and lactic acid production), solid residue from hydrolysis) treatment • Valuable feedstock for production of biomethane and biofertiliser in an AD plant • High calorific value solid biofuel for heat and electricity production through a cogeneration process (Waste to Energy). • produce compost Packaging, distribution and selling of final product	Financial aspects: New bioprocesses for lactic acid production are cheaper than the fossil-derived lactic acid processes, since the latter use much more energy in the pre-treatment stage, which increases the cost of the final product on the market.		

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KEY PARTERNSHIPS	KEY ACTIVITIES			
Public/private investment Collaboration to conduct the study for a plant (if new) and the necessary permission documents.	Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers Distribution/selling of final product Residue (from fermentation (ethanol and lactic acid production), solid residue from hydrolysis) treatment • Valuable feedstock for production of biomethane and biofertiliser in an AD plant • High calorific value solid biofuel for heat and electricity production through a cogeneration process (Waste to Energy). • produce compost			

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	KEY ACTIVITIES Change culture in the value chain of bioproducts (increase acceptance of bioproducts) explore new market segments if exist			
	KEY RESOURCES • Infrastructure and equipment • Feedstock: Cellulosic rejections UWWS. OFMSW. • Energy • Personnel • Financial resources		CHANNELS Promotion through the relative networks, local associations of farmers, agronomists etc Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products)	

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			CHANNELS Sales through Company Website, online shops, on-site (if exists)	

COSTS • Labour: Labour cost • Materials: materials cost (feedstock, other additional materials) • Infrastructure cost/ maintenance cost • Separate collection cost • Waste treatment cost incl. waste disposal (cost of disposing waste outputs) • Operational costs • Communication, dissemination costs	REVENUES • Product sale revenue: sale of product, component or material • Revenues from selling co-products that could be valorized as compost or biofuel.
SOCIAL & ENVIRONMENTAL – The main problem with the use of lignocellulosic materials is the absence of low-cost technological processes to obtain high value-added end products	SOCIAL & ENVIRONMENTAL + Increase of jobs in circular materials/repair and refurbishment service, recovery and recycling sector Ethyl lactate and other acid esters are employed as toxic-free biodegradable bio-solvents and they had been proven to be suitable as additives in foodstuffs. Reduction of use of petroleum-derived raw materials (utilization of biowaste)

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10.8. PLA production

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock providers -HoReCa -household users, -farmers -Fruit and vegetable market -municipalities Technology providers (pre-treatment, enzymatic hydrolysis, fermentation, Lactic acid Purification (optional), PLA polymerizatio) Experts for maintenance services	Product design for defining characteristics such as biodegradability of PLA. Collection of raw materials from local suppliers Storage of raw materials Production of PLA Promoting local value chains/markets/materials Product quality control – product certification (eco-labeling/standardization to validate environmental value) Packaging and distribution of final product KEY ACTIVITIES	Commercialization of Polylactic Acid (PLA), a biopolymer that is biocompatible, biodegradable and presents thermoplastic properties similar to PET. PLA is the most produced bioplastic globally, with a growing market [196] This plastic is biodegradable and does not release toxic residues. The use of these bioproduct is beneficial from an environmental point of view as it can supplement conventional plastics, consuming other resources as fossil fuels for their production	B to B Personal contact with wholesale customers (eg food industry, feed industry, feed companies) Sales according to customer's order Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	-applications for films, -bottles, -as agriculture films, -medical and laboratory devices, -pharmaceutical industry, -food packaging, etc. -textile sector

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KEY PARTERNSHIPS Partnerships to develop collection network • Company for raw material and products transportation. • Company providing equipment for the biowaste collection. Partners for product's packaging and distribution Reverse logistics - Collaboration for the residue exploitation (material or energy exploitation) Collaboration to conduct the study for the plant and the necessary permission documents.	Reverse Logistics: collaboration for waste/residue treatment (biomass and residual growing media (broth) from fermentation can undergo a material/energetic valorisation process – e.g. anaerobic digestion for biogas production. These residues are organic and non-toxic) explore new market segments if exist Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers			
	KEY RESOURCES Infrastructure and equipment Feedstock Lactobacillus, enzymes. Personnel Financial resources		CHANNELS Promotion through the relative networks (pharmaceutical, cosmetic production) Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc)	

<table>
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<td>CHANNELS

Participation in relevant campaigns, local events (for raising awareness and demonstrating the products)

Sales through Company Website, online shops, on-site (if exists)</td>
<td></td>
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<tr>
<td colspan="3">COSTS

• Labour: Labour cost
• Materials: materials cost (feedstock, other additional materials)
• Infrastructure cost/ maintenance cost
• Separate collection cost
• Waste treatment cost incl. waste disposal (cost of disposing waste outputs)
• Operational costs
• Communication, dissemination costs</td>
<td colspan="2">REVENUES

• Product sale revenue: sale of PLA
• Waste as value: revenue stream from waste or co-product being used instead of disposed</td>
</tr>
</table>

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SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +
PLAs are more expensive than non-sustainable plastics PLA production process produces greenhouse gases CO_2 and CH_4. However, the emission of gases from this biotechnological process is 50 % less than the production process of PLA from fossil resources. Potential increase of environmental impacts due to additional transport between value chains.	Reduced waste to landfill. Reduced waste to incineration Reduction of use of conventional fossil fuels (utilization of biowaste) This plastic is biodegradable and does not release toxic residues.

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10.9. 2,3 butanediol production

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Collaboration to conduct the study for the plant and the necessary permission documents. Technology providers for: Pre-treatment/ Feedstock conditioning, hydrolysis, fermentation, biomass separation, supernatant recovery Raw materials providers: collected from -HoReCa -household users, -farmers -Fruit and vegetable market -municipalities -garden, forest and park waste	Collection of raw materials from local suppliers Collaboration with technology providers. Storage of raw materials Promoting local value chains/markets/materials Production of 2,3 butanediol Product quality certification (ISO or something else?), eco-labeling / standardization to validate environmental value Packaging and distribution of final product Reverse Logistics: collaboration for waste/residue treatment	Commercialization of 2,3 butanediol -environmental friendly product. 2,3 butanediol is produced from garden and vegetable waste while conventional 2,3 butanediol is produced through chemical methods from fossil sources and it requires high energy intensity and the use of expensive catalysts. -2,3 butanediol has a wide range of applications such as Food additives sector, solvents, polymers etc.	B to B Personal contact with wholesale customers (eg food industry, feed industry, feed companies) - Sales according to customer's order - Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• Food additives sector. Diacetyl can be obtained by dehydrogenation of 2,3-BDO. Diacetyl is a flavoring agent. • High quality aviation fuel. This is currently the most important application of 2,3-BDO of fossil origin. Octane • is obtained by hydrogenation of 2,3-BDO. • Solvents. Methyl-ethyl ketone (MEK) is produced by dehydration of 2,3-BDO. MEK can be applied into fuels, • resins, paints and solvents.

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KEY PARTERNSHIPS Other partnerships with organisations/clusters etc. across the value chain to strengthen circularity (e.g. sharing infrastructure or other resources mutualisation, public partners, research partners, industrial clusters) Partnerships to develop collection network • Company for raw material and products transportation. • Company providing equipment for the biowaste collection. Partnerships for packaging and distribution of product Collaboration for the residue exploitation.	KEY ACTIVITIES Remains of seeds, bagasse and lignocellulosic vegetables that have not been able to degrade during the process can be valorised to compost or, in the most favourable cases, to produce vegetable oils and other added-value products. Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers explore new market segments if exist			CUSTOMER SEGMENTS • Polymers. Further dehydration can also yield the monomer 1,3-butadiene, which might be applied in the • production of synthetic rubber, polyesters and polyurethanes. • Cosmetics, drugs and lotions. Polyimide can be prepared using 2,3-BDO as precursor by esterification.
	KEY RESOURCES Specialised production process: Specialised process and facilities ensured feedstock and/or by-products (Seasonality and variability)		CHANNELS Promotion through the relative networks, local associations of farmers, agronomists etc Advertising, communication and dissemination activities (Newsletters, Blogs,	

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KEY RESOURCES

Other raw materials: Enterobacter ludwiggii: Facultatively anaerobic gram-negative bacteria
- Sulphuric acid: H_2SO_4.
- Enzymes
- Oxygen
- Ethanol, Acetic acid

Personnel

Financial resources

CHANNELS

Social media, tv/radio etc)

Participation in relevant campaigns, local events (for raising awareness and demonstrating the products)

Sales through Company Website, online shops, on-site (if exists)

COSTS

- Labour: Labour cost
- Materials: materials cost (feedstock, other additional materials)
- Infrastructure cost/ maintenance cost
- Separate collection cost
- Waste treatment cost incl. waste disposal (cost of disposing waste outputs)
- Operational costs
- Communication, dissemination costs

REVENUES

Product sale revenue: sale of product, component or material (customer owned)
-Waste as value: revenue stream from waste or co-product being used instead of disposed

SOCIAL & ENVIRONMENTAL −

2,3-Butanediol needs further processing to arrive to final marketable product

SOCIAL & ENVIRONMENTAL +

-Reduced waste to landfill. Reduced waste to incineration

	2,3 butanediol is produced from garden and vegetable waste while conventional 2,3 butanediol is produced through chemical methods from fossil sources and it requires high energy intensity and the use of expensive catalysts.

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10.10. Biochar production with slow pyrolysis

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers (Municipal WWTPs, Private WWTPs, producers of oil or compost) Certified transport company for raw material and/or product Technology: Partners providing key technologies – pyrolysis, off-gas cleaning system Experts for maintenance services Partnerships for packaging and distribution of product	Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Collection and/or storage of feedstock (sewage sludge) Production of the biochar (drying, pyrolysis, Off-gas cleaning system) Product quality control – product certification Reverse logistics-collaboration for valorization of gas produced Packaging and distribution of products	Commercialise biochar as a component for soil improvements, circular fertilizers/ biostimulants Biochar can be used for soil application as it keeps a significant amount of the nutrients from sewage sludge, especially phosphorus. The use of this bioproduct is beneficial from an environmental point of view as it can supplement “standard” chemical fertilisers/biostimulants. This offers to the farmers & other end users sustainable circular fertilizers which could reduce the need for mining industry.	B to B - Personal contact with wholesale customers (eg agricultural cooperatives) - Sales according to customer’s order - Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• Farmers • Agronomists (nursery gardens) • Agricultural cooperatives • Forestry activities • Energy sector (biofuels)

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KEY PARTERNSHIPS Public/private financing Collaboration to conduct the study for a plant (if new) and the necessary permission documents. Reverse logistics-collaboration for valorization of gas produced.	KEY ACTIVITIES Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers		CUSTOMER RELATIONSHIPS B to C • Personal contact with customers or relative networks (e.g. farmers) • Sales according to customers' order • Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs) eco-labeling/standardisation to validate environmental value Public acceptance for shift to bio-based products Informing/educating on bio economy potential and value proposition	
	KEY RESOURCES • Infrastructure and equipment.		CHANNELS	

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	• Feedstock (sewage sludge) • Other resources: • Personnel • Financial resources		Promotion through the relative networks (e.g. farmers' networks) Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc.) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists)	

COSTS • Labour: Labour cost • Materials: materials cost (feedstock, other additional materials) • Infrastructure cost/ maintenance cost • Logistics: collection & transportation cost • Waste treatment cost (off-gas cleaning system) • Operational costs • Communication, dissemination costs	REVENUES Product sale revenue: sale of product biochar Waste as value: revenue stream from waste or co-product being used instead of disposed (gas)
SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +

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High energy consumption for drying the initial feedstock that enters the pyrolysis process. Off-gas cleaning system is required in case part of the gases are condensed or used for cogeneration	By-products (the non-condensable gases and the oil) produced during slow pyrolysis can be used for energy production Avoidance of landfilling large amounts of sewage sludge Stability of biochar infers the potential for this product to be considered as a carbon sequestration and climate mitigation tool. Biochar has fertilizer and liming properties and can be used to increase soil water retention, as pH buffer, it allows also the recycling of some plant nutrients and constitutes an important reservoir of carbon in the soil. Biochar production is considered carbon negative Biochar production has a huge opportunity for community acceptance as it can partly solve the odours coming from the decomposition of sludge and wastewater

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10.11. Production of functional ingredients from spent coffee grounds (SCG)

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Providers of SCGs: collected from HoReCa and potentially household users, hotels, restaurants, coffee shops and coffee companies the main suppliers of coffee Technology providers for: thermal pre-treatment to prepare the waste, extraction process, or enzymatic hydrolysis Experts for maintenance services Collection & Transportation of raw materials (SCG) -Companies/municipalities for transportation and collection of raw materials and products.	Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Collection and/or storage of feedstock Production of aromatic flavor components or/and coffee oil or/and carotenoids Product quality control – product certification Reverse Logistics: collaboration for waste/residue treatment (residue from fermentation process and the solvents from the extraction process)	Production and commercialization of aromatic flavor components, coffee oil and/or carotenoids This process produces natural oils and flavours in a sustainable way that can replace oils and flavours with harmful chemical components	B to B - Personal contact with wholesale customers (eg food industry, feed industry, feed companies) - Sales according to customer's order - Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs) eco-labeling/standardisation to validate environmental value Informing/educating on bio economy potential and value proposition for oils, flavors and carotenoids produced by SCG.	• food industry • animal food industry • cosmetic, • pharmaceutical, • nutraceutical industries

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-Companies providing the collection equipment Partnerships for packaging and distribution of product Collaboration for the residue exploitation. Public/private financing Collaboration to conduct the study for a plant (if new) and the necessary permission documents.	Packaging and distribution of products Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers			
	KEY RESOURCES Infrastructure and equipment. Feedstock Other resources: hexane and ethanol for the extraction. Enzymes, sulphuric acid, $(NH_4)_2$ SO_4, KH_2PO_4, $MgSO_4$, glucose for carotenoids production Personnel Financial resources		CHANNELS Promotion through the relative networks, (pharmaceutical, cosmetic production) Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists)	

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COSTS	REVENUES
Labour: Labour cost Materials: materials cost (feedstock, other additional materials) Infrastructure cost/ maintenance cost Separate collection cost Waste treatment cost incl. waste disposal (cost of disposing waste outputs) Operational costs Communication, dissemination costs	• Product sale revenue: sale of product (aromatic flavour components (diacetyl and acetaldehyde), oils from SCGs, carotenoids) • Waste as value: revenue stream from by-product (solid waste from fermentation process)
SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +
Use of chemical solvents may be included for the extraction process Large-scale bioprocesses/plants for industrial production of oils and aromas are not under developing due to low reliable and profitable economic aspects. Separate collection of a specific waste stream, SCGs.	Avoidance of landfilling large amounts of biowaste (SCGs) Recourse efficiency through the SCGs valorisation Products produced from SCGs (aromas, natural flavours, carotenoids, food ingredients, nutraceuticals, food preservatives and cosmetic ingredients) are aligned with end-users' demands about sustainable ingredients in the products. This can make the bio-product understandable and trustful and able to increase its social acceptance

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10.12. Biochemical production of functional ingredients from animal by-products

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Collaboration to conduct the study of the plant (if needed) and the necessary permission documents Collection & Transportation of raw materials (fish/meat waste) and transportation of products coming from fish/meat waste treatment. -Companies/municipalities for transportation and collection of raw materials and products. -Companies providing the collection equipmen (special care for animal biowaste-sensitive, oxidize quickly)	Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Collection and/or storage of feedstock Gelatin or collagen hydrolysate production Product quality control – product certification Packaging and distribution of products collaboration for waste/residue treatment Exhausted raw material is organic waste that can be valorised (AD, compost).	Production of gelatine or hydrolysed collagen - The use of this bioproducts is beneficial from an environmental point of view as this product can be a substitute for collagen hydrolysate produced by the ovine and pig by products. Ability of processing small quantities of biowaste. preferable and more viable to produce higher added-value bioproducts	B to B - Personal contact with wholesale customers (eg food industry, feed industry, feed companies) - Sales according to customer's order - Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs) eco-labeling/standardisation (product purity) to validate environmental value Informing/educating on bio economy potential and value proposition of gelatin, hydrolysed collagen	-animal feed -cosmetic, -pharmaceutical,

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<table>
<tr>
<td rowspan="2">KEY PARTERNSHIPS

Collaboration for reaching feedstock:
- HoReCa sectors,
- Markets ((i.e., butcheries, fisheries) and
- Households.
- aquaculture industries,
- slaughterhouses and
- food processing industries

Collaboration with technology providers

Products packaging

Collaboration for the residue exploitation. Residue produced during treatment stages is organic waste that can be valorised for AD or compost.

Public/private financing</td>
<td>KEY ACTIVITIES

Cooling water can be reused in watering plants in outdoor and indoor agrolabs.

Comunication and dissemination activities, maintenance of partnerships with customers, partners and suppliers</td>
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<td>KEY RESOURCES
- Infrastructure and equipment.
- Feedstock
- Personnel
- Raw materials: biomass, filtration grounds, water (decalcified). Enzymes (commercial).
- Sulphuric acid (4 % of the feedstock weight).
- Financial resources</td>
<td>CHANNELS

Promotion through the relative networks(pharmaceutical, cosmetic production)

Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc)

Participation in relevant campaigns, local events (for raising awareness and demonstrating the products)</td>
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			CHANNELS Sales through Company Website, online shops, on-site (if exists)	

COSTS - Labour: Labour cost - Materials: materials cost (feedstock, other additional materials) - Infrastructure cost/ maintenance cost - Separate collection cost - Waste treatment cost incl. waste disposal (cost of disposing waste outputs) - Operational costs - Communication, dissemination costs	REVENUES sale of end products (gelatine or hydrolysed collagen) revenue stream from waste valorization (organic waste that can be valorised (AD, compost))

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SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +
Odour pollution Rapid oxidation and decomposition of the biowaste and their bioproducts, which increases the costs of storage, conservation and transportation	This product can be a substitute for collagen hydrolysate produced by the ovine and pig by products The bioproducts obtained can arouse social interest as gelatine is useful in food and pharmaceutical products and hydrolysed collagen has a great value in the cosmetic and food industry. EU regulation promotes the protein recovery and recycling process of animal by-products (European Regulation 2009/1069/CE). For the production of higher added-value products is preferred processing small quantities of waste (applicable technology for small scale investments)

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10.13. Production of biopesticides

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers Municipalities/Regions, Waste management plants, AD plants, Local agricultural cooperatives, HORECA, farmers. Partners providing specialised technologies (hydrolysis, fermentation) Experts for maintenance services	Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Storage of raw materials Collection and/or storage of feedstock Bioproduct production (Stabilisation & homegenisation of OFMSW , hydrolysis, fermentation) Product quality control – product certification Packaging and distribution of products	Commercialisation of the bacteria Bacillus Thuringiensis (Bt) (biological pesticide). The use of this bioproduct is beneficial from an environmental point of view as it can supplement conventional chemical pesticides Bt from biowaste has reduced production costs compared with Bt produced from other high-priced raw feedstocks.	B to B • Personal contact with wholesale customers or relative networks (eg Agricultural cooperatives) • Sales according to customers' order • Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• Farmers • Agronomists (nursery gardens) • Agricultural cooperatives

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KEY PARTERNSHIPS Partnerships to develop collection network • certified transport company for raw material and/or product • company for the biowaste collection equipment (e.g. bins). Packaging and distribution of biopesticides Collaboration for residue management Public/private financing Collaboration to conduct the study for a plant (if new) and the necessary permission documents.	KEY ACTIVITIES Residue treatment Exploitation of the solid residue from hydrolysis & fermentation as: - as for instance insect breeding. - organic fertiliser - biogas Residual broth can be treated as wastewater. - Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers		CUSTOMER RELATIONSHIPS B to C • Personal contact with customers or relative networks (e.g. farmers) • Sales according to customers' order • Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs) eco-labeling/standardisation (καθαρότητα προϊόντος) to validate environmental value Informing/educating on bio economy potential and value proposition	
	KEY RESOURCES • Infrastructure and equipment. • Food waste		CHANNELS Promotion through the local associations of farmers, agronomists etc.	

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<td>KEY RESOURCES
Other resources: Bacillus thuringiensis,
Water content and nutrient adjustment
Personnel
Financial resources</td>
<td></td>
<td>CHANNELS

Advertising, communication and dissemination activities (Newsletters,
Blogs, Social media, tv/radio etc)

Participation in relevant campaigns, local events (for raising awareness and demonstrating the products)

Sales through Company Website, online shops, on-site (if exists)</td>
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<tr>
<td colspan="3">COSTS
Labour: Labour cost
materials: materials cost (feedstock, other additional materials)
Infrastructure cost/ maintenance cost
Separate collection cost
Waste treatment cost incl. waste disposal (cost of disposing waste outputs)
Operational costs
Communication, dissemination costs</td>
<td colspan="2">REVENUES
Product sale revenue: sale of product
Waste as value Sales from Fertilizer (residue)</td>
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SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +
Besides the acceptance of the bioproduct, the process might imply some matter of concern, like odous. Odour management is highly recommended to avoid community acceptance barriers due to odour nuisances.	More efficient use of resources since raw materials for conventional pesticides production is saved. Biopesticides are effective and have lower ecologic impact than traditional ones, being therefore widely accepted by society The production of biopesticides will contribute to reduce GHG emissions from the extraction of raw materials for conventional pesticides production

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10.14. Production of biostimulants and biofertilizers

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers Municipalities/Regions, Waste management plants, AD plants, Local agricultural cooperatives, HORECA, farmers, WWTPs Partners providing specialised technologies (hydrolysis, fermentation, purification). Experts for maintenance services	Collaboration with feedstock suppliers and technology providers Promoting local value chains/markets/materials Collection and/or storage of feedstock Bioproduct production (homegenisation of OFMSW, hydrolysis, fermentation) Product quality control – product certification Packaging and distribution of products	-Production of biofertilisers and biostimulants from OFMSW or UWWS is a novel technology. -The use of biofertilisers can improve the productivity per unit area in a relatively short time. Consequently, they can reduce the use costs compared to chemical fertilisers. Additionally, their easy way of application consumes smaller amounts of energy. This means lower costs associated with the process of fertilisation. - Biofertilisers and biostimulants provide ecofriendly source of plant nutrients and simultaneously minimize the use of chemical fertilizers and pesticides, without compromising the production yields.	B to B • Personal contact with wholesale customers or relative networks (eg Agricultural cooperatives) • Sales according to customers' order • Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	• Farmers • Agronomists (nursery gardens) • Agricultural cooperatives

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KEY PARTERNSHIPS Partnerships to develop collection network • certified transport company for raw material and/or product • company for the biowaste collection equipment (e.g. bins). Packaging and distribution of biostimulants and biofertilisers Collaboration for residue management Public/private financing	KEY ACTIVITIES Residue treatment Exploitation of the solid residue from hydrolysis & fermentation as: - as for instance insect breeding. - organic fertiliser - biogas Residual broth can be treated as wastewater. - Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers	VALUE PROPOSITION - The use of biofertilisers is beneficial from an environmental point of view as they can supplement to chemical biofertilisers.	CUSTOMER RELATIONSHIPS B to C • Personal contact with customers or relative networks (e.g. farmers) • Sales according to customers' order • Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	
KEY PARTERNSHIPS Collaboration to conduct the study for a plant (if new) and	KEY RESOURCES • Infrastructure and equipment		CHANNELS	

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the necessary permission documents.	• Feedstock OFMSW or UWWS • Other resources: enzymes • Personnel Financial resources		Promotion through the local associations of farmers, agronomists etc. Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc) Participation in relevant campaigns, local events (for raising awareness and demonstrating the products) Sales through Company Website, online shops, on-site (if exists)	

COSTS • Labour: Labour cost • materials: materials cost (feedstock, other additional materials) • Infrastructure cost/ maintenance cost • Separate collection cost • Waste treatment cost incl. waste disposal (cost of disposing waste outputs) • Operational costs • Communication, dissemination costs	REVENUES • Product sale revenue: sale of product • Waste as value Sales from Fertilizer (residue)
SOCIAL & ENVIRONMENTAL −	SOCIAL & ENVIRONMENTAL +

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The production cost of biofertilisers and biostimulants from OFMSW and UWWS is not fully calculated yet (TRL 5) and this could be a barrier for its adoption from farmers.	• Reduce the use of chemical fertilizers • The use of biofertilisers can improve the productivity per unit area in a relatively short time • Easy way of application consumes also smaller amounts of energy • Biostimulants and biofertilisers have a well-established market and an increasing potential of application, because they meet society's concern about sustainability of the agriculture sector • Social acceptance

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10.15. CO2 fermentation

KEY PARTERNSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Feedstock suppliers: Municipalities/Regions, AD plants, (UWWS and biogas from AD plant to provide CO2 emmissions) Partners providing key technologies Experts for maintenance services Partnerships for packaging and distribution of organic compounds, biomethane Public/private financing Collaboration to conduct the study for a plant (if new) and the necessary permission documents.	Collaboration with feedstock suppliers and technology providers Bioproduct production (bioelectrochemical CO2 conversion) Collection and/or storage of feedstock Product quality control – product certification Packaging and distribution of the organic compounds Biomethane and acetate Communication and dissemination activities, maintenance of partnerships with customers, partners and suppliers	Comercialisation of products: biomethane, organic compounds probable earning of carbon credits The use of this bioproduct is beneficial from an environmental point of view as it can supplement conventional acetate, other energy sources (in case of biomethane)	B to B Personal contact with wholesale customers (eg food industry, feed industry, feed companies) - Sales according to customer's order - Providing continuously updated information for the product(s) online (website, newsletters, social media, blogs)	pharmaceutical industry, textile, paints, plastics, films, fuels, energy

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	KEY RESOURCES		CHANNELS	
	• Infrastructure and equipment. UWWS and biogas from AD plant to provide CO_2 Other resources: Enriched homoacetogens • Personnel • Financial resources		Promotion through the relative networks Advertising, communication and dissemination activities (Newsletters, Blogs, Social media, tv/radio etc) Participation in relevant campaigns, Sales through Company Website, online shops, on-site (if exists)	

COSTS	REVENUES
• Labour: Labour cost • Materials: materials cost (feedstock, other additional materials) • Infrastructure cost/ maintenance cost • Waste treatment cost incl. waste disposal (cost of disposing waste outputs) • Operational costs • Communication, dissemination costs	Product sale revenue: sale of product (biomethane, organic compounds)
SOCIAL & ENVIRONMENTAL − For economic profitability, the nutrient recovery plant should be coupled to the AD plant and avoid transportation costs.	SOCIAL & ENVIRONMENTAL +

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The technologies of bioconversion of UWWS by CO_2 fermentation with bioelectrochemical systems are under development and construction at pilot process scale	the quality of the biogas increases by removal of the CO_2 and, on the other hand, the CO_2 transforms into a series of chemical building blocks with added value no emissions recorded from this technology, direct CO_2 sequestration from the technology.

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