Ref. Ares(2024)4246460 - 12/06/2024

MAINSTREAM BIO

MAINSTREAMING SMALL-SCALE BIO-BASED SOLUTIONS ACROSS RURAL EUROPE

D2.1

Catalogues of technologies, business models and social innovations for small-scale bio-based solutions

WR, INNV & WHITE

Version 12 June 2024

Funded by the European Union

PROJECT INFORMATION

PROGRAMME	Horizon Europe
TOPIC	HORIZON-CL6-2021-CIRCBIO-01-08
TYPE OF ACTION	HORIZON Coordination and Support Actions
PROJECT NUMBER	101059420
START DAY	1 September 2022
DURATION	36 months

DOCUMENT INFORMATION

TITLE	Catalogue of technologies, business models and social innovations for small-scale bio-based solutions
WORK PACKAGE	WP2
TASK	2.1
AUTHORS (Organisation)	Bert Annevelink & Martien van den Oever (Wageningen Research); Iñigo Rodilla Ojeda, Ana Casillas González & Beatriz Deltoro (Innovarum); Anastasios Galatsopoulos & Sofia Michopoulou (White Research); and with a contribution of Vagelis Koufalis (DRAXIS Environmental S.A.)
REVIEWERS	Petar Borisov (Agricultural University of Plovdiv); Evangelia Tsagaraki & Georgios Spyridopoulos (Q-PLAN International Advisors PC)
DATE	12 June 2024

DISSEMINATION LEVEL

PU	Public, fully open	x
SEN	Sensitive, limited under the conditions of the Grant Agreement	
Classified R-UE/EU-R	EU RESTRICTED under the Commission Decision No2015/444	
Classified C-UE/EU-C	EU CONFIDENTIAL under the Commission Decision No2015/444	
Classified S-UE/EU-S	EU SECRET under the Commission Decision No2015/444	

DOCUMENT HISTORY

Version	Date	Changes	Responsible partner
1.1	18/11/2022	First draft	WR
1.2	27/1/2023	Second draft	WR
1.3	31/1/2023	Third draft	WR
1.4	17/3/2023	Fourth draft with contribution of DRAXIS	WR, INNV & WHITE
1.5	5/4/2023	Fifth draft with final catalogues	WR, INNV & WHITE
1.6	11/4/2023	Final draft for review by AUP & Q-PLAN	WR, INNV & WHITE
2.0	19/4/2023	Final report	WR, INNV & WHITE
2.1	12/6/2024	Comments of periodic review processed - Final version	WR

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

ABBREVIATIONS

BM	Business Model
BSF	Black Soldier Fly
CH_4	Methane
CHP	Combined heat and power
Cl	Chloride
CO	Carbon monoxide
CO_2	Carbon dioxide
DME	Dimethyl ether
DoA	Description of Action
DSS	Decision Support System
EU	European Union
GHG	Greenhouse Gas
GMP	Good Manufacturing Practices
H_2	Hydrogen
H_2O	Water
H_2S	Hydrogen sulfide
HTC	Hydrothermal carbonization
HTL	Hydrothermal liquefaction
IEA	International Energy Agency
K	Potassium
KPI	Key Performance Indicator
LHV	Lower heating value

LNG	Liquefied natural gas
M€	Million euro
MIPs	Multi-Actor Innovation Platforms
MJ	Megajoules
MSD	Micro-scale digester
N	Nitrogen
N_2	Nitrogen gas
NH_3	Ammonia
P	Phosphorous
PHA	Polyhydroxyalkanoate
R&D	Research & development
SI	Social Innovation
SME	Small and Medium-sized Enterprise
SMS	Spent mushroom substrate
SNS	Synthetic natural gas
SSO	Source Separated Organics
TRL	Technology Readiness Level
VC	Value Chain
WP	Work package

Executive Summary

MainstreamBIO is a HORIZON Coordination and Support Actions project funded by the European Union under grant agreement 101059420. It started in September 2022 and will have a duration of 36 months. The project aims to co-develop innovation support services and digital tools to build awareness, understanding and capacity to uptake small-scale bio-based solutions in line with market demand and regional specificities. As part of the project activities related to the development of the MainstreamBIO digital toolkit, the present report presents the input for the MainstreamBIO online catalogue of small-scale bio-based technologies, business models and social innovations to offer "hands-on" business and technical support accounting for economic, social and environmental dimensions across all development stages of a project comprising small-scale bio-based solutions.

Small-scale biobased technologies are often the central part of a new business model of a local biobased solution. A business model is a conceptual framework that describes how a company creates, delivers, and captures value. It is the plan that a company uses to generate revenue and make a profit. A business model can be seen as the overall strategy that guides a company's operations and decision-making processes. Social Innovation provides an effective approach towards achieving societal behavioral changes and promoting sustainability. Social innovation is a participatory process that involves various stakeholders and can be applied to tackle global and local issues, including environmental challenges and their impacts on people's lives, health, and wellbeing. Ultimately, SI contributes to the development of sustainable solutions to pressing social needs.

In an early stage it was decided to have three separate catalogues namely on technologies, business models and social innovations for small-scale biobased solutions, instead of one fully integrated catalogue. All the information that was collected through the literature search and consultations with experts was processed in catalogue information templates (see Annex B - Annex D). Besides general literature sources MainstreamBIO also specifically looked at recent European projects like Power4Bio, BE-Rural and Bio4Africa.

In total 16 small-scale biobased technologies in the bioeconomy sector were described. By examining the small-scale technology list, stakeholders can obtain a basic understanding of the key aspects of potentially suitable technology solutions for their specific case. The final selection of 34 business models shows a good picture of the availability of alternatives in the EU. Most of the available feedstocks in the EU are represented along the catalogue, so the replicability and transferability can be ensured except for obvious limitations as climate or access to feedstock. The 19 examples in the social innovations catalogue aim to address social and environmental challenges while also creating economic opportunities. By examining these examples, insights can be gained into the ways in which social innovation is being used to drive positive change in this field.

A matching table has been constructed that standardizes the description/names of the following categories: feedstock, technology, and product. This matching table can be used to connect the three catalogues and it will can be implemented in the digital toolkit. The information in the three catalogues will be input for 'Development of a methodology for matching available biomass and waste streams with market and technology information (multi-criteria decision making model)' (Task 2.4) and 'Development, upgrade and integration of digital tools in the MainstreamBIO digital toolkit' (Task 2.5) of the MainstreamBIO project.

1. Introduction

1.1 Cataloguing of technologies, business models and social innovations for small-scale bio-based solutions

As far as bioeconomy is concerned, experiences from practice show that solely focussing on technological innovations will not guarantee developing business opportunities and improving livelihoods in rural contexts. Rural communities face social challenges (e.g. depopulation, ageing, difficult access to infrastructure and services, social exclusion for certain groups) which call for models at the intersection of technological and social innovation linked with inclusive business models.

This deliverable D2.1 describes the results of Task 2.1 'Cataloguing of technologies, business models and social innovations for small-scale bio-based solutions' of the MainstreamBIO project. The overall purpose of the Task has been to develop a catalogue of small-scale bio-based solutions (technologies, business models and social innovations) to prove inspiration and guidance for rural actors, while being a building block of the MainstreamBIO Decision Support Tool to be developed at a later stage of the project. The idea was to catalogue and classify solutions according to: (i) context (e.g. rural, urban, peri-urban, profit vs non-profit, community vs industry-driven); (ii) type of solution (tech, social or business model); (iii) biomass type, (iv) scale (farm, village or community level); (v) technological readiness level; and (vi) market deployment level.

The deliverable D2.1 will be used as input for the 'Development of methodology for matching available biomass and waste streams with market and technology information' (Task 2.4) and the 'Development, upgrade and integration of digital tools in the MainstreamBIO digital toolkit' of the MainstreamBIO project (Task 2.5).

1.2 Approach and methodology

This section will give a general description of the approach and methodology followed for the preparation of this report. More details on the preparation of each of the three individual catalogues comprising the report is presented in Sections 2.2, 3.2 & 4.2.

The three partners involved in Task 2.1 (WR, INNV and WHITE) held several meetings at regular intervals to coordinate the work. Halfway this process DRAXIS also joined these meetings to learn more about the type of information that was generated, so that the integration of the results of cataloguing activities under Task 2.1 into the MainstreamBIO Digital Toolkit (Task 2.5, final version expected to be delivered in August 2025) could be guaranteed and optimized.

In an early stage it was decided to have three separate catalogue templates namely on technologies, business models and social innovations for small-scale bio-based solutions, instead of one, fully integrated catalogue. The main reason for this choice was the different nature of the available information on these three topics. However, efforts were made to specify and standardize linking pins like feedstock names and product names between at least the technology and business model catalogue. Nevertheless, linking the social innovation aspects to the two forementioned catalogues

Funded by the European Union

was a challenge since social innovations can often be applied in all technology-business model combinations. Therefore, the social innovations were not specifically linked to the other two catalogues.

The three partners (WR, INNV and WHITE) that were responsible for the content of the individual catalogues first performed a thorough bibliographic review, looking at literature sources in general and also looking specifically at recent European projects (like POWER4BIO[1], BE-Rural[2] and Bio4Africa[3]).

During the work it became obvious that the 15 structured interviews that were planned in the DoA were not necessary/useful to collect further information. Literature sources were sufficient to obtain a good description. However, as an addition to these literature sources five internal WR experts were nevertheless consulted about the content of the small-scale biobased technology catalogue, using a free format approach (direct contact and emails with specific questions concerning the categories of technologies that fell under their expertise). They were asked to check the collected information in the draft version of the technology catalogue, and to supply references to further information if needed. Finally, all the information of the consulted WR experts was combined and integrated with the information of the literature study in the technology catalogue. In the case of the business models catalogue and the social innovations catalogue it turned out to be very difficult to get a response from further experts. So, in that case only a few quick calls to an external expert could be made to verify information or obtain references to additional information. No specific records have been kept of these short calls.

For reporting purposes three different catalogue information templates were designed with a layout specifying the target data categories for technologies, social innovations & business models (Sections 2.2, 3.2 & 4.2). All the information that was collected through the literature search and consultation with experts was then processed in these catalogue information templates (Annex B, C and D).

1.3 Definition of small-scale in the context of the catalogues

A clear definition of the meaning of small-scale bio-based technology had to be agreed upon for the MainstreamBIO project scope. The trending definition of this term considers both quantitative (processing volumes and overall cost) and qualitative criteria (e.g. single farmer, group or community level).

At the kick-off meeting of the MainstreamBIO project a reference was made to Sair et al. (2021) who present a methodology to specify the concept of scale. They include the factors feedstock, process, economy and mobility of a biorefinery facility in their definition. Small-scale biorefineries are

[1] https://power4bio.eu/

[2] https://be-rural.eu/

[3] https://www.bio4africa.eu/

Funded by the European Union

characterized by small investment costs (less than 2 M€), a low processing capacity (less than 100 ton/day) and a low process complexity, while the end-products' added value is variable. The mobility of the technology is optional, but not necessary as criterion for small-scale biorefineries.

The small-scale definition discussion was continued at a WP1-WP2 coordination meeting. It was concluded that some small-scale technologies could require an even higher investment than the 2 million euros that are mentioned in Sair et al. (2021). Furthermore, the equivalent of 2 million euros does not have the same value in different parts of Europe. Often a small-scale bio-based solution is a mix of technologies, varying from simple to more sophisticated. It also depends on the consortium that is applying the small-scale technology: a single farmer, a group of farmers and/or other stakeholders, a municipality, etc. When it is applied by a major industry it will be large-scale, but in the case of a Small and medium-sized enterprise (SME) it could also be small-scale. Furthermore, the business model description does not take into account the scale of the technology yet. The scale will be further defined when the actual business plan (which is more concrete than the business model) is drafted, in which the investment plan is determined. The same holds for the social innovations, that do not really look at scale yet, but more at what society could earn with/benefit from the innovation. Looking at the list of technologies a criterion for small-scale could be if the technology can be implemented at local (village) scale.

A problem with the Technology Readiness Level (TRL) could be that some of the found technologies are only still in the pilot or demo phase (TRL 6-7). In that case relatively low investment amounts could suggest small-scale. However, the final commercial implementation could bet at a (much) larger scale. So it is important to know if the small-scale technology is already commercially available (TRL 8-9) or if it will still be small-scale once the pilot phase has been further developed into commercial scale.

So the final conclusion was to partially use quantitative and qualitative criteria for the selection of what is small-scale and take a flexible approach, with no clear cut boundaries and without the use of the less than 2M€ investment costs as a criterion. Furthermore, we worked backwards: first look at long lists of technologies that are given in various EU-projects (e.g. Power4Bio) and judge relevance for use at local scale by considering complexity and required investment costs.

1.4 Content of deliverable

Chapter 1 gives an introduction to the work on the technology, business model and social innovation catalogues for small-scale bio-based solutions. Then Chapter 2 until 4 describe the detailed approach per catalogue and the general overview of the results for each individual catalogue. Chapter 5 describes the links between the three catalogues and finally Chapter 6 gives some general conclusions. Annex A shows the connection between the content of the small-scale technology catalogue and the content of the business model catalogue. Finally, the catalogues with the detailed information can be found In Annex B until D.

Funded by the European Union

2. Catalogue on small-scale bio-based technologies

2.1 Introduction

A bio-based conversion technology transforms a certain biomass feedstock or a mix of feedstocks (inputs) into a mix of products (outputs). Often other auxiliary inputs are needed like energy, water or catalyst. Small-scale bio-based technologies are often the central part of a new business model of a local bio-based solution. Therefore, it will be useful to have an overview of the most common small-scale bio-based technologies. For the MainstreamBIO project ‘most common’ means that only the higher Technology Readiness Levels (TRL7-9) were taken into account in the catalogue. Technologies that are still at an early stage of development (TRL1-6) were excluded because they cannot be implemented in small-scale regional business models yet.

The technology list of the Biorefinery Outlook 2030 project (Platt et al., 2021) in Table 1 was used as a starting point for identifying which small-scale technologies should be described. The Biorefinery Outlook 2030 list contains four main categories of technologies:

- biochemical;
- chemical;
- mechanical and thermochemical and;
- thermochemical.

As discussed in Section 1.3 it is difficult to determine the exact size-range of small-scale technologies. However, it was decided that the scale of chemical technologies will most likely be too large and too complex for local small-scale bio-based solutions. Therefore, all chemical technologies were excluded from the catalogue of small-scale bio-based technologies (see Table 3 in Section 2.3). Also some specific technologies were excluded in the other main categories because of their large-scale character: enzymatic processes in the biochemical category, and supercritical conversion in the thermochemical category. In the mechanical and thermomechanical category the technology types extraction and separation have been combined in this catalogue as one technology type, since there is some overlap. Also some extra small-scale technology types were added to the MainstreamBIO list compared to the original list of Biorefinery Outlook 2030 project (Platt et al., 2021). These additions concerned the following biochemical technologies: upgrading biogas and cultivation (both mushroom and algae).

In the thermochemical category, most technologies can have both a large-scale or small-scale set-up. In this catalogue the focus is on small-scale technologies of course. However, the description of the technologies is kept rather general, applying to both scales. The size of the small-scale variants will be further described in the specific examples of Business Model (see Chapter 3 and Appendix C).

Table 1: Bio-based technologies described in the Biorefinery Outlook 2030 project (Platt et al., 2021).

Technology Category	Technologies within category
Biochemical	• Aerobic conversion • Anaerobic digestion • Enzymatic process • Fermentation • Insect-based bioconversion • Other biochemical conversion
Chemical	• Catalytic • Esterification • Hydrogenation • Hydrolysis • Methanation • Chemical Pulping • Steam reforming • Water electrolysis • Water gas shift • Other chemical conversion
Mechanical and thermochemical	• Blending • Extraction • Mechanical and thermomechanical disruption & fractionation • Mechanical pulping • Separation processes • Other mechanical and thermochemical conversion
Thermochemical	• Combustion • Gasification • Hydrothermal liquefaction • Pyrolysis • Supercritical conversion • Torrefaction & Carbonization • Other thermochemical conversion

2.2 Setup of technology catalogue & factsheets

The first step in setting up the technology catalogue & factsheets was to choose which aspects had to be taken into account in the description of each technology. Relevant aspects in the catalogue description should contain useful information for the design process of a small-scale bio-based solution. Furthermore, sufficient information should be available to give a reliable description (garbage-in is garbage-out). Finally, the aspects should be of a from that can be incorporated in the MainstreamBIO Decision Support System (DSS) and Toolbox that will be developed later on in Task 2.4 and Task 2.5. The aspects of small-scale bio-based technologies that were chosen are described in Table 2.

Table 2: Template for a general description of small-scale bio-based technologies in Annex B.

Title

Very short. E.g. 'B1. Aerobic conversion (composting)', B2. Anaerobic digestion', etc.

A. Potential Feedstock

Categories

Indicate highest level(s) of feedstock categories according to 'Matching categories'

Examples

Examples of feedstock that can be converted by the general technology.

B. Technology

Technology Name

To facilitate quick discrimination of technology applied.

TRL

To indicate readiness for implementation.

Description of Technology

Description of the (series of) technology used, in short but full sentences. Attention for the following topics:

- Subsequent process steps, the conditions (temperature, time, additives needed, etc), what is converted into what, conversion yields and purity.
- Specific requirements: E.g. Specific feedstock quality (e.g. achieved by pre-treatment); Safety aspects; Limitations.
- Challenges which require attention to make the innovation successful
- Further references

C. Product(s)

Product Name(s)

To clearly list main (type of) products and side products, and eventually their quality ranges and application/purpose.

Eventually also indicate waste streams which need to be disposed.

D. References

Numbered references ([1], [2], etc.) that can be mentioned in the description above. Each technology starts numbering at [1] again.

An important source of information for the description of the chosen small-scale bio-based technologies was found in literature (Platt et al., 2021; Groenestijn et al., 2019; Annevelink et al., 2016). The Power4Bio interactive catalogue of bio-based solutions was another important source both for the small-scale technology catalogue and for the business model catalogue (Power4Bio, 2019a, 2019b, 2019c & 2020). Furthermore, the results of various European projects like Bio4Africa[1] (2023), AgriForValor[2] (2016) and BE-Rural[3] (2019) were studied. These projects often only present a very short description of a technology. However, it was useful to see which small-scale technologies were mentioned to check the MainstreamBIO technology catalogue for completeness. Finally, the technology descriptions were synchronized as much as possible with the descriptions in the catalogue of best practices nutrient recycling that was simultaneously being developed in MainstreamBIO's Task 2.2, which will be described in MainstreamBIO deliverable D2.2. Consultations on small-scale bio-based technologies were conducted with five experts within Wageningen Research that were not directly involved in the MainstreamBIO project, including Johan van Groenestijn (Biochemical technologies), Lesly Garcia (Biorefinery classification), Edwin Keijsers (Mechanical & thermomechanical technologies), René van Ree (Thermochemical technologies) and Iris Vural Gursel (Biorefinery classification). That way extra information was collected for further improvements of the small-scale bio-based technology catalogue.

2.3 Cataloguing Results

Table 3 is presenting a range of small-scale bio-based technologies in the bioeconomy sector. The table provides a short description of each technology. By examining this list stakeholders can support their choice of a suitable technology solution for their specific case. More information for each identified small-scale bio-based technologies is included in Annex B.

Table 3: Overview of small-scale bio-based technologies (Annex B).

Code	Small-scale technology	Brief description
	Biochemical	
B1	Aerobic conversion (composting)	Aerobic conversion of instable fractions of bio-based feedstock into mainly carbon dioxide (CO_2) and water by microorganisms that thrive under aerobic conditions, i.e. where plenty of oxygen is available, resulting in residual stable fraction of biomass which can be used e.g. as soil improver
B2	Anaerobic digestion	Anaerobic digestion is a biological process in which micro-organisms break down organic material under oxygen-free conditions into useful compounds such as methane (biogas).
B2b	Upgrading biogas	During the upgrading process (almost) all contaminations (e.g. carbon dioxide) are filtered from the biogas and it is dried, so it can be used as green gas.

[1] https://www.bio4africa.eu/

[2] https://agriforvalor.eu/

[3] https://be-rural.eu/

B3	Fermentation	Fermentation is a process in which micro-organisms (bacteria, yeasts, moulds) are used to convert organic material into alcohol, acids or hydrogen, for instance, which can be used in food and chemical industry. Often carbon dioxide is produced as a (not always useful) co-product.
B4	Insect-based bioconversion	Insect-based bioconversion also known as insect farming is based on growing a selection of insect species like e.g. Black Soldier Fly (BSF) larvae, house fly maggots, mealworms, and grasshoppers-crickets and different rearing substrates to produce e.g. protein rich feed.
B5a	Cultivation Mushrooms	The production system of mushrooms from residues.
B5b	Cultivation Algae	The production system of algae from residues.
	Mechanical and thermomechanical	
B6	Blending or mixing	Blending or mixing is used to modify the specification of biomass streams for different purposes, such as meeting the required emission, minimizing the ash production, obtaining the desired nutritional requirements for a specific animal or creating building materials.
B7	Extraction & separation processes	Extraction is a recovery and purification technology to extract impurities or valuable compounds. Separation is an important process for the conversion of biomass into components for use in chemicals, energy and materials.
B8	Mechanical and thermomechanical disruption & fractionation	Mechanical and thermomechanical disruption & fractionation are processes to modify the shape, particle size, bulk density and/or moisture of biomass.
B9	Mechanical pulping	Mechanical pulping is the process to open up the fibrous structure of plants or wood by grinding or refining. It frees fibre bundles, (partly) creating single fibres and fibril structures that can be used for the production of moulded fibre products, paper and fibre board materials.
	Thermochemical	
B10	Combustion	During combustion the biomass reacts with an oxygen surplus, and carbon dioxide, water and ash are primarily produced. Heat is released in this process, which can be used to produce steam that drives a steam turbine to produce electricity. Also efficient co-production of power and heat can be applied by using so called CHP-plants (part of the heat is used to produce power, the other part for producing heat).

B11	Gasification	During gasification, biomass is converted into combustible product gas at high temperatures (more than 600°C) with a controlled amount of oxygen (or air). Depending on the use of the product gas, it is called fuel gas in case will be used for energy (power and/or heat) applications, and syngas in case it will be used for the often catalytically supported synthesis of bio-based products (transport fuels, chemicals). All the material that is not converted into gas ends up in a remaining fraction called biochar, which has properties similar to activated carbon, and can be used as a soil enricher or as a fuel for heating the gasifier.
B12	Hydrothermal liquefaction (HTL)	Hydrothermal liquefaction (HTL) is a process to increase the energy content of wet organic containing streams. Through this process biomass can be converted into a heavy oil (biocrude) product (similar to heavy fuel oil) without drying the biomass.
B13	Pyrolysis	In the pyrolysis process, the biomass is thermally cracked at temperatures between 400°C and 600°C in an oxygen-free environment, producing a combustible gas, pyrolysis oil and char. Pyrolysis oil can be used as fuel and as a source for a naphtha-cracking process in which chemicals can be extracted. The gas by-product is usually burned in order to generate process heat for the pyrolysis reactor, and the biochar is a solid carbonaceous residue and it is suitable as soil improver or as solid fuel.
B14	Torrefaction & Carbonization	Torrefaction & carbonization are thermal processes to convert biomass into a coallike material, with higher energy density and hydrophobic characteristics compared to the original biomass and can withstand biodegradation. This delivers improved retention (stability), and reduced storage and transportation costs. The material is suitable for gasification and co-firing in coal-fired power stations.

3. Catalogue on small-scale bio-based business models

3.1 Introduction

A business model is a conceptual framework that describes how a company creates, delivers, and captures value. It is the plan that a company uses to generate revenue and make a profit. A business model can be seen as the overall strategy that guides a company's operations and decision-making processes (Osterwalder & Pigneur, 2010).

Some of the key characteristics of a business model include:

- **Value proposition:** This is the unique value that a company offers to its customers. It includes the products or services that the company provides, as well as the benefits that customers receive from using them.
- **Revenue streams:** These are the different ways in which a company generates revenue, such as through product sales, subscriptions, licensing fees, or advertising.
- **Cost structure:** This refers to the costs that a company incurs in order to create and deliver its products or services. It includes both fixed and variable costs, such as rent, salaries, materials, and marketing expenses.
- **Customer segments:** These are the specific groups of customers that a company targets with its products or services. This can include different demographics, geographic locations, or industries.
- **Channels:** This refers to the different channels or methods that a company uses to reach and communicate with its customers. This can include online advertising, social media, email marketing, or direct sales.
- **Key activities:** These are the specific activities or processes that a company needs to perform in order to deliver its products or services. This can include product development, manufacturing, marketing, or customer service.
- **Key partnerships:** These are the relationships that a company forms with other businesses or organizations in order to support its operations. This can include suppliers, distributors, or technology partners.

Overall, a business model provides a framework for a company to create, deliver, and capture value in a sustainable and profitable way. It is an essential tool for any business looking to succeed in the marketplace.

If the basis of a business model relays in a biological supply form (biomasses) from very different origins (agriculture, forestry, aquaculture, among others), these business models are considered bio-based business models.

Bio-based business models have gained increasing attention in recent years as a promising approach to fostering sustainable rural development in the European Union (EU). These models promote the use of renewable resources and the development of local value chains, which can contribute to the creation of jobs, income and wealth in rural areas, while reducing their dependence on non-renewable resources and enhancing their resilience to economic and environmental challenges.

Bio-based business models can take various forms, ranging from agroforestry and organic farming to bioenergy production and biorefinery activities, and can involve a wide range of actors, including farmers, small and medium-sized enterprises, research institutions, and local authorities.

In this context, the EU has developed a range of policies and initiatives to support the uptake of bio-based business models, including the Bioeconomy Strategy[1], the Common Agricultural Policy[2], and the European Innovation Partnership on Agriculture[3]. These initiatives aim to create a favourable policy and regulatory environment, foster research and innovation, and provide financial and technical support to rural communities and businesses to facilitate the transition towards more sustainable and resilient rural economies.

In parallel, several innovation projects funded under different programmes (Horizon 2020, Horizon Europe, LIFE, INTERREG) have been working on the scouting, dissemination, and development of bio-based business models. These projects consider the previously mentioned policies and strategies and suggest tailored improvement to the business models they work with.

Catalogues of bio-based business models are a great source of information for most of the agents involved in the bio-based value chains since they can get ideas about alternative technologies or feedstock that could satisfy their needs.

3.2 Setup of business model catalogue & factsheets

Interesting small-scale business models across Europe were researched online. Additionally, to valorise the efforts of previous projects, catalogues and data sheets from several of them were thoroughly analysed. Business models compliant with the requirements of MainstreamBIO were included in the business model catalogue, always referencing the source of information. The most important concept to be considered was the scale of the production capacity or the investment in order to be aligned with the project scope, which is to be focused on small-scale experiences and/or rural initiatives.

In fact, the first batch of business models described was based on the description of the business models linked to the technologies detected in Annex B. Then, the business model catalogue (Annex C) was completed by including additional business models with non-technical approaches, i.e. no 100% focused on the valorisation of waste streams.

[1] European Commission, Directorate-General for Research and Innovation, (2018). A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment: updated bioeconomy strategy, Publications Office. https://data.europa.eu/doi/10.2777/792130

[2] https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-2023-27_en

[3] https://ec.europa.eu/eip/agriculture/en.1.html

The main sources of information were the catalogues of projects as RUBIZMO[1], BE-Rural[2], COOPID[3], POWER4BIO[4], LIVERUR[5], AGROinLOG[6] together with some of the experiences analysed in the study carried out by INNOVARUM in 2019 about the participation of the agricultural sector in the BBI JU7.

Once the business models were selected, INNOVARUM defined the list of categories that will constitute the factsheets of the catalogue. The categories included were mainly inspired on the ones from the business model canvas (included and briefly described in the previous section).

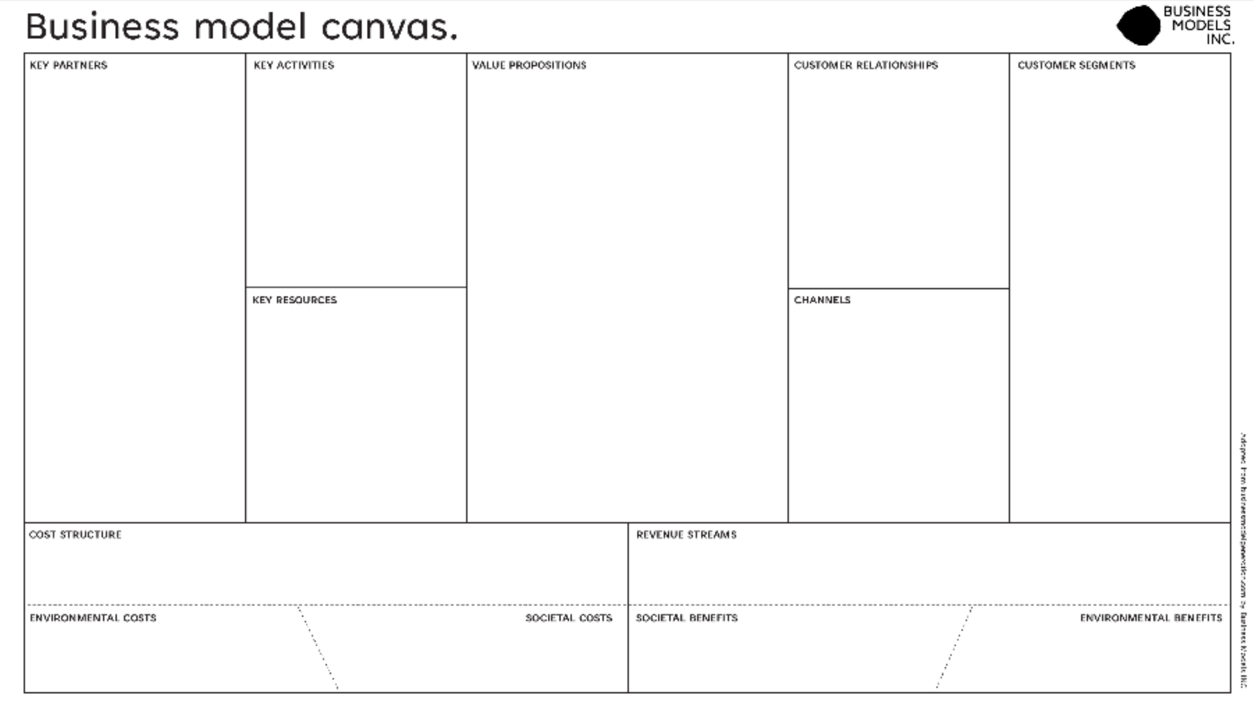

Figure 1. Business model canvas template[8].

It was decided to rename the categories and select just some of the categories, customising the definition to a bio-based business model. The aim of the redefinition is to improve the understanding of the factsheets, using the value chain as basis for the description.

[1] https://rubizmo.eu/

[2] https://be-rural.eu/

[3] https://coopid.eu/

[4] https://power4bio.eu/

[5] https://liverur.eu/

[6] http://agroinlog-h2020.eu/es/inicio/

[7] https://innovarum.es/wp-content/uploads/2020/07/2019.BBIJU-Study.pdf

[8] https://www.businessmodelsinc.com/en

The factsheet describes what the business owner needs (feedstock), how they valorise the raw materials (technology) and what they get (product). In addition, a brief assessment on the impact generated in different aspects (most of them linked with the Sustainable Development Goals).

As result, the factsheet was created and completed with the relevant information gathered for each of the elements enlisted in the next section. Table 4 shows the template that was used during the collection of the information.

Table 4: Template for factsheets of business models with small-scale bio-based technologies in Annex C.

A. General

Title

Concise description of the innovation, including feedstock, technology/ies and product(s). Acronym between brackets at end, if available.

Keywords

To facilitate finding related innovations with similar aspects.

Example user / provider of technology[1]

Relevant website(s)

Contact person[2]

Contact details if a specific person is known.

May help a lot in case of large companies. Persons may change jobs.

B. Feedstock

Main feedstock

Main feedstock that is converted by the example user of the innovation.

Potential other feedstock

Often, mutatis mutandis, technologies can handle a range of feedstocks.

Required Feedstock Quality

Technologies may require specific feedstock quality, e.g. achieved by pre-treatment.

Feedstock price, trade spot and location

To facilitate translation of useful cost-benefit data from elsewhere to own situation.

[1] The sign '-' will be inserted in data fields where no information can be found.

[2] In all business models, contact details (email, phone, location) were public (normally, in the "Contact" section of the company's web). In some specific cases, info was public in a "yellows pages" website.

C. Technology

Technology Name

To facilitate quick discrimination of technology applied.

TRL

To indicate readiness for implementation.

Description of Technology

Description of the applied technology/ies in short but full sentences. Attention for the following topics:

- Subsequent process steps (e.g. milling, hydrolysis, fermentation, purification), the conditions (temperature, time, additives needed), what is converted into what, conversion yields and purity.
- Feedstock flexibility: Elaboration on which type of feedstocks may be used and their limitations.
- Products: For which applications and sectors can they be used.
- Innovativeness: Including patents filed or granted
- Challenges which require attention to make the innovation successful
- Further references

Key partners

The main partners that are involved in the business model (such as e.g. feedstock providers, Technology providers and logistics companies)

- Converters
- Operation technicians
- Logistics company

Key resources

The main resources that are involved in the business model (such as e.g. feedstock, technology and logistics)

Capacity

Feedstock input and product output, in ton/annum, at given dry matter content.

Investment Costs

To facilitate quick discrimination for potentially interested entrepreneurs/investors.

E.g. using CAPEX estimation method by Bridgewater

Operational Costs

Even when difficult to obtain, interesting to facilitate quick discrimination for potentially interested entrepreneurs/investors.

Per ton input feedstock or output product, at given dry matter content.

D. Product(s)

Product Name(s)

To clearly list main products and side products, and eventually their quality and application/purpose. Eventually also indicate waste streams which need to be disposed.

Price, trade spot and location

To facilitate translation of useful cost-benefit data from elsewhere to own situation.

E. Impact

Environmental Benefits

Indicating quantitative or qualitative benefits, compared to (fossil) benchmarks.

Challenges for Implementation

Indicating potential hurdles when setting up the solution.

For example: (waste) legislation, market readiness level, weakness of value chain (e.g. transportability), farmers not willing to guarantee multi annual supply, etc.

Job Creation

Relevant topic in rural areas.

(could be part of next topic)

Socio - Economic

Indicating local and societal impact, public perception, political attractiveness, etc.

For example: Farmers interest is to get nutrients back after biogas production of side-stream.

F. References

Numbered references ([1], [2], etc.) that can be mentioned in the description above. Each technology starts numbering at [1] again.

3.3 Cataloguing Results

A summary of the small-scale bio-based business models that were described in the catalogue in Annex C is given in Table5.

Table 5: Overview of business models that implement small-scale bio-based technologies (Annex C).

Code	Factsheet	..
C1. Business models based on Aerobic conversion		
C1.1	Pindos	This Greek company converts poultry manure into organic fertilizers using aerobic conversion.

Funded by the European Union

C1.2	Pedrín	This Spanish company converts goat and sheep manure into organic fertilizers using aerobic conversion.
C2. Business models based on Anaerobic digestion		
C2.1	Biowert	This German company converts grass juice and food residues into biogas through anaerobic digestion. Biogas is converted into electricity.
C2.2	HoSt	This Dutch company uses anaerobic digestion to convert cattle manure into biogas. Three products are derived: biomethane, electricity and nitrogen-rich fertilizer.
C2.3	Pilze-Nagy	This Hungarian company uses anaerobic digestion to convert spent mushroom substrate and other agri-food wastes into biogas. Besides electricity, they also obtain solid and liquid fertilizers.
C2.4	Lantmännen	This Swedish company uses anaerobic digestion to convert pig and poultry manure into biogas for electricity and heat production. As a by-product, they obtain fertilizers.
C2.5	Biogas Brålanda AB	This Swedish company uses anaerobic digestion to convert livestock manure, agricultural residues and slaughterhouse waste into biogas for electricity and heat production. A portion is converted into biofuel for transport.
C2.6	Biogal	Biogal is a Polish company that uses anaerobic digestion to convert pig manure, agricultural waste and expired food into biogas. Electricity, heat production and fertilizers are the final products.
C2.7	Caviro	Caviro, an Italian company, uses anaerobic digestion to convert winery waste and mowing waste into biogas and bioethanol. As a by-product, they obtain fertilizers.
C2.8	Carbery	The Irish company Carbery pays special attention to dairy industry wastes. As an example, they use anaerobic digestion to convert whey permeate into bioethanol and biogas.
C2.9	Valio	Valio, a Finnish dairy company, uses anaerobic digestion to convert cattle manure into biogas for their logistic vehicles.
C2.10	Azienda Mengoli	Azienda Mengoli, an Italian family farm, uses anaerobic digestion to convert cattle manure, energy crops and agricultural residues into biogas for electricity production.
C3. Business models based on Fermentation		
C3.1	Toastale	Toastale is a British company that ferments unused bread to produce beer.
C4. Business models based on Insect-based bioconversion		
C4.1	Bestico	Dutch company Bestico revalorizes agri-food residues into feed and fertilizers by insect bioconversion.

Funded by the European Union

C4.2	madebymade	Madebymade is a German company that produces proteins from organic residues (e.g. food waste) via insect bioconversion.
C4.3	Ÿnsect	Ÿnsect, a French company, uses insect bioconversion to transform organic food waste into feed and fertilizers.
C5. Business models based on Cultivation		
C5.1	Rotterzwam	Rotterzwam is a Dutch company that grows oyster mushrooms using coffee residues, straw and lime.
C5.2	Pilze-Nagy	Hungarian company Pilze-Nagy grows oyster mushroom in cereal straw. Oyster mushroom substrate can also be commercialized.
C5.3	Spawnfoam	Spawnfoam is a Portuguese start-up that uses organic and agroforestry residues to grow fungus. The mycelium is the main component of their biocomposite.
C5.4	Ecovative	Ecovative, an American company, uses agricultural residues to grow fungus for biocomposite production.
C6. Business models based on Blending or mixing		
C6.1	Hempire	Polish company Hempire produces insulation and construction materials by mixing hemp hurd.
C7. Business models based on Extraction & separation processes		
C7.1	Add Essens	Add Essens is a Belgian company dedicated to producing specialty oils and additives for food, food supplements & cosmetics from fruit juice residue streams by pressing and solvent extraction.
C7.2	Natac Group	The NATAC Group is a Spanish company using olive oil industry by-products to produce food additives by extracting.
C8. Business models based on Mechanical and thermomechanical disruption & fractionation		
C8.1	Biowert	Biowert is a German company using meadow grass silage to produce grass fibre enhanced plastic granulates and natural insulation material by mechanical treatment and hot pressing.
C8.2	Møllerup Brands	Møllerup Brands is a company from Denmark using second-life materials to produce growing, insulating and construction material by shredding and mixing.
C8.3	MW Biomasse AG	MW Biomasse AG is a German company using forestry residue to produce pellets and chips for energy applications by mechanical disruption.
C8.4	Biomassehof-Chiemgau	Biomassehof-Chiemgau is a German company using wood residues to produce pellets for energy applications by mechanical disruption.

C8.5	APS	APS (Agroindustrial Pascual Sanz) is a Spanish company with expertise in machinery adaptation for pelletization of lucerne and other biomasses.
C8.6	Pelletierungs Genossenschaft	Pelletierungs Genossenschaft is an Austrian cooperative using agricultural waste from different sources based to produce pellets for multiple applications (energy, cattle bedding) by mechanical disruption.
C8.7	EIPIS	EIPIS is a Greek organization using forestry to produce pellets by mechanical disruption.
C9. Business models based on Mechanical pulping		
C9.1	Bio-Lutions	Bio-Lutions is a German company using agricultural residue to produce tableware and packaging material by mechanical treatment and hot pressing.
C10. Business models based on Combustion		
C10.1	ZP Victor Asenov	ZP VICTOR ASENOV is a vegetable producer in Bulgaria, using biomasses from surrounding businesses to generate heat by oxydrogen combustion.
C11. Business models based on Gasification		
C11.1	Hynoca	Hynoca is a French company using wood waste to produce renewable hydrogen by thermolysis (gasification).
C12. Business models based on Torrefaction & Carbonization		
C12.1	TerraNova	Terranova is a German company using sewage sludge to produce bio-coal by hydrothermal carbonization (HTC).

4. Catalogue on small-scale bio-based social innovations

4.1 Introduction

The European Commission's definition of social innovations as "new ideas that meet social needs, create social relationships and form new collaborations" highlights the importance of prioritizing social benefits over personal or corporate gain. Addressing complex social challenges such as climate change, poverty, and sustainability requires innovative solutions that combine the strengths of multiple stakeholders through cross-sectoral cooperation. Social Innovation (SI) provides an effective approach towards achieving societal behavioral changes and promoting sustainability. SI is a participatory process that involves various stakeholders and can be applied to tackle global and local issues, including environmental challenges and their impacts on people's lives, health, and wellbeing. Ultimately, SI contributes to the development of sustainable solutions to pressing social needs (Biggs et al., 2010). Overall, the main characteristics of social innovation, are presented in Table 6.

Table 6: Characteristics of Social Innovation (EC, 2013).

Characteristics of Social Innovation	
Open to all	Social Innovation is open to all in terms of knowledge-sharing and the ownership of knowledge.
Multi-disciplinary	Social Innovation is multi-disciplinary and more focused on problem-solving rather than being limited to one profession or department.
Participative and empowering	An effective Social Innovation is participative and empowering of citizens and users, avoiding the traditional 'top-down' and expert-led approach.
Demand-led	Social Innovation is demand-led rather than supply-driven, prioritizing the needs of society over commercial interests.
Tailored	Solutions offered by Social Innovation are tailored rather than mass-produced, as each problem has its unique context, and personalized solutions are necessary to address them effectively.

Social innovations that concentrate on the development of the bioeconomy are gaining more attention and are recognized as a significant initiative in the European Union's innovation policy. The EU social innovation initiative and the EU Bioeconomy have both developed within the last decade and were launched around the same time. The latter was introduced in 2012 through the Commissions communication “Innovating for sustainable growth: a bioeconomy for Europe”. Since then, the EU social innovation initiative has developed into an increasingly prominent concept and it promises great changes to pressing issues (European Union, 2018). These are distanced from other innovations strategies due to the fact that they move beyond the focus on enterprise-driven technical innovation to include other sectors such as professions, social services, environment even health and education (Ludvig et al., 2018). Thus, adding a social dimension to innovation by including social-ecological innovation and economic evolvement in rural areas. All these imply an opportunity for the rural sector to take a lead in the sustainable development of the bioeconomy. Furthermore, bioeconomy social innovations are more than able to contribute to the development of a sustainable and inclusive bio-based society (Melnykovych et al., 2018).

Under the framework of T2.1, WHITE conducted a targeted desk-research on the existing bioeconomy oriented social innovations. Results are both focused on MainstreamBIO's rural areas and other cases that were identified.

4.2 Setup of social innovation catalogue & factsheets

Social innovation (SI) in the context of bioeconomy and rural sector is characterized by its openness to sharing knowledge and ownership, as well as its high integration of different disciplines, cultures, and multiple stakeholders. These characteristics make SI a key asset in developing efficient and sustainable solutions that can empower citizens, especially those in vulnerable groups in rural communities.

There are three key approaches to social innovation in bioeconomy and rural sector that are outlined by the Bureau of European Policy Advisors (BEPA, 2011):

- *Social demand*: This approach responds to social demands that are traditionally not addressed by the market or public authorities, such as improving the livelihoods of smallholder farmers, enhancing food security, or mitigating the effects of climate change on rural communities.
- *Societal challenges*: This approach focuses on innovative solutions that integrate social, economic, and environmental challenges in bioeconomy and rural sector, such as developing sustainable and eco-friendly agriculture practices, improving waste management systems, or promoting circular economy.
- *Systemic change*: This approach focuses on organizational development and changes in relations between institutions and stakeholders to bring about systemic change in bioeconomy and rural sector. It aims to create a more sustainable and equitable system that benefits all stakeholders, including smallholder farmers, rural communities, and the environment.

In addition to these core elements, SI in bioeconomy and rural sector is characterized by being cross-sectoral, open, and collaborative. It also leads to grassroots initiatives that involve local communities and enhances society's capacity to act. Finally, SI in bioeconomy and rural sector must be innovative, meet a social need, lead to actual implementation, and be more effective than existing solutions.

To identify social innovations in the bioeconomy as part of Task 2.1 of the MainstreamBIO project, we created a factsheet with four main sections (see Table 7):

- activities;
- actors involved;
- impact on bioeconomy development, and;
- social impact.

Most of the social innovations were identified using the SIMRA[1] (Social Innovation in Marginalised Rural Areas) platform, an EU-funded project. The activities section outlines the specific actions taken by actors involved in the innovation process. The actors involved section describes the individuals and organizations contributing to the social innovation. The impact on bioeconomy development section assesses the potential effects of the innovation on the broader bioeconomy, including economic and environmental impacts. Finally, the social impact section evaluates the potential social implications of the innovation, including social equity and empowerment. This categorization process allowed for a clear and structured understanding of the social innovations being developed and implemented in various cases, providing a useful framework for evaluation and further development in the MainstreamBIO project.

Table 7: Template for social innovations related to small-scale bio-based solutions in Annex D.

D#. Name Social innovation' s name, e.g. " L'Atelier Paysan" <u>Description</u>: Short description of the social innovation, e.g. provide information on: • main objectives • social innovation's target • approach • etc. <u>Activities</u>: Short description of the main activities performed by the social innovation. <u>Actors involved</u>: What are the main actors involved in the social innovation, e.g. local farmers, regional authorities, volunteers, companies, civil society etc. <u>Impact for bioeconomy development</u>: What is the main impact of the social innovation to bioeconomy development, e.g. resource & energy efficiency, waste management, lower water consumption etc. <u>Social impact</u>: What is the main social impact of the social innovation, e.g. public participation education / training, assistance & advice, online resources, food waste management, job creation etc.

[1] http://www.simra-h2020.eu/

4.3 Cataloguing results

Table 8 is presenting a range of social innovations in the bioeconomy sector. These innovations aim to address social and environmental challenges while also creating economic opportunities. The table provides a snapshot of the diverse approaches being taken to promote sustainable production, reduce waste, and empower communities within the bioeconomy. By examining these examples, insights can be gained into the ways in which social innovation is being used to drive positive change in this field. More information for each identified social innovation is included in Annex D.

Table 8. Overview of factsheets of cases with social innovations (Annex D).

CODE	FACTSHEET	SHORT DESCRIPTION
D1	*L'Atelier Paysan*	This cooperative aims to empower farmers by promoting technical and technological sovereignty through an open source resource platform for farm production tools, which provides access to online resources, videos, trainings, and knowledge exchange sessions.
D2	*Organic Food Valley (EkoLubelszczyzna)*	This social innovation project aims to develop a cooperative network between different actors involved in the production, processing, and marketing of organic food and eco-products/services.
D3	*Rural HUB*	The Rural HUB connects socially responsible individuals and organizations with traditional farmers through an educational complex and co-working space, offering comprehensive programs for sustainable farm development in rural areas.
D4	*ARDAC*	The reforestation and sustainable forest management project aimed to address deforestation and local development, with an innovative aspect being the management of non-wood forest products from the biggest laurel forest in Lebanon.
D5	*Gela Ochsenherz*	The Demeter farm in Lower Austria is a partnership between employees and a group of around 300 consumers who collaboratively work together through an association.
D6	*Federatie Landbouw en Zorg - Network Care farming*	The foundation aims to professionalize agriculture and facilitate regional organizations in caring for farmers, likely as a non-profit organization funded by donations or grants.
D7	*Land Sharing for food and social good*	The Land Sharing for Food and Social Good project promotes sustainable farming by transferring knowledge through intergenerational cooperation.
D8	*Mazi*	Mazi leads the regeneration of degraded farmland in the Mediterranean through community-supported agroforestry, adopting the 'syntropic' model of agriculture that mimics nature's patterns for a diverse and resilient ecosystem benefiting the environment and the community.
D9	*Integrated Ecosystemic value-enhancement of the Guadeloupe Forest*	The VALAB project promotes sustainable vanilla production while preserving forest ecosystems and enhancing livelihoods, by balancing economic, ecological, and social considerations in

Funded by the European Union

	Agrobiodiversity (VALAB)	agricultural practices to reconcile vanilla production with forest conservation.
D10	*Big Akwa - Fish farming in a new innovative way – symbiosis with pulp mills*	Big Akwa is a social innovation company that combines fish farming with pulp mills through industrial symbiosis, to achieve sustainable and resource-efficient food production with lower costs and reduced environmental impact.
D11	*Agtira - Tomato farming in symbiosis with fish farming*	Agtira's closed-cycle system is highly beneficial for resource and energy efficiency, reducing water consumption, waste disposal needs, and transportation, while increasing produce freshness and decreasing food waste.
D12	*Collection of food waste*	Örnsköldsvik municipality's innovative waste management system efficiently produces biogas and biofertilizer from food waste, contributing positively to the environment, society, and the agricultural sector.
D13	*Cloughjordan EcoVillage*	Cloughjordan EcoVillage is a unique development that emphasizes sustainable living practices and community engagement.
D14	*Shared composting*	The "Root" Foundation is promoting sustainable development through shared composting and collaboration with various agricultural and environmental organizations to restore and conserve biodiversity and natural resources, with a focus on soil.
D15	*Planeta Madera*	Planeta Mandera promotes sustainable forest management practices in Spain through information dissemination and encouraging the implementation of sustainable practices.
D16	*Apadrina un olivo*	Apadrina un olivo is a successful initiative that recovers abandoned olive trees in Oliete, Teruel through sponsorship, creating job opportunities and attracting tourism.
D17	*Haver til maver*	Haver til Maver is a non-profit organization that focuses on promoting sustainability, food culture, and health among children and young people in Denmark.
D18	*Too good to go*	Too Good To Go is a Danish success case in the fight against food waste.
D19	*Kafsimo*	Kafsimo is a community-based project in Northern Greece that collects used coffee grounds from cafes and converts them into clean biofuel.

5. Links between the three catalogues

5.1 Matching categories to connect catalogues

Although the information is stored in three separate catalogues (Annex B, C and D), it is also a requirement to connect these three sources of information in the next steps of the project for the Decision Support System (DSS) methodology (Task 2.4) and MainstreamBIO Toolbox (Task 2.5). For that purpose, a matching table has been constructed that standardizes the description/names of the following categories: feedstock, technology and product (see Table 9). The basis for this standardization was found in the Biorefinery Outlook 2030 project (Plat et al., 2021), that was building on the IEA Bioenergy Task 42 classification. Small modifications were made for the MainstreamBIO project, e.g. extraction & separation process were combined into one category (see further details in Section 2.1). That way the three catalogues can be connected through those fields by looking at the same standardized descriptions.

Table 9: Matching categories to connect catalogues.

Feedstock	
Secondary biomass: Microbial biomass Secondary biomass: Residues from agriculture Secondary biomass: Residues from aquatic biomass Secondary biomass: Residues from forestry and forest-based industry Secondary biomass: Residues from nature and landscape management Secondary biomass: Residues from recycled bio-based products Secondary biomass: Residues from livestock production Secondary biomass: Residues from food industry Secondary biomass: Other organic residues	Primary biomass: Aquatic biomass Primary biomass: Lignocellulosic from croplands and grasslands Primary biomass: Lignocellulosic wood/forestry Primary biomass: Oil crops Primary biomass: Starch crops Primary biomass: Sugar crops Other primary biomass
Technology	
Biochemical: Aerobic conversion Biochemical: Anaerobic digestion Biochemical: Enzymatic process Biochemical: Fermentation Biochemical: Bioconversion Biochemical: Cultivation Biochemical: Other biochemical conversion	Chemical: Catalytic Chemical: Esterification Chemical: Hydrogenation Chemical: Hydrolysis Chemical: Methanation Chemical: Chemical Pulping Chemical: Steam reforming Chemical: Water electrolysis Chemical: Water gas shift Chemical: *Other chemical conversion
Mechanical and thermomechanical: Blending Mechanical and thermomechanical: Extraction & separation processes	Thermochemical: Combustion Thermochemical: Gasification Thermochemical: Hydrothermal liquefaction

Funded by the European Union

Mechanical and thermomechanical: Disruption & fractionation Mechanical and thermomechanical: Mechanical pulping Mechanical and thermomechanical: Forming Mechanical and thermomechanical: Other mechanical and thermomechanical conversion	Thermochemical: Pyrolysis Thermochemical: Supercritical conversion Thermochemical: Torrefaction & Carbonization Thermochemical: Other thermochemical conversion
Product	
Chemicals: Additives Chemicals: Agrochemicals Chemicals: Building blocks Chemicals: Catalysts & Enzymes Chemicals: Colorants Chemicals: Cosmeceuticals Chemicals: Flavours & Fragrances Chemicals: Lubricants Chemicals: Nutraceuticals Chemicals: Paints & Coatings Chemicals: Pharmaceuticals Chemicals: Solvents Chemicals: Surfactants Chemicals: Other chemical product	Materials: Composites Materials: Fibres Materials: Organic Fertilizers Materials: Polymers Materials: Resins Materials: Other material product
Food	Animal Feed
Energy: Cooling agents Energy: Fuels Energy: Heat Energy: Power Energy: Other energy product	

5.2 Integration in the MainstreamBIO Toolkit

The technologies, business models and social innovations included in the D2.1 catalogues will be part of the MainstreamBIO digital toolkit and they will be used as the input tables for the Decision Support System function of the toolkit. More specific, the user of this tool will have the possibility to match available feedstocks (biomass/waste streams) with the aforementioned small-scale bio-based technologies, business models and social innovations aiming for economic, social and environmental sustainability. The gathered technologies, business models and social innovations will be listed in the main page of the MainstreamBIO digital toolkit (Task 2.5) and along with the best nutrient recycling practices, which will be collected from Task 2.2, they will form the starting input. The user can choose one available option from each category and design different suitable value chain combinations, which will be assessed by the tool taking into account different aspects (e.g., job creation, environmental impact). In this way, the user can export two or three options and study this information in order to develop the most suitable future plan according to their necessities.

6. Conclusion

Three individual catalogues of technologies, business models and social innovations for small-scale bio-based solutions have been described (see Annex B - Annex D). In total 69 catalogue records have been developed: 16 small-scale bio-based technology records, 34 business model records and 19 social innovation records. The information was supported by consultations with five WR experts.

A range of small-scale bio-based technologies in the bioeconomy sector was described. By examining the small-scale technology list, stakeholders can support their choice of a suitable technology solution for their specific case.

The final selection of business models shows a good picture of the availability of alternatives in the EU. Most of the available feedstocks in the EU are represented along the catalogue, so the replicability and transferability can be ensured except for obvious limitations as climate or access to feedstock.

The examples in the social innovations catalogue aim to address social and environmental challenges while also creating economic opportunities. By examining these examples, insights can be gained into the ways in which social innovation is being used to drive positive change in this field.

A matching table has been constructed that standardizes the description/names of the following categories: feedstock, technology and product. This matching table can be used to connect the three catalogues and it will can be implemented in the digital toolkit.

The information in the three catalogues will be input 'Development of methodology for matching available biomass and waste streams with market and technology information' (Task 2.4) and 'Development, upgrade and integration of digital tools in the MainstreamBIO digital toolkit' (Task 2.5) of the MainstreamBIO project.

7. Literature

Agriforvalor, 2016. Good practice cases in practical applications of agro and forestry side-streams processing. Deliverable, AGRIFORVALOR project (Grant Agreement 696394), 53 pp.

Annevelink, E., H.L. Bos, K.P.H. Meesters, M.J.A. van den Oever, W. de Haas, P.J. Kuikman, R.P.J.J. Rietra, N. Sikirica, 2016. Circular Solutions; Part IV From Waste to Resource. TO2 federatie, De samenwerkende organisaties in toegepast onderzoek, Rapport, 65 pp.

BEPA, 2011. Empowering people, driving change: Social innovation in the European Union. Brussels: Bureau of European Policy Advisers, European Commission.

BE-Rural, 2019. Small-scale technology options for regional bioeconomies. Deliverable 2.1, BE-Rural project, 57 pp.

Biggs, R., F.R. Westley & S.R. Carpener, 2010. Navigating the Back Loop: Fostering Social Innovation and Transformation in Ecosystem Management. Ecology and Society. 15:2 (9); in ISABEL Project report, 2016, SI and CE best practices, methods and tools across Europe.

Bio4Africa, 2023. Catalogue of bio-based technologies.
https://www.bio4africa.eu/technologies/technology-catalogue/

EC, 2013. Guide to social innovation,
http://s3platform.jrc.ec.europa.eu/documents/20182/84453/Guide_to_Social_Innovation.pdf

European Union, 2018. A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment, Updated Bioeconomy Strategy; European Union: Luxembourg, p. 107.

Groenestijn, J. van, P. Harmsen & H. Bos, 2019. Biomass for the Circular Economy: Everything you wanted to know about biomass but were afraid to ask. (Groene grondstoffen; No. 23). Wageningen Food & Biobased Research. https://doi.org/10.18174/503632.

Ludvig, A., G. Weiss, S. Sarkki, M. Nijnik & I. Živojinovi´c, 2018. Mapping European and forest related policies supporting social innovation for rural settings. For. Policy Econ., 97, 146-152.

Melnykovych, M., M. Nijnik, I. Soloviy, A. Nijnik, S. Sarkki & Y. Bihun, 2018. Social-ecological innovation in remote mountain areas: Adaptive responses of forest-dependent communities to the challenges of a changing world. Sci. Total Environ., 613–614, 894–906.

Osterwalder, A. & Y. Pigneur, 2010. Business model generation. John Wiley & Sons.

Platt, R., A. Bauen, P. Reumerman, R. van Ree, C. Geier, I. Vural Gursel, L. Garcia, M. Behrens, P. von Bothmer, J. Howes, Y. Panchaksharam, K. Vikla, V. Sartorius & E. Annevelink, 2021. EU Biorefinery Outlook to 2030 for deployment. Studies on support to R&I policy in the area of bio-based products and services, LOT3. Expert report written by E4tech, WUR, BTG, FNR &ICONS, 394 pp.

Power4Bio, 2019a. Stakeholder requirements for a catalogue on bio-based solutions. Deliverable 3.1 (confidential), Power4Bio project, 40 pp.

Power4Bio, 2019b. Database to store the examples in the catalogue. Deliverable 3.2 (confidential), Power4Bio project, 73 pp.

Power4Bio, 2019c. Catalogue with bio-based solutions. Deliverable 3.3, Power4Bio project, 48 pp. https://power4bio.eu/wp-content/uploads/2020/05/POWER4BIO_D3.3_Catalogue_with_bio-based_solutions.pdf

Power4Bio, 2020. Best practice examples. Deliverable 3.4, Power4Bio project, 62 pp. https://power4bio.eu/wp-content/uploads/2020/04/POWER4BIO_D3.4_Best_practices_of_bio-based_solutions.pdf

Sair, A.A., K. Kansou, F. Michaud & B. Cathala, 2021. Multicriteria definition of small-scale biorefineries based on a statistical classification. Sustainability, 13, 7310, https://doi.org/10.3390/su13137310.

Annex A. An overview of small-scale bio-based technologies and business models implementing them

Table 10: Overview of small-scale bio-based technologies and examples of business models including them.

Code	Small-scale technology	Implemented in Business Model
	Biochemical	
B1	Aerobic conversion (composting)	C1.1 (Pindos) C1.2 (Pedrin)
B2	Anaerobic digestion	C2.1 (Biowert), C2.2 (HoSt) C2.3 (Pilze-Nagy) C2.4 (Lantmännen) C2.5 (Biogas Brålanda AB) C2.6 (Biogal) C2.7 (Caviro) C2.8 (Carbery) C2.9 (Valio) C2.10 (Azienda Mengoli)
B2b	Upgrading biogas	-
B3	Fermentation	C3.1 (Toastale)
B4	Insect-based bioconversion	C4.1 (Bestico), C4.2 (madebymade) C4.3 (Ÿnsect)
B5a	Cultivation Mushrooms	C5.1 (Rotterzwam), C5.2 (Pilze-Nagy) C5.3 (Spawnfoam) C5.4 (Ecovative)
B5b	Cultivation Algae	-
	Mechanical and thermomechanical	
B6	Blending or mixing	C6.1 (Hempire)
B7	Extraction & separation processes	C7.1 (Add Essens), C7.2 (Natac Group)

B8	Mechanical and thermomechanical disruption & fractionation	C8.1 (Biowert), C8.2 (Møllerup Brands) C8.3 (MW Biomasse AG) C8.4 (Biomassehof-Chiemgau) C8.5 (APS) C8.6 (Pelletierungs Genossenschaft) C8.7 (Elpis)
B9	Mechanical pulping	C9.1 (Bio-Lutions)
	Thermochemical	
B10	Combustion	C10.1 (ZP Victor Asenov)
B11	Gasification	C11.1 (Hynoca)
B12	Hydrothermal liquefaction (HTL)	-
B13	Pyrolysis	-
B14	Torrefaction & Carbonization	C12.1 (TerraNova)

Annex B. Catalogue of small-scale bio-based technologies

B1. Aerobic conversion (composting)

A. Potential Feedstock

Categories

Secondary biomass: Residues from forestry and forest-based industry; Residues from nature and landscape; Residues from livestock production; Organic residues from restaurants, food shops and households.

Examples

Suitable raw materials are Source Separated Organics (SSO), pruning and mowing material (grass, verge grass, grass from nature areas, foliage), straw, dry manure types, the thick fraction of digestate from various types of digesters, thickened sludge from biological wastewater treatment and residues of the agro-industry. The material must be damp but solid and porous, which excludes liquids and slurry. To guarantee a high quality compost pieces of glass, metal and plastic should be avoided in the raw material. [2, 5]

B. Technology

Technology Name

Aerobic conversion

TRL

9

Description of Technology

An *aerobic conversion* process relies on microorganisms that thrive under aerobic conditions i.e. where plenty of oxygen is available and a sufficient amount of feedstock is present [1].

An example is composting, a microbiological process in which heterogeneous organic material is oxidised and broken down into compost, CO_2, H_2O and heat in a set-up where air passes through a heap (pile, mound) of porous, solid material. Although composting can occur spontaneously in the field (for example in mown verge grass), the process referred to here is controlled composting. It is often carried out with forced ventilation (through a ventilator) in a container, hall or in the open air. [2]

The aim of composting is to produce a final product that is stable, free of pathogens and germinable weed seeds. The composting process proceeds through three phases: i) mesophilic 10-45°C, ii) thermophilic 45-70°C and iii) maturation (curing). [3]

As composting is a kind of biological combustion process, heat is emitted which can also be used. The heat also causes water to evaporate and the material becomes drier, and many pathogens and seeds of weeds are exterminated due to the high temperature (70°C). The process takes a few weeks. [2]

C. Product(s)

Product Name(s)

Compost is the most important product. It is the material that has not been converted during the composting process, for example minerals and organic material that is difficult to break down, such as certain fractions of lignocellulose (pieces of woody material) and humic acids produced during the process. Compost can be used as a soil improver both in structure and nutritional qualities for arable farming and horticulture. Certain types of compost can be used as a growth substrate for mushroom cultivation. A second product is ***heat*** but it is only utilized by a minority of composting businesses. Some businesses have even allocated a new use to the condensed water produced by the evaporation. [2, 3, 4]

D. References[1]

[1] Platt et al., 2021.

[2] Groenestijn et al., 2019.

[3] MainstreamBIO, 2023. Catalogue best practices nutrient recycling. Manure composting/ hygienation.

[4] Annevelink et al., 2016.

[1] See Chapter 7 Literature for the full description of some of the references used in Annex B.

B2. Anaerobic digestion

A. Potential Feedstock

Categories

Secondary biomass: Residues from livestock production; Residues from nature and landscape management; Residues from food industry; Other organic residues

Examples

Many raw materials are suitable for anaerobic digestion such as vegetable, fruit and garden waste (SSO, Source Separated Organics), fresh cattle manure, poultry manure, sludge from sewage treatment plants, verge grass, other grass types, grass juice, agricultural residues, residue streams from the food industry, swill (mainly kitchen waste and food scraps), expired food, marc and other by-products of distillery process, and industrial wastewater with high concentrations of organic substances. Manure is often processed together with corn, grass or another co-substrate during a co-fermentation process to obtain a higher biogas yield with the same reactor volume. [2, 4]

B. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

Anaerobic digestion is a series of biological process in which micro-organisms break down organic material under oxygen-free conditions. This usually refers to methane fermentation in which the final product is biogas, a mixture of methane and carbon dioxide. Anaerobic digestion therefore is a form of fermentation. The recalcitrant part remains and is called digestate. The process takes place in stirred and heated reactors, often with a volume of more than 1,000 m^3, and the conversion of solid organic substances into biogas usually takes one month. [1, 2, 4]

There are mainly two different methods for digestion shortly**,** ***mono- and co-digestion***. With mono-digestion, manure (e.g. cattle or pig) is the sole input stream into the digester. Co-digestion is the digestion of both manure in combination with other input streams like crop residues or grass. In both systems, the aim is to produce biogas. Typical composition of biogas is 60% methane (CH_4), 35% carbon dioxide (CO_2), 5% other gasses, such as hydrogen sulphide (H_2S), ammonia (NH_3) and others. Biogas can be used to produce energy by burning it directly (heat) or in a combined heat and power device (heat and electricity combined). Digestate can be used as fertilizer since it contains nutrients such as N, P and K. Digestion of manure has a positive environmental effect. [3]

There are basically two subtypes of digestion (next to the already mentioned main types, co- and mono-digestion): namely ***wet and dry digestion***. Wet digestion means that a big basin with a stirring mechanism (mixing the slurry) is filled with a liquid mixture. Dry digestion is suitable for fibrous/stalky materials, that are difficult to digest in a slurry. An example of a feedstock suitable for dry digestion is grass or straw. Dry digestion is done by an airtight device/container with a sprinkler in the roof. Biomass is placed on the floor and liquid (e.g. manure) is sprayed over the biomass. The liquid seeps through the biomass to the floor, which is permeable for the liquid. In the floor, the liquid is collected and pumped to the sprinklers again. Most common in the market are wet digestors and these are widely commercially available. Dry digestors are less popular market and mainly used for digestion of SSO. [3]

Most digestors are ***mesophile digestors***, that run on temperatures between 37°C and 40°C. In these digestors the manure is kept for about 15 to 40 days. There are also ***thermophile digestors***, that are kept at a temperature of around 55°C. In these digestors the substrate is kept for about 10 to 20 days. The time that the substrate is kept in a digestor is depending on the rate of the digestion process and on the composition of the substrate that is digested. [3]

C. Product(s)

Product Name(s)

Biogas (60% methane (CH_4), 35% carbon dioxide (CO_2), 5% other gasses, such as hydrogen sulphide (H_2S), NH_3 and others) is the primary product. The biogas can be used in a combined heat and power plant (CHP) for the production of electricity and heat. It can also be upgraded to Bio-LNG (see technology B2b). The by-product of anaerobic digestion is ***digestate*** that still contains unfermented organic material, water and minerals (including phosphate and ammonia). In SSO digestion, the digestate is composted and in manure digestion the digestate is usually used to fertilise agricultural land. [1, 2]

D. References

[1] Platt et al., 2021.

[2] Groenestijn et al., 2019.

[3] MainstreamBIO, 2023. Catalogue best practices nutrient recycling. Anaerobic digestion WR.

[4] IEA Bioenergy Task 37 Energy from Biogas, https://task37.ieabioenergy.com/

B2b. Upgrading biogas

A. Potential Feedstock

Categories

Platform: Biogas

Examples

Biogas. [1, 2]

B. Technology

Technology Name

Upgrading biogas

TRL

9

Description of Technology

As mentioned the typical composition of ***biogas*** is 60% methane, 35% carbon dioxide, 5% other gasses, such as hydrogen sulphide, ammonia and others. It is also saturated with moisture. Biogas as such is not suitable for grid purposes (such as in the Netherlands). Therefore, the biogas has to be upgraded to grid gas quality, i.e. biogas can be further upgraded to a quality similar to that of natural gas with 90% methane and 10% nitrogen, dry and with almost no hydrogen sulphide and ammonia. During the upgrading process all contaminations are filtered from the biogas and it is dried. Also almost all of the carbon dioxide is selectively extracted. This purified biogas is called ***green gas*** and can be injected into the natural gas grid. Alternatively, the purified gas can be compressed and put in bottles. That is bio-CNG (compressed natural gas).

A further route can be to liquefy the green gas to ***Bio-LNG*** and to use this as transport fuel. LNG stands for liquefied natural gas. Bio-LNG can be produced by cooling to -162°C in order to make the gas liquid, although some processes liquefy at -120°C. LNG is stored in well insulated vessels. Because any vessel will inevitably 'leach' heat from the environment to the liquid LNG, the LNG will slowly evaporate. This is not an issue as long as the evaporation rate is low compared to the consumption rate. However, storage over a longer time without consumption, will lead to considerable losses. Consequently, LNG is more suitable for trucks and coaches than for passenger cars. [1, 2]

C. Product(s)

Product Name(s)

Green gas that can be injected in the natural gas grid or ***Bio-LNG*** that is suitable for road transport, in particular for trucks and coaches. [1]

Funded by the European Union

D. References

[1] Annevelink et al., 2016.
[2] MainstreamBIO, 2023. Catalogue best practices nutrient recycling. Anaerobic digestion WR.

B3. Fermentation

A. Potential Feedstock

Categories

Primary biomass: Sugar crops; Starch crops

Secondary biomass: Residues from agriculture

Examples

The most important raw material, called substrate in fermentation science, consists of fermentable sugars: monosaccharides (such as glucose) and disaccharides (such as sucrose, or sugar crystalline).

These can be directly extracted from sugar cane and sugar beet and are present in molasses.

Alternatively, fermentable sugars can be produced from starch (by enzymatic hydrolysis). A wide range of biomass types can be used as a source of starch such as corn, wheat and barley.

In addition, fermentable sugars can be produced from cellulose or lignocellulose as well. Biomass that contain these compounds are for example corn stover, straw, grass, leaves and wood chips. Lignocellulose needs to be pre-treated to make it accessible to hydrolytic enzymes. Such pre-treatment may be carried out using high temperatures, acids, alkali, solvents and/or mechanical disruption of the fibres. Cellulose and hemicellulose needs to be enzymatically hydrolysed into (fermentable) monosaccharides.

As it is economically beneficial to achieve high product concentrations in a fermentation process, the raw material may not be diluted too much with water. The raw material should preferably contain more than 25% of dry matter, which means that vegetables, fruit, juices and wastewater are less suitable.

Raw materials with high carbohydrate content are the most frequently used. Other types of raw materials, such as organic acids, proteins, amino acids, alcohols, fats and glycerol, can also be used in fermentation processes, which enlarges the eligible categories of biomass. Completely different products can be created from these raw materials. Raw materials that contain organic acids e.g. are biologically acidified organic waste and sewage sludge. Protein containing sources maybe press cakes of oil seeds or food products. An important source of glycerol is the production of fatty acids methyl esters (biodiesel) from vegetable oil; glycerol is a by-product. [2, 3]

B. Technology

Technology Name

Fermentation

TRL

9

Description of Technology

Fermentation is a process in which micro-organisms (bacteria, yeasts, moulds) are used to convert organic material into a wide range of organic compounds such as alcohols, organic acids, hydrogen and carbon dioxide. Although fermentation is sometimes defined as conversion under oxygen-free conditions (anaerobic), the definition is often broadened to include processes that need oxygen (aerobic). The processes used in the chemical and energy sectors are often carried out in a stirred reactor vessel (fermenter) with a liquid that usually contains carbohydrates, but sometimes organic acids as well. The substrate and the fermenter need to be sterilised regularly in order to work with one type of micro-organism in the form of a pure culture. [1, 2]

Large-scale industrial fermentation processes - like for the production of bioethanol, lactic acid and succinic acid - use starch or sugar as a feedstock. In Europe, these raw materials are extracted from crops like corn and sugar beets.

Another source for fermentable sugars may be lignocellulose (waste) streams. These contain polysaccharides likes cellulose and hemicellulose, which are built in the lignocellulose complex. There are several different routes to extract fermentable sugars from the lignocellulose complex. In order to produce fermentable sugars (mono saccharides) from such feedstocks, the lignocellulose complex needs to be destabilised in order to make the polysaccharides available and allow hydrolysis into the sugars. Large-scale installations are needed for this. The routes include (subsequent) combination of (strong or weak) acid or alkaline conditions, elevated or high temperature, use of super-heated steam, fungi and enzymes. Most often the sugars are separated in an aqueous solution and the lignin fraction is removed in the solid residue. [3]

C. Product(s)

Product Name(s)

Important products in the energy carrier category are ***ethanol, butanol, isobutanol*** (all three are liquid transport fuels) and ***hydrogen gas***. In the category Chemicals lactic acid, a building block for the bioplastic polylactic acid, is important as well as ***polyhydroxyalkanoate (PHA)***, a bioplastic which accumulates in the form of granules in bacteria cells. The trend suggests that the fermentation products ***succinic acid, itaconic acid and other dicarboxylic acids*** are becoming increasingly important due to their suitability for the production of bioplastics. Apart from an application in energy and chemicals, fermentation is a process that is known for its use in the production of beer, wine, bread, baker's yeast, citric acid, antibiotics, enzymes and amino acids. [2]

D. References

[1] Platt et al., 2021.

[2] Groenestijn et al., 2019.

[3] Annevelink et al., 2016.

B4. Insect-based bioconversion

A. Potential Feedstock

Categories

Secondary biomass: Residues from agriculture; Other organic residues

Examples

Possible feedstocks include organic agricultural residues (e.g. vegetable and fruit) and food residues (e.g. bread & rolls losses).

B. Technology

Technology Name

Insect-based bioconversion

TRL

7-8

Description of Technology

Insect-based bioconversion also known as insect farming is based on the selection of insect species e.g. Black Soldier Fly (BSF) larvae, house fly maggots, mealworms, and grasshoppers-crickets and different rearing substrates. The main benefits of this conversion process are reduction of waste by producing high quality protein (mainly for animal feed) and the extraction of products such as oil, natural fertilizer and chitin. [1]

Black soldier fly larvae are grown in crates on rack cupboards and fed with agricultural and food residue streams. Technology is simply scalable to the amounts of vegetable residue streams available, whether smaller or larger quantities. Larvae are harvested, dried & used as feed (when grown on GMP+ food safety assured side streams) or further refined to a protein rich fraction and lipids. Larvae and protein fraction contain essential amino acids which are low in feeds produced from plants. During harvesting the insects are sieved out of their remaining feed medium, the fine fraction (left-overs, debris, etc.) is sold as fertilizer (compost). Also the substrate residue (skins of worms) remaining after pressing of the worms can be used as fertilizer. [2]

C. Product(s)

Product Name(s)

The product is black soldier fly larvae that contain proteins (insect based) and fat (insect based), which contains unsaturated fatty acids. Furthermore, organic fertilizer. [2, 3]

D. References

[1] Platt et al., 2021.
[2] Power4Bio Catalogue - Bestico factsheet.
[3] Power4Bio Catalogue - Madebymade factsheet.

B5a. Mushroom cultivation

A. Potential Feedstock

Categories

Secondary biomass: Residues from agriculture; Residues from forestry and forest-based industry; Other organic residues

Examples

Various feedstocks can be used like coffee grounds, wheat straw, horse manure, other pasteurized/ sterilized cellulosic materials, crop stalk and Alfalfa residues. [1, 2]

B. Technology

Technology Name

Cultivation

TRL

9

Description of Technology

The production system consists of multiple technology steps: chopping and composting straw, solid-state fermentation, mixing other feedstocks with straw and lime, inoculating the feedstock mix with mushroom spawn and putting the mixture on growing beds or in growing bags. Different types of inoculants can be applied that have different growing characteristics. The mixture is incubated at 20-24 °C in the dark for 2-3 weeks, during which white mycelium is formed. To produce the mushroom the mixture is placed under fruiting conditions (with indirect light). The mushrooms are harvested after a 5-8 weeks growing period. The moisture content of the feedstock has to be under 14% otherwise the storage can be problematic due to heating. [1, 2]

C. Product(s)

Product Name(s)

Mushrooms and spent mushroom substrate. Besides this mushroom substrate (straw-based growth substrate inoculated with mushroom spawn) can also be a separate product. [1, 2]

D. References

[1] Power4Bio Catalogue - Rotterzwam factsheet.

[2] Power4Bio Catalogue - Pilze-Nagy factsheet.

B5b. Algae cultivation

A. Potential Feedstock

Categories

Secondary biomass: Residues from livestock production

Examples

The liquid fraction of cattle manure, digestate from anaerobic digestion.

B. Technology

Technology Name

Cultivation

TRL

9

Description of Technology

Algae can be grown on the liquid fraction of cattle manure or on digestate from anaerobic digestion. In these feed streams there are (still) nutrients and sugars, which can be used by the algae. These nutrients and sugars are valuable so that retrieving them is worthwhile. Thereby, the amount of waste is reduced. Some algae species are on the lists of approved animal feeds. However, there can be still a problem with the legislation within Europe, in case particles of the manure are harvested together with the algae. [1]

Algae can be grown in multiple ways. A two phase reactor is one of the possibilities already used on a small pilot scale, where digestate is used as a nutrient source in the culture. The liquid fraction of cattle manure or digestate is used as substrate. In the first phase algae are grown phototrophic autotrophically. Light is used as an energy source, CO_2 is used as carbon source and nutrients (mainly nitrogen (N) and phosphorous (P)) are used to grow algae. After this phase the algae are concentrated using membrane technology. During the second phase the algae are grown mixotrophically. During this phase microalgae use CO_2 as well as organic carbon sources in the presence of light to increase the biomass. During this phase, only a small percentage of the medium is digestate, around 2%. The difficulty with digestate is it's dark colour. When algae are grown in tubular closed loop reactors in the presence of light, a medium which is too dark will block the light. Filtration of the digestate or a different cultivation method could be a possible solution for this problem. The digestate could also be diluted. [1]

C. Product(s)

Product Name(s)

Protein rich algae (50% proteins). [1]

D. References

[1] MainstreamBIO, 2023. Catalogue best practices nutrient recycling. Algae cultivation.

B6. Blending or mixing

A. Potential Feedstock

Categories

Primary biomass: Lignocellulosic from cropland

Secondary biomass: Residues from agriculture; Residues from nature and landscape management

Examples

Feedstocks for insulation can be e.g. hemp hurds, hemp fibres, fibrous residues and straw. [2]

B. Technology

Technology Name

Blending or mixing

TRL

9

Description of Technology

Blending or mixing is used to modify the specification of biomass streams for different purposes. For instance blending feedstocks in order to meet required emission, or to minimize ash production during power generation or in the animal feed industry, when a variety of feedstocks are blended to meet the desired nutritional requirements for a specific animal. Another output of blending or mixing can be building materials, e.g. the mixture of semi-structural lignocellulosic fibre and inorganic mortal can be cast in the wood timber frame construction of a house to provide insulating walls, or it can be sprayed. Also, fibrous feedstock can be blended with polymers to provide feedstock for e.g. profile extruded decking, siding and fencing or for injection moulding products. [1, 2]

C. Product(s)

Product Name(s)

Blended feedstock, e.g. improved feedstocks for combustion, animal feed, insulation materials, etc. [1, 2]

D. References

[1] Platt et al., 2021.

[2] Power4Bio Catalogue - Hempire factsheet.

B7. Extraction & separation processes

A. Potential Feedstock

Categories

Secondary biomass: Residues from food industry.

Examples

Feedstocks can include juice pressing residue (pits, seeds, pulp, grape lees, peel) and vegetables. [2]. Other examples are olive pomace, olive leaves and olive stones. [3]

B. Technology

Technology Name

Extraction & separation processes

TRL

8-9

Description of Technology

Extraction is a recovery and purification technology. It includes liquid-liquid extraction and solid-solid extraction. Impurities or valuable compounds are extracted and /or concentrated from a bulk phase by using a solvent that has an affinity with desired compound. This technology is often used with compounds that have a higher boiling point than water, resulting in lower energy requirement than distillation. [1]

Separation is an important process for the conversion of biomass into components for use in chemicals, energy and materials. An example of a liquid-liquid separation process is distillation. Liquid-solid separation includes evaporation and membrane separation. And dissolved-liquid separation includes crystallization, filtration and membrane separation. Other methods are screening to separate particle sizes and influencing the density by using a cyclone or sink-float.

Certain target components often need to be extracted from a solution containing compounds, and be further purified. An example is the distillation of ethanol from a fermentation liquid. The separation of solid substances and liquids, such as pressing oil from seeds, extracting substances from biomass, such as minerals, and separating particles of solid substance (sieving) is also regularly used in production processes. [1, 4]

Mechanical solid-liquid separation includes various technologies, using a screw press, belt press, centrifuge, grid, sieves filters, or a screener. Separators are efficient in producing a solid fraction with high dry matter content on a relatively cost-effective basis. During slurry or digestate separation, solids, and liquids are mechanically separated into a ***liquid and a solid fraction***. [5]

Fibre Separation is the process of separation of fibres from non-fibrous cellular tissues and the woody part of the stem through dissolution and decomposition of pectins, gums and other mucilaginous substance. The process may employ e.g. bacteria and moisture to dissolve or rot away the cellular tissues and other substances surrounding bast-fibre bundles, through their enzymatic action loosens the fibre strands and facilitates the separation of the fibre from the stem. The fibres are then mechanically extracted, washed, dried and marketed and the whole process is known as retting. Improper retting may lead to bad or inferior quality of fibre in spite of good crop. [1]

C. Product(s)

Product Name(s)

Anti-oxidants, colorants, food additives, food supplements, dietary fibre. Feed may be obtained as a by-product. [2, 3]

D. References

[1] Platt et al., 2021.

[2] Power4Bio Catalogue - EcoTreasures factsheet.

[3] Power4Bio Catalogue - Natac factsheet.

[4] Groenestijn et al., 2019.

[5] MainstreamBIO, 2023. Catalogue best practices nutrient recycling. Mechanical solid-liquid separation.

B8. Mechanical and thermomechanical disruption & fractionation

A. Potential Feedstock

Categories

Secondary biomass: Residues from agriculture; Residues from forestry and forest-based industry; Residues from nature and landscape management.

Examples

Examples of feedstocks are meadow grass and agricultural residues like tomato stalks and cereal straw. [2, 3]

B. Technology

Technology Name

Mechanical and thermomechanical disruption & fractionation

TRL

9

Description of Technology

Mechanical and thermomechanical disruption & fractionation are processes to modify the shape, particle size, bulk density and/or moisture of biomass. These processes use (thermo)mechanical energy to separate the raw material into e.g. a liquid fraction and a solids fraction, or to refine fibrous feedstock into finer fibres/particles. [1]

By choosing the temperature, intensity and type of mechanical disruption the separation between the solid and liquid fraction can be influenced with regard to efficiency and selectivity for different components. [3]

C. Product(s)

Product Name(s)

Fibres for feed, protein, organic acids and mineral containing juices, for pig feed and fertiliser. Insulation materials, fibre reinforced composites. [2, 3]

D. References

[1] Platt et al., 2021.

[2] Power4Bio Catalogue - Biowert factsheet.

[3] Keijsers, E., 2023. Personal communication.

B9. Mechanical pulping

A. Potential Feedstock

Categories

Secondary biomass: Residues from agriculture; Residues from forestry and forest-based industry; Residues from nature and landscape management.

Examples

Grass and hay for moulded fibre egg boxes, tomato and bell pepper stalks for paper, sugar beet pulp for paper.

B. Technology

Technology Name

Mechanical pulping

TRL

9

Description of Technology

Mechanical pulping is the process to open up the fibrous structure of plants or wood by grinding or refining. It frees fibre bundles, (partly) creating single fibres and fibril structures. The process is optimised to create a fibrous stream that fits into a fibre web, e.g. for board material, moulded fibre or paper. [1]

Mechanical refining (patented process), without using heat or chemicals, into 'self-binding' micro and nano fibrillated fibcro® natural fibres . No components are extracted. The fibres are mixed with water and stirred into a pulp. The pulp is then pressed into shape (tableware or packaging material) and hot- pressed using bio-heat. The process requires 3.5 litres of water per 1 kg of product . [2]

C. Product(s)

Product Name(s)

Fibres for the production of moulded fibre products, paper and fibre board materials.

D. References

[1] Keijsers, E., 2023. Personal communication

[2] Power4Bio Catalogue - Bio-Lutions factsheet.

B10. Combustion

A. Potential Feedstock

Categories

Secondary biomass: Residues from agriculture; Residues from forestry and forest-based industry; Residues from nature and landscape management.

Examples

The most suitable biomass for combustion contains hardly any water and minerals. Combustion could use e.g. biomass pellets with a low mineral content, such as wood pellets. Apart from wood pellets, pellets made from straw-like biomass can also be used. Furthermore, straw, lignin, paper slurry, agricultural residues and chicken manure can also be combusted. [2]

Different biomass types have various burning tendencies and degradation patterns, and they release varying amounts of energy depending on the kind of biomass and its content. Materials high in hydrogen and carbon make good combustion fuels. In an ideal world, all hydrogen and carbon would split off and react with oxygen in the air to form water vapor, carbon dioxide, and heat. Biomass is divided into three major components: cellulose, hemicellulose, and lignin, as well as three minor components: proteins, sugars and aliphatic acids, and lipids. They have various burning tendencies and degradation patterns, and they release different amounts of energy depending on the kind of biomass and its content. [3]

Heterogeneous biomass is often wet and contains relatively many components that cause problems in the incinerators (potassium (K), chloride (Cl) and protein). Therefore, combustion of heterogeneous biomass is usually not preferred. It is often part of organic fraction of Municipal Solid Waste (MSW), and for example in the Netherlands is burned in waste incinerator plants which included very advanced flue gas clean-up systems. [4]

B. Technology

Technology Name

Combustion

TRL

9

Description of Technology

Combustion is a chemical reaction of a fuel in presence of an oxidizer (commonly oxygen) and heat. The fuel and the oxidizer exothermally react together to form new chemical substances, often gaseous products. [1, 5]

During combustion the biomass reacts with an oxygen surplus, and carbon dioxide, water and ash are primarily produced. Heat is released in this process, which can be used to produce steam that drives a steam turbine to produce electricity. Also efficient co-production of power and heat can be applied by using so called CHP-plants (part of the heat is used to produce power, the other part for

Funded by the European Union

producing heat). Depending on the technology installed, biomass can be used on its own as fuel. Biomass is also additionally used in boilers in which steam, hot water or only heat are produced for purposes other than the production of electricity. Households use biomass for fireplaces and barbecues. [2, 5]

The choice of the right type of reactor for a specific type of feedstock – resulting in the right combustion environment – is very important for high-efficient and complete combustion of the feedstock. In various types of combustion reactors, biomass is burnt to be transformed into usable heat energy. What remains are a variety of gases, pieces of partly oxidized hydrocarbons, and water vapor. During combustion, the biomass loses moisture initially at temperatures of up to 100°C, utilizing heat from other particles that release their heat value. [3]

Although there are several combustion methods available, the basic idea of biomass combustion is the same for all. The combustion process is divided into three stages which can occur simultaneously within a fire:

- ***Drying*** - All biomass contains moisture, which must be removed before burning can occur. The heat for drying is supplied by radiation from flames and heat stored in the combustion unit's body.
- ***Pyrolysis*** - The volatile gases are generated when the temperature of the dry biomass rises between 200°C and 350°C. Carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and high molecular weight compounds (tar) are pyrolysis products that condense to liquid when cooled. These gases react with the oxygen in the air to produce a yellow flame. The heat from the burning gases is utilized to dry the fresh fuel and release additional volatile gases, making this process self-sustaining. To keep this stage of the combustion process going, oxygen must be supplied. Char is the substance that remains after all of the volatiles have been burnt away.
- ***Oxidation*** - The char oxidizes or burns at around 800°C. Again, oxygen is required, both at the fire bed for carbon oxidation and above the fire bed, where it combines with carbon monoxide to generate carbon dioxide, which is released into the atmosphere. A long residence time for fuel in a combustor allows for complete consumption of the fuel. [3].

C. Product(s)

Product Name(s)

Heat is the primary product of combustion and it can be used in various ways. The heat can be (partially) converted into ***electricity***. Heat can also be used for heating of industrial processes or homes. Usually, not all the heat can be deposited in this way because the demand (especially from households) varies greatly in the seasons. The heat demand is often setting the framework for the capacity of an overall CHP-plant, the remaining heat is used then for power production. In this way all combustion energy can be used optimising overall system efficiency. [2, 4]

Combustion ash, which has a high mineral content, is also produced. The chemical composition of biomass combustion ash varies depending on biomass qualities and incineration settings. The ash is often disposed of in landfills or piles. The ash from biomass combustion could also be employed in applications such as agriculture, land remediation, environmental protection, zeolite synthesis, rare earth metal recovery, and plastic manufacture. However, its use is dependent on the physicochemical properties of the ash itself. E.g. chicken manure combustion ash produces a high added-value fertiliser. [2, 3]

Flue gases form another 'product' and depending on the scale of the technology and the environmental constraints applicable, flue-gas scrubbing must be carried out before allowing these gases to be discharged into the atmosphere. [2]

D. References

[1] Platt et al., 2021.

[2] Groenestijn et al., 2019.

[3] MainstreamBIO, 2023. Catalogue best practices nutrient recycling. Combustion.

[4] Annevelink et al., 2016.

[5] IEA Bioenergy Task 32 Biomass Combustion, https://task32.ieabioenergy.com/

B11. Gasification

A. Potential Feedstock

Categories

Secondary biomass: Residues from agriculture; Residues from forestry and forest-based industry; Residues from livestock production; Residues from food production

Primary biomass: Lignocellulosic wood/forestry

Examples

Gasification is suitable for relatively dry biomass streams (>85 % dry matter), often woody biomass. This could also be demolition wood as experience has shown, but also solid biomass waste streams from wineries, breweries, cotton ginning and rice industries, seed-oil mills (olive, sunflower, cotton etc.), chicken farms (manure) and fruit processing units (jam, juice production). [2, 3, 4]

B. Technology

Technology Name

Gasification.

TRL

8

Description of Technology

During ***gasification*** biomass is converted at high temperatures (more than 600°C) with a sub-stoichiometric amount of oxygen (or air) into combustible product gas that mainly contains carbon dioxide (CO_2), carbon monoxide (CO), hydrogen (H_2), methane, water (H_2O) and nitrogen (N_2). In direct gasifiers the biomass is in direct contact with oxygen/air to produce the heat needed, whereas in indirect gasifiers the heat is produced indirectly in a parallel reactor. Indirect gasifiers produce a product gas with relatively high amounts of CH_4. Depending on the use of the product gas, it is called ***fuel gas*** in case will be used for energy (power and/or heat) applications, and ***syngas*** in case it will be used for the often catalytically supported synthesis of bio-based products (transport fuels, chemicals). [1, 2, 5]

The product gas contains contaminants related to the feedstock type like, for example hydrochloric acid, ammonia and hydrogen sulphide. For use as ***fuel gas*** it has to be cleaned to remove gas contaminants before secondary conversion in a prime mover (gas engine, gas turbine, CHP-unit) to both protect these apparatus from damage and to meet the applicable flue gas emission constraints. ***Syngas*** also has to be cleaned before further conversion via often catalytical downstream processes. Using catalytic processes requires even more stringent gas clean-up to prevent catalyst poisoning, i.e. deactivation. Product gas clean-up can take place with dry systems at relatively high-temperature or with wet so called scrubbing systems operating at lower temperatures. [1, 2, 5]

Although the above ***fuel gas*** is the primary product, it needs to go through other conversion processes in order to make it into a usable product. The fuel gas can be burned directly to generate electricity. The gas can also be used to co-fire in an (existing) boiler to produce steam and / or electricity. In these applications, gasification is a first step in a combustion process. Gasification however, offers some additional features where the chemical constituents of the ***syngas*** are used. Gasification then supplies a syngas with chemical building blocks that can be used as a starting point to manufacture fertilizers, pure hydrogen, methane, liquid transportation fuels such gasoline and diesel and/or chemicals and chemical building blocks for polymers/plastics. [1, 4, 5]

Biomass gasification couples the possibility of co-producing heat, electricity and biochar by valuably utilizing agricultural solid waste streams. Gasification ***biochar*** contains a considerable amount of minerals and recalcitrant carbon and is considered as an attractive product for soil amendment due to its fertilizer and carbon sequestration potential. The application of biochar improves soil fertility through two mechanisms: adding nutrients to the soil (such as K, to a limited extent P, and many micronutrients) or retaining nutrients from other sources, including nutrients from the soil itself. Its addition increases soil pH, electric conductivity, organic matter and total nitrogen. [3, 5]

C. Product(s)

Product Name(s)

The product gas can be used directly, after purification, as ***fuel gas*** for engines and gas turbines for ***electricity and heat*** generation.

Syngas (mainly hydrogen and carbon monoxide) can be used to synthesise ***chemicals***. The most common process is methanization, in which hydrogen gas and carbon monoxide are converted into gas with a high methane content. The gas produced is called ***Synthetic Natural Gas (SNG)***, which can be injected into the natural gas grid after purification and/or upgraded to Liquified Natural Gas (LNG) for storage and/or use as transport fuel.

Syngas can also be used to synthesise methanol, ethanol and dimethyl ether (DME). The Fischer-Tropsch process (large-scale) can be used to convert the gas into ***liquid hydrocarbons*** (usually alkanes). ***Methanol and ethanol*** can also be produced by variants of this process.

All the material that is not converted into gas ends up in a remaining fraction called ***biochar***, which has properties similar to activated carbon, and can be used as a soil enricher or as a fuel for heating the gasifier. [2, 3]

D. References

[1] Platt et al., 2021.

[2] Groenestijn et al., 2019.

[3] MainstreamBIO, 2023. Catalogue best practices nutrient recycling. Gasification.

[4] Annevelink et al., 2016.

[5] IEA Bioenergy Task Gasification of Biomass and Waste, http://task33.ieabioenergy.com/

B12. Hydrothermal liquefaction (HTL)

A. Potential Feedstock

Categories

Secondary biomass: Residues from agriculture; Residues from forestry and forest-based industry; Residues from nature and landscape management; Other organic residues

Examples

The process can handle a diverse range of biomass, including garbage, waste from agriculture, black liquor, lignin, sawdust, sludge and wood. These streams do not have to be dry. The optimal moisture content is 25-30%. [2]

B. Technology

Technology Name

Hydrothermal liquefaction (HTL)

TRL

7-8

Description of Technology

Hydrothermal liquefaction (HTL) is a process to increase the energy content of wet organic containing streams. Through this process biomass can be converted into a heavy oil (biocrude) product (similar to heavy fuel oil) without drying the biomass. HTL takes place at a pressure of 120-180 bar and a temperature of 300-350ºC. By hydro-deoxygenation a large portion of the oxygen in the biomass is released in the form of CO_2, allowing the biomass to get a higher energy density than the original biomass. The biomass also becomes fluid. [1, 2, 3]

C. Product(s)

Product Name(s)

The ***biocrude*** is a heavy organic liquid that solidifies at 80ºC and that is immiscible with water. It has an oxygen content of 10% - 18%, and a lower heating value (LHV) of 30-35 MJ/kg, which is almost double the LHV of a typical biomass feedstock. In addition to the biocrude a gas arises (> 90% CO_2, remainder CO), and also an aqueous phase containing dissolved organic substances such as acetic acid and ethanol.

Through the hydrogenation of the biocrude at large-scale conversion plants, products like diesel, kerosene, or other (chemical) end-products can be made. [2]

D. References

[1] Platt et al., 2021.

[2] Annevelink et al., 2016.

[3] IEA Bioenergy Task 34 Direct Thermochemical Liquefaction, https://task34.ieabioenergy.com/

B13. Pyrolysis

A. Potential Feedstock

Categories

Secondary biomass: Residues from forestry and forest-based industry; Residues from agriculture

Examples

While pyrolysis can be carried out with a wide range of biomass types, the products, and in turn the raw materials, must meet certain requirements. From an economic perspective, residue streams such as agricultural waste, pruning wood and verge grass are the most attractive feedstocks for pyrolysis. However, the high mineral content in these types of biomass makes the pyrolysis oil unsuitable for use as fuel, but it could perhaps be used in the future as a source for the extraction of chemicals. The biomass preferably does not contain too much water (less than 10%). Dried wood, dried manure, straw, olive residues and dried sludge have been tested or specified. [2, 3, 4]

B. Technology

Technology Name

Pyrolysis

TRL

8-9

Description of Technology

In the ***pyrolysis*** process the biomass is thermally cracked at temperatures between 400°C and 600°C in an oxygen-free environment. It is always also the first step in combustion and gasification processes, where it is followed by total or partial oxidation of the products. Pyrolysis converts biomass into a solid product (char), condensable vapours (bio-oil) and gases (e.g. CO_2, CO, CH_4, H_2 etc.). Primarily, the interaction between pyrolysis temperature and residence time influences the yield distribution and quality characteristics of these products.

There are roughly three different types of pyrolysis with a different ratio of the three products: slow pyrolysis (mainly char), intermediate pyrolysis (both char and pyrolysis oil at an intermediate vapour residence time of 20 seconds) and fast pyrolysis (mainly pyrolysis oil at a fast vapour residence time of 2 seconds). Torrefaction (with a solids residence time of 30 minutes) and carbonisation (with a solids residence time of hours) are slow forms of pyrolysis and will be described as technology B14.

In the ***fast pyrolysis*** process at 500°C around 75% of the biomass is converted into bio-oil and the remainder into biochar (12%) and gas (13%). Fast pyrolysis does justice to its name because the process takes no more than two seconds. First the feedstock needs to be dried to a moisture content of 10% or less in order to minimize the water in the product liquid oil. Then grinding of the feedstock is needed (to around 2 mm in the case of fluid bed reactors) to give sufficiently small particles to ensure rapid reaction in the pyrolysis reactor. The process is usually carried out in a fluidised bed reactor and does not need to operate under pressure. Pyrolysis oil has an energy density which is up to 4 to 20 times higher than the solid biomass. The pyrolysis oil contains a wealth of valuable chemicals that can be extracted theoretically through biorefining (see technology description B7).

Furthermore, often a system is added to combust the produced gas and char to provide heat for the reactor or dryer or export. [1, 2, 3, 4]

C. Product(s)

Product Name(s)

The primary product of rapid pyrolysis is ***pyrolysis oil***, a mixture of hundreds of components containing aromatic compounds (such as phenol), sugar derivatives, organic acids (such as acetic acid), and other substances. Like petroleum, pyrolysis oil can be used as fuel and as a source for a naphtha-cracking process in which chemicals can be extracted. A disadvantage is the high oxygen content which limits the quantity that can be added to a cracker unit. The oil has a far higher density than the original biomass, which is more convenient for storage and transport purposes. The ***gas by-product*** is usually burned in order to generate process heat for the pyrolysis reactor, and the ***biochar*** is a solid carbonaceous residue and it is suitable as soil improver or as solid fuel. [2, 3]

D. References

[1] Platt et al., 2021.

[2] Groenestijn et al., 2019.

[3] Annevelink et al., 2016.

[4] IEA Bioenergy Task 34 Direct Thermochemical Liquefaction, https://task34.ieabioenergy.com/

B14. Torrefaction & Carbonization

A. Potential Feedstock

Categories

Secondary biomass: Residues from forestry and forest-based industry; Residues from agriculture.

Examples

In principle, torrefaction & carbonization can be applied to many biomass types, but considerable experience has been gained primarily with wood and forestry residues. However, also sewage sludges, agricultural residues, food residues and the organic fraction (urban solid wastes) have been used. [2, 3]

B. Technology

Technology Name

Torrefaction & Carbonization

TRL

9

Description of Technology

Torrefaction and **carbonization** are slow forms of pyrolysis (see description B13). Torrefaction & carbonization are thermal processes to convert biomass into a coallike material, with higher energy density and hydrophobic characteristics compared to the original biomass.

Torrefaction (with a solids residence time of 30 minutes) involves breaking down biomass at a temperature of 290°C in an oxygen-free environment. During this process the biomass is dried and converted into solid substances, while gases are also produced. The gases are used to supply energy for the process. The process can be carried out in various reactors, such as rotating drums or band driers.

Carbonization (with a solids residence time of hours) involves breaking down biomass (e.g. wood) at a temperature above 280°C in the absence of oxygen . Carbonization continues until only the carbonised residue called charcoal remains. Unless further external heat is provided, the process stops and the temperature reaches a maximum of about 400 °C. This charcoal, however, will still contain appreciable amounts of tar residue, together with the ash of the original wood. [1, 2, 4]

C. Product(s)

Product Name(s)

The primary product of torrefaction is ***biocoal*** (black pellets), which is drier than the original raw material (wood), has a higher density, a seven times higher energy density, is more water-resistant and can withstand biodegradation. As a consequence, the advantages of the more coallike material over wood include improved retention (stability), and reduced storage and transportation costs. The

Funded by the European Union

material is suitable for gasification and co-firing in coal-fired power stations. The main product of carbonization is ***charcoal***. [2]

D. References

[1] Platt et al., 2021.

[2] Groenestijn et al., 2019.

[3] Power4Bio Catalogue - TerraNova factsheet.

[4] IEA Bioenergy Task 34 Direct Thermochemical Liquefaction, https://task34.ieabioenergy.com/

Annex C: Catalogue of business models that implement small-scale bio-based technologies

C1. Business models based on Aerobic conversion

C1.1 Poultry manure based AEROBIC CONVERSION producing fertilizers (Pindos)

A. General

Title

Poultry manure based AEROBIC CONVERSION producing fertilizers (Pindos)

Keywords

fertilizer, manure, poultry, broiler

Example user / provider of technology

https://www.pindos-apsi.gr/

Contact person

tech@pindos-apsi.gr, EO Artas Ioanninon, Ioannina 455 00 / Greece, +30 26510 57511

B. Feedstock

Main feedstock

Residues from livestock production

Potential other feedstock

Residues from aquatic biomass

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Aerobic conversion

TRL

9

Description of Technology

- Feedstock streams (dead poultry and broiler farm manure) are collected from the farms by dedicated personnel and transported by special vehicles to the company's treatment plants.
- The ashes of incinerated dead poultry are combined with broiler farm manure and other organic wastes.
- The mix undergoes aerobic digestion, becoming stable, high-quality, and safe to use as recyclable organic and biological solid fertilizer.
- Other Outputs: water vapor (from incinerating).

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- AGROSYN

Price, trade spot and location

-

E. Impact

Environmental Benefits

- Greenhouse Gas (GHG) reduction
- Climate change mitigation/adaptation
- Soil protection

Challenges for Implementation

-

Job Creation

800 job positions.

Socio - Economic

The produced fertilizer is sold to local farmers, mainly cereal producers. Said cereal can be implemented in the nutrition of poultry, ultimately impacting on the feed of the described technology.

F. References

[1] https://www.pindos-apsi.gr/

[2] COOPID Success case - Pindos

C1.2 Goat and sheep manure based AEROBIC CONVERSION producing fertilizers (Pedrín)

A. General

Title

Goat and sheep manure based AEROBIC CONVERSION producing fertilizers

Keywords

fertilizer, manure, goat, sheep

Example user / provider of technology

https://organicospedrin.com

Contact person

contacto@organicospedrin.com, Paraje "La Asomada", 20-358, 30550 Abarán, Murcia / Spain, +34 968 43 42 53

B. Feedstock

Main feedstock

Residues from livestock production

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Aerobic conversion

TRL

9

Description of Technology

- Manure from goat and sheep husbandry is fed into an aerobic digestor.
- The organic matter is subjected to high temperatures (> 70ºC).
- The obtained liquid fertilizer undergoes several quality controls to confirm it complies with the quality standards before being commercialized.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Organic fertilizer (Producto Líquido Natural Pedrín)

Price, trade spot and location

-

E. Impact

Environmental Benefits

- GHG reduction
- Climate change mitigation/adaptation
- Soil protection

Challenges for Implementation

-

Job Creation

16 job positions.

Socio - Economic

- Job generation
- Decent work conditions

F. References

[1] https://organicospedrin.com

[2] LIVERUR Global Database

[3] https://www.libertaddigital.com

C2. Business models based on Anaerobic digestion

C2.1 Grass juice and food residues based ANAEROBIC DIGESTION producing electricity (Biowert)

A. General

Title

Grass juice and food residues based ANAEROBIC DIGESTION producing electricity (Biowert)

Keywords

biogas, grass juice, food residues, electricity, heat, bioenergy

Example user / provider of technology

https://biowert.com/

Contact person

Vera Schwinn, v.schwinn@biowert.com, Ochsenwiesenweg 4, D-64395 Brensbach / Germany, +49 6161 806 630

B. Feedstock

Main feedstock

Food residues

Potential other feedstock

Grass juice

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- The biogas plant is mainly fed by food leftovers and fat, that are both partly hygienised or non-hygienised. The biogas plant is furthermore fed by grass juices as by-products from the biorefinery.
- Biogas is produced by anaerobic digestion and then converted into electrical energy and heat.
- Around 500 kg of nutrients can be supplied to the biogas process from one tonne of dry matter of grass processed in the biorefinery.
- At the end of the cycle, the process water is recovered from the substrate and a material with high nitrogen content is separated and used as an organic fertiliser (AgriFer).
- Other Input Materials: water

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

-

Investment Costs

8 million €

Operational Costs

Operating costs for the biogas plant are typical as per market standards, but combining the biorefinery and biogas plant allows for headcount synergies.

D. Product(s)

Product Name(s)

- Electrical energy
- Organic fertilizer (with high nitrogen content)

Price, trade spot and location

Electricity and heat prices are set by feed-in tariffs.

E. Impact

Environmental Benefits

- Environmentally friendly produced biogas, electricity and heat; waste reduction & producing green energy by utilising agricultural and food industrial wastes.
- Renewable energy replaces commercial fuels.
- Usage of commercial fossil resource-dependent fertilisers is reduced by applying AgriFer as biofertilizer.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

Social impacts can arise if facilities and industrial jobs are created in structurally weak regions, that usually are agricultural heavy. Public perception of the technology and its attractiveness for entrepreneurs in the bio-based industry lies in the circular economy model it represents, its low environmental impact and positive environmental effect by the reduction of fossil raw material consumption.

Biogas systems can support rural development and mitigate the negative effects of general economic fluctuations by local energy and fertiliser production; biogas drastically reduces the dependence of local communities on imported fuels and increases the local energy supply; farmers can get a new social function as energy producers or waste managers.

Standard work safety measures need to be applied.

F. References

[1] https://biowert.com/

[2] Larisa Lovrencec, 2010. Highlights of socio- economic impacts from biogas in 28 target regions. D.2.4. of IEE Project ‘BiogasIN’ (Contract No. IEE/09/848 SI2.558364)

[3] Power4Bio Catalogue - Biowert factsheet

C2.2 Cattle manure based ANAEROBIC DIGESTION producing biogas (HoSt)

A. General

Title

Cattle manure based ANAEROBIC DIGESTION producing biogas (HoSt)

Keywords

anaerobic digestion, manure, biogas, biomethane, small scale, natural gas, farm

Example user / provider of technology

https://www.bioenergyfarm.eu/en/

https://www.europeanbiogas.eu/

https://geniaglobal.com/en/

The provider of the technology is HoSt (https://www.host.nl))

Contact person

Host, Sjaak Klein Gunnewiek, info@host.nl, Thermen 10, 7521 PS Enschede, The Netherlands, +31 53 460 90 80

B. Feedstock

Main feedstock

Fresh cattle manure

Potential other feedstock

Sewage sludges, poultry manure, grass, cereal straw, agricultural residues

Required Feedstock Quality

Dry matter content typically 9 w-%

Feedstock price, trade spot and location

111 €/tonne dry matter in The Netherlands

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- The manure is anaerobically digested in the digester and converted into biogas (57 % v/ v CH_4).
- In the biogas upgrading system, it is upgraded to biomethane (green gas or renewable gas, 89 % v/v CH_4).
- Subsequently, the product gas with natural gas quality is fed directly into the natural gas network.
- In order to reduce the production costs, the company generates its own electrical energy and sells the surplus energy.
- One of the by-products of the process is biogas digestate. This material, being rich in nitrogen, is used as fertilizer by local farmers.
- Other Input Materials are heat and power.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

15,000 tonne/year

Investment Costs

0.239 million €

Operational Costs

-

D. Product(s)

Product Name(s)

- Biomethane
- A side product is digestate.

Price, trade spot and location

- Biomethane 130 €/MWh

E. Impact

Environmental Benefits

Less chemical fertilizers. GHG emissions can be reduced when shifting from natural gas to green gas. Methane emissions from the field (after adding manure) can be reduced. Bonus received from generation of renewable energy (Biogas).

Challenges for Implementation

Information about microscale digestion, and appropriate support is needed.

Job Creation

Micro-scale digesters (MSD) do not require many man-hours for operation. Farmers can operate and maintain them themselves. This means more work for farmers, but according to those who operate such plants, it is manageable. On the other hand, new workplaces can be created in other areas, i.e. technology providers, plant developers, and technical support.

Socio - Economic

In case of MSD local resources are used and local companies perform maintenance of installations. Therefore, the capital remains in the region. This contributes to improving quality of life of the residents.

MSD are usually built on farms, near houses. The proximity is much closer than in the case of large-scale installations. The distance from other buildings should be enough to make the noise level acceptable.

Farmers who have neighbours with animal farms can launch a biogas project together or make an agreement to utilize also their manure. This type of cooperation can tighten social cohesion.

Decentralized energy production in plants with MSD improves the security of energy supply for households through reducing grid loads. Furthermore, the significant costs for the grid losses and for the grid stabilization can be avoided.

Moreover, producing energy for the farm may be profitable mostly due to the avoided cost of energy purchase. The income from surplus energy sales may be an additional advantage and shorten the payback time of the investment.

Digestate is a better fertilizer than untreated manure. With better manure management due to the application of digestate instead of manure, fewer chemical fertilizers are needed on the farm, with the same crop yields.

F. References

[1] https://www.host.nl/en/biogas-plants/agricultural-biogas-plants/

[2] Cornelissen Consulting Services B.V. www.cocos.nl

[3] DCA Multimedia B.V. www.boerenbusiness.nl

[4] www.bio-up.nl

[5] https://www.host.nl/en/biogas-plants/agricultural-biogas-plants/

[6] Power4Bio Catalogue - HOst factsheet

C2.3 Spent mushroom substrate & other agricultural and food industrial wastes based ANAEROBIC DIGESTION producing biogas & electricity (Pilze-Nagy)

A. General

Title

Spent mushroom substrate & other agricultural and food industrial wastes based ANAEROBIC DIGESTION producing biogas & electricity (Pilze-Nagy)

Keywords

electricity, biogas, anaerobic digestion, spent mushroom substrate, oyster mushroom, mushroom, fertiliser, agricultural residues, food industry wastes, bioenergy, biofertiliser

Example user / provider of technology

http://pleurotus.hu/biogaz

Contact person

Pilze-Nagy Kft, Adrienn Nagy, a.nagy@pleurotus.hu, Talfája 47/B., 6000 Kecskemét, Hungary, +36 76 502 030

B. Feedstock

Main feedstock

Spent mushroom substrate (SMS)

Potential other feedstock

Food industrial wastes, food residues, other food processing residues, marc and other by-products of distillery process, sludge from slaughterhouse, poultry manure, expired food

Required Feedstock Quality

-

Feedstock price, trade spot and location

The main feedstock is the waste of the oyster mushroom production and the secondary feedstocks are wastes of other agricultural and food industrial processes, so feedstock price is not relevant.

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- After harvesting the oyster mushroom fruiting bodies, spent mushroom substrate (SMS) is transported into the biogas plant and mixed with other residues (poultry manure, marc, expired food, oil based mud, etc.).
- 110 m^3 biogas can be produced per tonne of input material (dry matter content: 50-60%).
- The plant can process maximum 10 thousand tonnes of biomass per year, 1-1,2 million m^3 biogas is produced per year from this amount of biomass.
- Biogas is converted into electrical energy (2,000-2,400 MWh/year) by burning it in a gas engine CHP (combined heat and power).
- Biogas digestate, the by-product of the anaerobic digestion process is separated: the solid phase (containing 3 w % nitrogen) is used as biofertilizer by local farmers and the liquid phase is stored in an open digestate storage pond
- A part of this liquid material is used for wetting the input material of the biogas plant and the rest is placed on agricultural fields as a liquid biofertilizer.
- Other Input Materials: water

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

Typical: 4,000 tonne dry matter/year

Maximum: 5,000 tonne dry matter/year

Investment Costs

1.340 million €

Operational Costs

-

D. Product(s)

Product Name(s)

- Electrical energy

Price, trade spot and location

- Electrical energy: 0,028 €/MJ in Hungary

E. Impact

Environmental Benefits

Waste reduction & producing green energy by utilising agricultural and food industrial wastes; renewable energy replaces commercial fuels; using of commercial fertilisers is reduced by applying separated biogas digestate as biofertilizer.

Challenges for Implementation

Malfunction or failure in the technical infrastructure (e.g. gas engine); optimization steps needed when starting the implementation.

Job Creation

3 employees for a plant of the same sizes as operated by Pilze-Nagy Ltd.

Socio - Economic

Funding Schemes: investment: 70% private + 30% public funding; Hungary: electricity generated from renewable energy sources and waste is promoted through feed-in tariffs

Public Support: 70% of the HUF 340 million (1 million euros) investment value of biogas plant was provided by the company (a part of it as bank loan), while further HUF 110 million (0,34 million euros) has arrived as support by the Environment Protection and Infrastructure Operative Program.

Socioeconomic: biogas systems can support rural development and mitigate the negative effects of general economic fluctuations by local energy and fertiliser production; biogas drastically reduces the dependence of local communities on imported fuels and increases the local energy supply; farmers can get a new social function as energy producers or waste managers.

F. References

[1] http://pleurotus.hu/biogas

[2] Larisa Lovrencec, 2010. Highlights of socio- economic impacts from biogas in 28 target regions. D.2.4. of IEE Project ‘BiogasIN’ (Contract No. IEE/09/848 SI2.558364

[3] Power4Bio Catalogue – Pilze-Nagy factsheet

C2.4 Manure and slurry based ANAEROBIC DIGESTION producing heat, electricity, and fertilizers (Lantmännen)

A. General

Title

Manure and slurry based ANAEROBIC DIGESTION producing heat, electricity, and fertilizers (Lantmännen)

Keywords

biogas, manure, slurry, poultry, electricity, heat, bioenergy

Example user / provider of technology

https://www.lantmannen.com/

Contact person

info@lantmannen.com, S:t Göransgatan 160A, Stockholm / Sweden, +46 10 556 00 00

B. Feedstock

Main feedstock

Residues from livestock production

Potential other feedstock

-

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- The biogas plant is fed by chemically and enzymatically pre-treated manure and slurry from pig and poultry farms.
- Biogas is produced by anaerobic digestion and then converted into electrical energy and heat.
- At the end of the cycle, a material with high nitrogen content is separated and used as an organic fertilizer.
- Other Input Materials: water

Key partners

- Feedstock providers (farmers, sawmill workers)
- Catalyst providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Catalysts (chemical and enzymatical pre-treatment, yeast)
- Technology
- Logistics

Capacity

-

Investment Costs

-

Operational Costs

These costs include logistics (bring in the feedstocks and deliver the products), handling of raw material, enzymes, heat, electricity, additives, maintenance, and staff costs.

D. Product(s)

Product Name(s)

- Electrical energy
- Heat
- Organic fertilizer (with high nitrogen content)

Price, trade spot and location

Biogas estimated market price: 1,000€/t.

E. Impact

Environmental Benefits

Coupled to waste reduction, there is environmentally friendly produced biogas, electricity and heat that replace commercial fuels. Moreover, use of commercial fossil-dependent fertilizers is reduced by applying the produced biofertilizer.

Challenges for Implementation

-

Job Creation

The creation of this biogas plant has led to the creation of 60 local jobs (accounting for both directly and indirectly related).

Socio - Economic

Local farmers have access to an unexpensive, high-quality fertilizer which increases their yields. On top of that, local consumers can purchase low-cost heat and electricity.

F. References

[1] https://www.lantmannen.com/

[2] AGROinLOG

C2.5 Manure, agricultural and slaughter waste based ANAEROBIC DIGESTION producing biogas (Biogas Brålanda AB)

A. General

Title

Manure, agricultural and slaughter waste based ANAEROBIC DIGESTION producing biogas (Biogas Brålanda AB)

Keywords

biogas, biomethane, manure, agricultural waste, slaughter waste, biofuel

Example user / provider of technology

-

Contact person

Bäkken's farm 1, 464 93 Mellerud, Västra Götaland county / Sweden

B. Feedstock

Main feedstock

- Residues from livestock production (80%).
- Residues from agriculture (10%).
- Other organic residues, mainly slaughterhouse residues (10%).

Potential other feedstock

-

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- Manure, agricultural and slaughter waste are collected from surrounding producers.
- All feedstock is derived to an anaerobic digester to produce biogas at BBAB (Biogas Brålanda AB). Part of said biogas is converted into biofuel (biomethane).
- GBAB (Grönt Brånsle i Sverige AB) distributes and sells a portion of biogas for private and public traffic in Trollhättan.
- The remaining biogas is converted into electricity and heat.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company
- Local administration
- Investors

Key resources

- Feedstock
- Technology
- Logistics
- Political support

Capacity

-

Investment Costs

Total investment costs: €7-€8 million (25% financed through various subsidies). This includes the entire infrastructure (anaerobic digesters and plant transforming raw biogas into biofuel and the distribution grid).

Operational Costs

-

D. Product(s)

Product Name(s)

- Fuels
- Heat
- Electrical power

Price, trade spot and location

-

E. Impact

Environmental Benefits

Biogas Brålanda AB secures a continuous production of biogas to the city, strengthening its position towards a more sustainable, electric-based private and public vehicle fleet.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

-

F. References

[1] https://www.allabolag.se

[2] https://www.trollhattanenergi.se/

[3] Rubizmo Business case Factsheet - Biogas Brålanda AB

C2.6 Pig farming manure and agricultural waste based ANAEROBIC DIGESTION producing biogas (Biogal)

A. General

Title

Pig farming manure and agricultural waste based ANAEROBIC DIGESTION producing biogas (Biogal)

Keywords

biogas, pig, manure, agricultural waste, biofuel

Example user / provider of technology

-

Contact person

sekretariat@biogal.pl, Boleszyn 7 13-308 Dark / Poland, +48 56 474 11 12

B. Feedstock

Main feedstock

- Residues from agriculture.
- Residues from livestock production.

Potential other feedstock

-

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- Pig manure, agricultural waste and expired food are provided by nearby producers.
- All feedstock is processed in an anaerobic digestor where bacteria convert the organic material to biogas (methane and CO_2).
- Said biogas powers motors, transforming into electrical power and heat.
- Biological residues from the digestor are commercialized as a natural fertilizer.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company
- Local administration

Key resources

- Feedstock
- Technology
- Logistics
- Political support

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Fuels
- Heat
- Electrical power
- Organic fertilizer (Naturgal)

Price, trade spot and location

-

E. Impact

Environmental Benefits

- GHG reduction
- Climate change mitigation/adaptation
- Soil protection

Challenges for Implementation

-

Job Creation

This business has created 50 direct employees and dozens of indirect jobs due to its connections to other local industries.

Socio - Economic

The biogas produced by Biogal heats the house of 95% of the population of Boleszyn and Mroczno.

F. References

[1] https://biogal.pl/

[2] COOPID Success case - Biogal

C2.7 Winery and industrial farming by-products, and mowing waste based FERMENTATION producing fuels, electricity and fertilizers (Caviro)

A. General

Title

Winery and industrial farming by-products and mowing waste based ANEROBIC DIGESTION producing fuels, electricity and fertilizers (Caviro)

Keywords

fermentation, winery residues, industrial farming, mowing waste, electrical power, heat, fertilizer

Example user / provider of technology

https://www.caviroextra.it/

Contact person

Andrea Farolfi, Via Convertite 8, 48018 Faenza / Italy, +39 0546 629111

B. Feedstock

Main feedstock

Residues from agriculture, industrial farming, and wine production

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Fermentation

TRL

9

Description of Technology

- The waste and by-products from CAVIRO's wine production are combined with mowing waste material collected by in the local area.
- Feedstock is supplied to the anaerobic digestor.
- The outputs include biofuels as biogas and bioethanol. Another part is converted to thermal energy and electricity, creating a virtuous circle between industrial production and energy from renewable sources.
- Organic parts of biomass and waste from industrial farming are treated to produce natural fertilizers.

Key partners

- Landowners
- Feedstock providers
- Technology providers
- Converters
- Operation technicians
- Logistics company
- Local administration

Key resources

- Feedstock
- Technology
- Logistics

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Organic fertilizers
- Fuels
- Heat
- Electrical power

Price, trade spot and location

-

E. Impact

Environmental Benefits

The different types of natural fertilizers return to the field, closing a virtuous cycle. Packaging is designed to use more sustainable materials.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

- Job generation
- Spreading of cooperative values
- Attention and cohesion of local community

F. References

[1] https://www.caviroextra.it/

C2.8 Whey permeate based ANAEROBIC DIGESTION producing bioethanol, biogas and fertilizers (Carbery)

A. General

Title

Whey permeate based ANAEROBIC DIGESTION producing bioethanol, biogas and fertilizers (Carbery)

Keywords

dairy, milk, whey, bioethanol, biogas, biofuel, fertilizer

Example user / provider of technology

https://www.carbery.com/

Contact person

info@carbery.com, Phale Lower, Ballineen, Co. Cork / Irland, +353 (0)23 8822200

B. Feedstock

Main feedstock

- Residues from milk production (whey permeate)

Potential other feedstock

-

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- Milk from farmer shareholders is processed to remove milk fat (derived to butter production).
- Skimmed milk is used to produce cheese and whey.
- Whey proteins are stripped from whey and sold for nutritional ingredients purposes.
- The derived waste, whey permeate, is fermented into bioethanol (12 million L/year).
- A co-product of said fermentation is stillage waste. This is the feedstock for anaerobic digestion, which produces biogas.
- The solid waste from the digester is treated into an organic fertilizer.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company
- Local administration
- Investors

Key resources

- Feedstock
- Technology
- Logistics
- Political support

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Fuel (bioethanol, biogas)
- Heat
- Electrical power
- Organic fertilisers

Price, trade spot and location

-

E. Impact

Environmental Benefits

Carbery's Ballineen facility, their most significant emitter of carbon emissions, is now fueled with natural gas, of which 4.6% is produced on-site in their anaerobic digester. Sludge from the anaerobic digestion is used as an energy source for the manufacturing plant and provides 9% of the Ballineen site's steam power.

Carbery has also installed reverse osmosis systems to recover and recycle water contained in whey permeate, reducing water waste.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

-

F. References

[1] https://www.carbery.com

C2.9 Manure based ANAEROBIC DIGESTION producing biogas for logistics and private transport (Valio)

A. General

Title

Manure based ANAEROBIC DIGESTION producing biogas for logistics and private transport (Valio)

Keywords

manure, dairy, milk, biogas, fertilizer, transport

Example user / provider of technology

https://www.valio.com/

Contact person

mediadesk@valio.fi, Meijeritie 6, FI-00370 Helsinki, Finland, +358 10 381 121

B. Feedstock

Main feedstock

- Residues from livestock production (manure)
- Other organic residues from dairy production

Potential other feedstock

-

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- Nutrients from manure are separated and derived to organic grain farms.
- Manure and feed waste are used as feedstock for biogas production at an anaerobic digester.
- Other less prominent feedstocks (such as by-products from dairy production, defective batches of fresh products, and products returned from stores), are processed accordingly to European legislation before being treated in the anaerobic digester.
- Obtained biogas is used in the company's logistic trucks. The surplus is commercialized for private transport.

Key partners

- Feedstock providers
- Converters
- Operation technicians

- Logistics company
- Local administration
- Investors

Key resources

- Feedstock
- Technology
- Logistics
- Political support

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Fuel (biogas)

Price, trade spot and location

-

E. Impact

Environmental Benefits

Biogas is obtained from otherwise less-to-non profitable waste streams, replacing polluting fossil fuels. Valio also trains its farmers to enhance carbon sequestering in their fields, reducing the carbon footprint of dairy production.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

- Job generation

F. References

[1] https://www.valio.com/

C2.10 Manure based ANAEROBIC DIGESTION producing biogas for logistics and private transport (Azienda Mengoli)

A. General

Title

Manure based ANAEROBIC DIGESTION producing biogas for logistics and private transport (Valio)

Keywords

manure, maize, sweet sorghum, triticale, biogas

Example user / provider of technology

Societa' Agricola Mengoli Rino Mauro e Gianni SS

Contact person

Via Bagnarese, 3, Castenaso, 40055, Bologna / Italy, +39 05 1787393, + 39 051 787206

B. Feedstock

Main feedstock

- Residues from livestock production (manure)
- Residues from agriculture

Potential other feedstock

-

C. Technology

Technology Name

Anaerobic digestion

TRL

9

Description of Technology

- The anaerobic digester runs mainly on disposals from the farm itself: cattle manure (40%) and energy crops (20%; e.g. maize, sorghum, triticale). The remaining feedstock consists on agro-industrial residues from nearby farms and agri-food companies.
- Biogas produced in the anaerobic digester powers the farm itself.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company
- Local administration
- Investors

Key resources

- Feedstock
- Technology
- Logistics
- Political support

Capacity

350 kW

Investment Costs

The initial investment to build the biogas plant amounted to €900,000 (15% was financed through regional funds, remaining 85% was acquired with a bank loan). The biogas plant was considered a profitable investment by the bank, so the founders did not encounter any problems to access private loans. Since then, total investment in the company increased to €1.4 million with plant upgrades.

Operational Costs

-

D. Product(s)

Product Name(s)

- Fuel (biogas)

Price, trade spot and location

Since 2006, GSE, the national Italian energy company (only entity allowed to buy energy in the country), has a 15-year contract with the farm to buy the energy at a fixed price (maximum 375 kW/hour). This is a real added value for the company, as it represents a new source of revenue.

E. Impact

Environmental Benefits

- GHG reduction
- Climate change mitigation/adaptation
- Soil protection

Challenges for Implementation

-

Job Creation

2 job positions.

Socio - Economic

- Area revitalisation

F. References

[1] https://www.crpa.it/

[2] https://www.agb-biogas.com/

[3] https://www.bestiame.info/

C3. Business models based on Fermentation

C3.1 Unsold bread based FERMENTATION producing beer (Toastale)

A. General

Title

Unsold bread based FERMENTATION producing beer (Toastale)

Keywords

fermentation, bakery waste, food residues, starch, beer, bread, brewery, barley malt

Example user / provider of technology

https://www.toastale.com/

https://www.beerproject.be/

https://www.instock.nl/en/

Contact person

Toast Ale Ltd, Louisa Ziane, hello@toastale.com, Toast Ale Bread Quarters, 25 Lavington Street, Southwark, SE1 0NZ, UK, +44 2037 441 616

B. Feedstock

Main feedstock

Unsold bread

Potential other feedstock

Barley grain, wheat grain, bread & rolls losses (surplus product retail, processing, bread crusts, dough)

Required Feedstock Quality

Food grade

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Fermentation

TRL

9

Description of Technology

- Process - Barley is malted (germination, release of starch and enzymes), add bread (1/3 of the mass of barley malt), mashing (conversion starch into sugars), lautering (separation into clear wort and residual grain), add hop, boiling the wort (sterilisation, create flavour), cooling, add yeast, fermenting (conversion sugars into ethanol and carbon dioxide), conditioning (aging, better taste) and filtering.
- Feedstock flexibility - Wheat, other bakery products, other material that contain starch can be used to produce beer.
- Products - 11 litre beer is produced from 1 kg bread.
- Innovativeness - Making beer from bread is a century old technology, but creating a good taste is an art. It can be adopted by any operational brewery.
- Investment costs are estimated using the Bridgewater method with 8 unit operations and 30 tonnes barley plus bread per year. This is the investment for a complete and new brewery.
- Other Input Materials are water, hop, barley and yeast.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

7 tonne dry matter/year

Investment Costs

6 million €

Operational Costs

-

D. Product(s)

Product Name(s)

- Beer
- Side Product: Brewer's spent grains

Price, trade spot and location

- Beer: 7.5 €/l

E. Impact

Environmental Benefits

Benefits - Avoiding GHG emission from landfilling bread, preventing environmental effects of barley cultivation.

Challenges for Implementation

Taste

Job Creation

3 direct jobs and 4 indirect jobs.

Socio - Economic

More interaction (cohesion) in a local community that collects unsold bread and transfers it to a local brewery.

Basic personal protection required for work safety.

F. References

[1] www.toastale.com

[2] www.beerproject.be

[3] Power4Bio Catalogue - Toastale factsheet

C4. Business models based on Insect-based bioconversion

C4.1 Organic side streams based BIOCONVERSION BY BLACK SOLDIER FLY LARVAE producing lipids & proteins for feed (Bestico)

A. General

Title

Organic side streams based BIOCONVERSION BY BLACK SOLDIER FLY LARVAE producing lipids & proteins for feed (Bestico)

Keywords

Agricultural residues; food residues; bioconversion; black soldier fly; lipids; proteins; feed

Example user / provider of technology

https://www.bestico.nl/

Contact person

-

B. Feedstock

Main feedstock

Agricultural and food residues

Potential other feedstock

-

Required Feedstock Quality

GMP+; insecticide free.

Feedstock price, trade spot and location

100 - 200 €/ton on-site in Netherlands [1].

C. Technology

Technology Name

Bioconversion by insects.

TRL

8

Description of Technology

- Black soldier fly is grown produced in crates on rack cupboards and fed with agricultural and food residue streams.
    - Technology is simply scalable to the amounts of vegetable residue streams available, whether smaller or larger quantities.
- Larvae are harvested, dried & used as feed (when grown on GMP + side streams) or further refined to a protein rich fraction and lipids. Larvae and protein fraction contain essential amino acids which are low in feeds produced from plants [2].
- During harvesting the insects are sieved out of their remaining feed medium, the fine fraction (left-overs, debris, etc.) is sold as fertilizer (compost). Also the substrate residue (skins of worms) remaining after pressing of the worms can be used as fertilizer.

Key partners

- Feedstock providers
- Converters
- Operation technicians

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

400 – 600 ton/year fresh. 10 ton/year Black soldier fly larvae; 90 ton/year proteins; 45 ton/year lipids.

Investment Costs

3 million € [1].

Operational Costs

-

D. Product(s)

Product Name(s)

Black soldier fly larvae; proteins; lipids.

Price, trade spot and location

2,000 – 2,500 €/ton for Black soldier fly larvae as pet food and feed;

3,000 – 3,750 €/ton for proteins as pet food and feed;

1,500 €/ton for lipids as feed [1].

E. Impact

Environmental Benefits

High quality feed can be produced at scalable scale, thus avoiding transportation from centralized specialized feed producers to remote areas.

Challenges for Implementation

-

Job Creation

20 – 25 jobs [1].

Socio - Economic

The technology allows to convert perishable food and agro-industrial residue streams into nutritious feed having a much longer shelf life [3]. Rural communities can thus produce their own high quality feed. A so called air washer reduces smell around the building to basically zero.

F. References

[1] Power4Bio Catalogue - Bestico factsheet

[2] https://dokumen.tips/documents/bsf-bioconversion-by-bestico-bv-abstract-bsf-bioconversion-by-bestico-bv.html

[3] https://power4bio.eu/wp-content/uploads/2020/04/POWER4BIO_D3.4_Best_practices_of_bio-based_solutions.pdf

C4.2 Organic residues based INSECT BREEDING producing proteins (madebymade)

A. General

Title

Organic residues based INSECT BREEDING producing proteins (madebymade)

Keywords

Agricultural residues, bakery waste, food industry wastes, food residues, starch, residues, vegetables, insects, native protein, lipids, poultry feed, biofertiliser, chemical free

Example user / provider of technology

https://madebymade.eu/

Contact person

dr. Jonas Finck, jonas.finck@madebymade.eu, +49 179 7394690

B. Feedstock

Main feedstock

Organic residues

Potential other feedstock

Vegetable residues, Fruit residues, Bread & rolls losses (Surplus product Retail, Processing, Bread crusts, Dough), Starch

Required Feedstock Quality

Dry matter content minimum 5 wt.%

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Insect breeding + biorefinery'

TRL

7

Description of Technology

The production process consists of the following phases/modules:

- Preparing the input. The larvae of the Black Soldier Fly (BSF) are generally able to convert any kind of organic residue.
- Rearing the larvae
- Separating the larvae from the organic fertilizer by sieving.
- Drying the larvae in an oven.
- Pressing the larvae separate fat from protein meal.

The technology madebymade uses originates from a variety of technology providers. Segments of the production process are outsourced to other companies. As much as possible, machinery and equipment already existing is being used, and where needed new technology is developed. No single company is individually able to meet the complete technological needs. The provider of technology is madebymade. The technology is easily scalable. [1]

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

Ultimately, typical production of 20 ton/day is foreseen [1]

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

Protein (insect based), >40 wt.%. < 8 wt.% fat

Fat (insect based), contains unsaturated fatty acids

Organic fertilizer

Price, trade spot and location

To facilitate translation of useful cost-benefit data from elsewhere to own situation.

E. Impact

Environmental Benefits

Products arise in a regional circular economy, thus saving transportation and related greenhouse gas emissions. The production process is resource saving and resource valorising at the same time because organic residues are used as input.

Compared to fish meal production, a 71% reduction of CO_2 emissions is claimed when substituted with insect protein and a 50% reduction of CO_2 emissions when substituting soy meal.

Challenges for Implementation

Legislation in the European Union currently does not allow the use of insect protein meal as feed in agriculture. As of right now, insect protein is only allowed as Pet feed and in aquaculture. Standards for residues such as food residues make it difficult to make them usable as input.

Job Creation

12 [1]

Socio - Economic

Organic waste can be converted in high quality feed regionally, bringing back employment to rural areas.

F. References

[1] Power4Bio Catalogue - madebymade factsheet.

C4.3 Organic residues based INSECT BREEDING producing proteins and fertilizers (Ÿnsect)

A. General

Title

Organic residues based INSECT BREEDING producing proteins and fertilizers (Ÿnsect)

Keywords

organic food waste, insects, worms, protein, fatty acids, chitosan, biofertiliser

Example user / provider of technology

https://www.ynsect.com/

Contact person

contact@ynsect.com, 1 Rue Pierre Fontaine, 91000 Évry-Courcouronnes,/ France, +33 1 64937100

B. Feedstock

Main feedstock

Organic residues

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Bioconversion (insect breeding).

TRL

9

Description of Technology

- Organic food waste from several origins is fed to mealworm (molitor) larvae.
- Worms are grown in patented vertical farms that optimize their growth and molecular components.
- These insects contain high quality proteins and other valuable compounds, such as fatty acids and chitosan (scarce compounds).
- Mealworms' dejections are processed into high-quality fertilizers.

Key partners

- Feedstock providers
- Technology providers
- Construction company
- Operation technicians
- Logistics company
- Local administration
- Investors

Key resources

- Land
- Technology
- Financial support
- R&D
- Political support

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Animal feed (aquaculture, pets, swine and poultry farming).
- Food (AdalbaPro).
- Organic fertilizer (Ynfrass).

Price, trade spot and location

-

E. Impact

Environmental Benefits

98% less land and 30% less resources than traditional livestock farming. Combat of overfishing.

Challenges for Implementation

Legislation in the European Union currently does not allow the use of insect protein meal as feed in agriculture, only as pet feed and in aquaculture.

Job Creation

Currently over 200 employees, expected to create up to 500 direct and indirect jobs in the mid-term.

Socio - Economic

- 35% more growth and 40% less mortality in farmed fish fed with these products.
- Reduced skin diseases and allergies in pets.
- 20% higher yields on vineyards, wheat and corn production, among other crops, when using this fertilizer.
- Boost flowering and drought resistance in ornamental plants.
- Expected lower cholesterol, higher vitamins and minerals levels in humans.
- Improved digestion and increased muscle mass in humans.

F. References

[1] https://www.ynsect.com/

C5. Business models based on Cultivation

C5.1 Coffee residues based GROWING producing mushrooms (Rotterzwam)

A. General

Title

Coffee residues based GROWING producing mushrooms (Rotterzwam)

Keywords

Coffee grounds, mushroom, oyster mushroom, food

Example user / provider of technology

https://www.rotterzwam.nl

https://grocycle.com

Contact person

-

B. Feedstock

Main feedstock

Coffee grounds

Potential other feedstock

Wheat straw; other pasteurized/sterilized cellulosic materials

Required Feedstock Quality

-

Feedstock price, trade spot and location

0 €/ton

C. Technology

Technology Name

Mushroom growing

TRL

9

Description of Technology

The process steps include [1]:

- Coffee grounds are mixed with straw (20 wt.% of coffee ground weight) and lime, and then mixed with Oyster mushroom spawn (10 wt.% of coffee ground weight)
- The mixture is put in growing bags and incubated at 20-24 °C in the dark for 2-3 weeks. White mycelium is formed.
- To produce the mushroom the bags are placed under fruiting conditions (with indirect light) and after 10-17 days the mushrooms are harvested.
- 1 Ton of coffee grounds (40 wt.% dry matter) yields 200 kg of oyster mushrooms

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

In 8 old containers about 80 tonnes of coffee grounds are converted into 16 tonnes of mushrooms per annum. [2]

Investment Costs

260 k€ [1]

Operational Costs

-

D. Product(s)

Product Name(s)

Oyster mushroom

Price, trade spot and location

About 12 €/kg [1]

E. Impact

Environmental Benefits

Coffee grounds are utilized for food production instead of composted.

Challenges for Implementation

Mould contamination in the bags.

Job Creation

1.5 [1]

Socio - Economic

Many products are transported from ports and rural areas into cities and a large amount of residues is transported out from the cities again. With the tendency of growing cities, transportation increases. Transforming residue streams into new products in the city itself, or in its direct proximity, may reduce traffic in metropolitan areas, while also reducing transportation costs and emissions like GHG and fine particles. However, such innovative waste management systems may also be applied in rural areas to valorize residue streams locally and keep employment and capital in the region. [2]

F. References

[1] Power4Bio Catalogue - Rotterzwam factsheet.

[2] https://power4bio.eu/wp-content/uploads/2020/04/POWER4BIO_D3.4_Best_practices_of_bio-based_solutions.pdf

C5.2 Cereal crop straw based GROWING producing Oyster mushroom and oyster mushroom substrate (Pilze-Nagy)

A. General

Title

Cereal crop straw based GROWING producing Oyster mushroom and oyster mushroom substrate (Pilze-Nagy).

Keywords

straw, mushroom, oyster mushroom, chemical free, food, cereal crops, vegan

Example user / provider of technology

http://pleurotus.hu/

Contact person

Pilze-Nagy Kft, Adrienn Nagy, a.nagy@pleurotus.hu, Talfája 47/B., 6000 Kecskemét, Hungary, +36 76 502 030

B. Feedstock

Main feedstock

Cereal straw

Potential other feedstock

Crop stalk, Alfalfa residues

Required Feedstock Quality

The crops should not by treated by herbicides such as chlormequat or mepiquat. The straw should not be contaminated with weeds. The moisture content has to be under 15% in order to prevent fires in stored bales of straw.

Feedstock price, trade spot and location

The typical price of straw in Hungary is 60 €/tonne dry matter. With a minimum of 40 €/tonne dry matter and a maximum of 150 €/tonne dry matter. However, the price of straw is fluctuating. E.g., in 2019 it was double or even higher (100-150 €/tonne dry matter) compared with the "average" level price (40-60 €/tonne dry matter), especially in Western Europe.

C. Technology

Technology Name

Mushroom growing

TRL

9

Description of Technology

- The production system consists of multiple technology steps: chopping and composting straw, solid- state fermentation, inoculating the bags of straw, ensuring growing conditions and harvesting oyster mushrooms after 5-8 weeks of growing period.
- Moisture content of the feedstock has to be under 14% otherwise the storage can be problematic.
- 3 tonnes of straw produced on one hectare can be converted into 1,8-2,0 tonnes oyster mushroom.
- After the harvest spent mushroom substrate is transported to a biogas plant.
- Other Input Materials are water and Oyster mushroom spawn.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

1,800 tonne dry matter/year

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Oyster mushroom
- Oyster mushroom substrate (straw- based growth substrate inoculated with oyster mushroom spawn)
- A side product is spent mushroom substrate.

Price, trade spot and location

- Oyster mushroom: 18,750 €/tonne dry matter on market in Hungary
- 900-1,000 tonnes of fresh oyster mushroom is produced per year on 1,800-2,000 tonnes of feedstock (calculated on dry matter), and the price of oyster mushrooms is 1,5 €/ kg (without packaging and transportation costs), which means that the gross revenue from oyster mushrooms is 700-800 €/tonne feedstock.

E. Impact

Environmental Benefits

Oyster mycelium takes up nutrients from the agricultural residues ensuring their valorisation.

Challenges for Implementation

Relatively high investment costs, maintenance of machinery background and supply of components needed can be problematic. There is a need for high quality workforce. Adaptation of the technology to different environmental conditions is possible but time consuming and knowledge-intensive.

Job Creation

The technology can be downscaled which can create great socio-economic potential to promote long-term sustainable growth, create jobs and thus decrease poverty in poorer regions.

44 employees in a plant of the same size as the one operated at Pilze-Nagy Ltd: mushroom growing & harvesting: 18; packaging: 20; management: 6.

The biogas plant requires only a few people to operate.

Socio - Economic

Oyster mushroom and substrate producing plant construction was a private investment with public support from the Hungarian Ministry of Agriculture and Regional Development and the County Council of Regional Development in Hungary.

Pilze-Nagy Ltd purchases half of the straw from nearby farmers (from the east side of Southern Great Plain) and half of the straw from dealers. This way the company can continuously monitor and control the price and quality differences on the market. Agricultural and food industrial residues are also bought from local farmers and food industry companies resulting revenues from their so far unused by-products.

There is a close cooperation with other mushroom growers, who are using Pilze-Nagy Ltd's oyster mushroom substrate and in the end Pilze-Nagy Ltd repurchases the final oyster mushroom from them.

The most important expenses are feedstock, energy and labour costs.

The waste of the growing process is spent mushroom substrate (SMS). To valorize this material, Pilze-Nagy Ltd invested in a biogas plant which can use SMS as main feedstock for electrical energy production. By producing electrical energy, the company reduces the production costs of oyster mushrooms and substrate and the risk of high energy prices.

F. References

[1] http://pleurotus.hu

[2] "Straw for Energy", Teagasc Energy FactSheet No 12., https://www.teagasc.ie/.../Teagasc-A4-Energy-Fact-Sheet-No.-12-Straw-for- Energy_2pp.pdf

[3] https://power4bio.eu/wp-content/uploads/2020/04/POWER4BIO_D3.4_Best_practices_of_bio-based_solutions.pdf

[4] Power4Bio Catalogue - Pilze-Nagy factsheet.

C5.3 Organic and agroforestry residues based GROWING producing fungus for biocomposites (Spawnfoam)

A. General

Title

Organic and agroforestry residues based GROWING producing fungus for biocomposites (Spawnfoam)

Keywords

organic residues, agroforestry residues, fungus, pottery, biocomposite

Example user / provider of technology

https://www.spawnfoam.pt/

Contact person

info@spawnfoam.pt, Régia Douro Park, 5000-033 / Portugal, +351 919 640 390

B. Feedstock

Main feedstock

- Residues from forestry and forest-based industry
- Other organic residues

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Fungus growing

TRL

9

Description of Technology

- Organic and agroforestry residues are prepared to serve as nutritive feed for the fungus. The preparation steps have not been disclosed.
- The grown mycelium is separated from the nutritive matrix and treated to act as cohesive, bonding agent of the biocomposite particles.
- Other Input Materials: water.

Key partners

- Feedstock providers
- Technology providers
- Operation technicians
- Local administration
- Investors
- R&D institutes
- Customers
- Social media companies

Key resources

- Feedstock
- Technology
- Skilled labour force
- Financial support
- R&D
- Political support

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Biocomposite
- Plant pots
- Construction boards
- Ornamental vases
- A side product is the spent fungus substrate.

Price, trade spot and location

-

E. Impact

Environmental Benefits

- GHG reduction
- Climate change mitigation/adaptation
- Soil protection
- Water protection
- Responsible consumption

Challenges for Implementation

-

Job Creation

-

Socio - Economic

- Job generation
- Well-being improvement

F. References

[1] https://www.spawnfoam.pt/

[2] Be Rural Catalogue, https://be-rural.eu/wp-content/uploads/2019/12/BE-Rural_D2.4_Regional_business_models.pdf

C5.4 Agricultural residues based GROWING producing fungus for biocomposites (Ecovative)

A. General

Title

Agricultural residues based GROWING producing fungus for biocomposites (Ecovative)

Keywords

agricultural residues, fungus, food, leather, foams, beauty industry, packaging, biocomposite

Example user / provider of technology

https://www.ecovative.com/

Contact person

Depending on the biomaterial application:

- hello@mushroompackaging.co
- For information regarding the remaining applications, an online form on the company's website must be filled in.

70 Cohoes Avenue, Green Island, New York, 12183 / USA, + 518 273 3753

B. Feedstock

Main feedstock

- Residues from agriculture

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Fungus growing

TRL

9

Description of Technology

- Interesting fungal species and strains are studied, brought to a pilot-scale farm and, lastly, exploited at a commercial scale.
- The fungi are grown for 5 days on locally available, cleaned agricultural residues.
- The grown mycelium is separated from the matrix, dehydrated, and heat treated to stop the growth and ensure the absence of spores and allergens.
- The resulting mycelium is shaped into the desired product.

Key partners

- Technology providers
- Operation technicians
- Logistics company
- Local administration
- Investors

Key resources

- Feedstock
- Technology
- Financial support
- R&D
- Political support

Capacity

Millions of pounds of mycelium annually.

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Biocomposites (AirMycelium™, MycoComposite™) useful in diverse markets (food, leather, foams, beauty and packaging).

Price, trade spot and location

-

E. Impact

Environmental Benefits

The farms needed to grow the fungi can be built close to the partners' facilities, and can seamlessly integrate with existing mushroom farm infrastructure, meaning less construction and logistics-related pollution.

To grow fungi, no light or water input are required, drastically minimizing the electricity and water waste derived from this technology compared to petroleum-based plastics.

The mechanical properties of the biomaterials are comparable to their plastic counterparts, while the environmental breakdown is faster and less detrimental. Home composting is plausible for all Ecovative products.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

Interesting fungi species and strains are researched, expanding the overall knowledge about this group of living beings.

F. References

[1] https://www.ecovative.com/

[2] https://ellenmacarthurfoundation.org/

[3] https://www.zoominfo.com/

C6. Business models based on Blending or mixing

C6.1 Hemp hurd based MIXING producing insulation and construction material (Hempire)

A. General

Title

Hemp hurd based mixing producing insulation and construction material (Hempire)

Keywords

Hemp; limestone; insulation material; construction material; biomaterial

Example user / provider of technology

https://hempire.tech

Contact person

Sergiy Kovalenkov [1]

B. Feedstock

Main feedstock

Hemp hurds; and lime

Potential other feedstock

Coconut shell fiber; rice fiber; palm tree fiber; straw; other locally produced feedstock can be suitable as well

Required Feedstock Quality

Hurd length preferrable ranges between 10-40 mm. Mouldy and wet feedstock is not suitable.

Feedstock price, trade spot and location

About 120 €/ton in Ukraïne in 2020 [2].

C. Technology

Technology Name

Mixing hemp, lime water and natural additive.

TRL

9

Description of Technology

- At the construction site, the ingredients are mixed for about 5 minutes: Hemp hurds, water and the so called 'fifth element', consisting of lime and natural additive.
- Mixing is performed for about 5 minutes and needs to be done above 0 °C.
- The mixture can be cast in the wood timber frame construction of a house to provide insulating walls using a mould system [3]. Alternatively, premanufactured plates or blocks can be moulded. Or it can be sprayed [4].
- It can be applied for: (non-load bearing) walls, roof, ceiling, floor, attic and basement.
- Exterior coating would have to contain no hemp hurds [5].

Key partners

- Technology providers
- Operation technicians
- Logistics company
- Local administration
- Investors

Key resources

- Feedstock
- Technology
- Financial support
- R&D
- Political support

Capacity

Typically 3,000 ton/year

Investment Costs

Ca 1.5 million €

Operational Costs

-

D. Product(s)

Product Name(s)

Hemp hurds; 'Fifth Element' binder (lime + natural additive); Hemp clay plaster; Hemp lime plaster; Insulation Panel

Price, trade spot and location

180 €/m3 on site in Ukraine in 2020 at a density of 260 kg/m^3 Hempire Mix insulation material.

480 €/ton in Ukraine in 2020 for lime based binder [2].

Cost calculation tool can be found here: https://hempire.tech/products/fifth-element-binder

E. Impact

Environmental Benefits

Producer claims lower CO_2 emissions compared to the more commonly used construction materials; CO_2 emissions of lime production and absorption during hardening are not mentioned. Because of the insulation capacity, less heating in winter and air conditioning in summer is required.

Challenges for Implementation

Lack of knowledge on the side of construction industry leaders as well as practical construction sector (conservative industry). Producing good quality hemp hurds (or similar) requires knowledge and know-how which is not yet broadly available. Price of plant based building materials like hempcrete is still higher compared with conventional mainstream materials.

Job Creation

4 jobs in the binder production facility, 4 jobs on the construction site.

Socio - Economic

Hempire Mix provides a natural insulation material, absorbing moisture during humid seasons and releasing moisture during winter season, thus improving indoor air quality (issue for so called passive houses).

The technology is quite simple to implement (low investment costs, standard mixing equipment suffices) and easily scalable.

F. References

[1] https://hempire.tech/about

[2] Power4Bio Catalogue - Hempire factsheet.

[3] https://www.hempirebuilding.net/index.php/hemplime-videos/how-to-pack-hemp-insulation

[4] https://urbannext.net/hemp-concrete/

[5] https://hempirebuilding.net/index.php/hemplime-videos/types-of-hempire-plaster

[6] https://power4bio.eu/wp-content/uploads/2020/04/POWER4BIO_D3.4_Best_practices_of_bio-based_solutions.pdf

C7. Business models based on Extraction & separation processes

C7.1 Fruit juice residue streams based PRESSING AND SOLVENT EXTRACTION producing specialty oils and additives for food, food supplements & cosmetics (Add Essens)

A. General

Title

Fruit juice residue streams based PRESSING AND SOLVENT EXTRACTION producing specialty oils and additives for food, food supplements & cosmetics (Add Essens)

Keywords

Extraction; biorefinery; grape marc; grape seed oil; food supplement; natural colorant; pilot plant; Toll manufacturing

Example user / provider of technology

https://addessens.com

Contact person

-

B. Feedstock

Main feedstock

Juice pressing residue (pits, seeds, pulp, grape lees, peel)

Potential other feedstock

Vegetables

Required Feedstock Quality

Food grade compatible

Feedstock price, trade spot and location

5 – 50 €/ton at factory gate in Belgium in 2020.

C. Technology

Technology Name

Solvent extraction (Aqueous, ethanolic, supercritical CO_2)

TRL

8

Description of Technology

- Juice pulp is dried and seeds are sieved out.
- Seeds are pressed to obtain the oil.
- Seed free dried pulp is solvent extracted (aqueous, ethanolic or super critical CO_2) for colorants and other functional components.
    - Otherwise, the seed free dried pulp is directly released to feed.
- A schematic representation of the processing and application options is given in [1].

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

300 – 900 ton/year [2].

Investment Costs

1.5 million € [2].

Operational Costs

-

D. Product(s)

Product Name(s)

Fruit seed oil; fruit fibre; fruit seed flour; fruit juice pulp extracts (e.g. colorants) for application in food (supplements), feed, cosmetics.

Price, trade spot and location

-

E. Impact

Environmental Benefits

-

Challenges for Implementation

- transportability), farmers not willing to guarantee multi annual supply, etc.

Job Creation

6 – 15 jobs.

Socio - Economic

Upgrading food residue streams.

F. References

[1] https://addessens.com/en/fruiticals-2/

[2] Power4Bio Catalogue - EcoTreasures factsheet

C7.2 Olive oil industry by-products based EXTRACTION producing food additives (Natac Group)

A. General

Title

Olive oil industry by-products based EXTRACTION producing food additives (Natac Group)

Keywords

Olive leaves, olive stones, olive pomace, extraction, tri-terpenes polyphenol

Example user / provider of technology

https://natacgroup.com/products/olive-extracts/

https://oleaf4value.eu/

Contact person

José Pinilla, jmpinilla@natacgroup.com

B. Feedstock

Main feedstock

Olive pomace

Potential other feedstock

Olive leaves; olive stones

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Extraction

TRL

9

Description of Technology

The process involves several extraction techniques and the exact technique depends on the feedstock. The plant in Hervas (Spain) is a multi-product and multi-feedstock extraction plant. [1]

Extracts can be made from olive pomace, olive stones, olive leaves and even from grape waste.

About 100 kg of products (polyphenols, triterpenes) can be made from one tonne of feedstock (with high dry matter content). [2]

Funded by the European Union

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

2,500 ton/year dry matter [1].

Investment Costs

7,700 k€ [1]

Operational Costs

-

D. Product(s)

Product Name(s)

Polyphenols and triterpenes (food additives)

Price, trade spot and location

750 €/ton for polyphenols [1]

E. Impact

Environmental Benefits

Application of olive-industry by-products as food additive is a more circular destination than landfilling (soil contamination and water-bodies pollution) or eventually application as feed (development continues). [2]

Challenges for Implementation

Legal barriers had to be overcome when it comes to convert residues into food (additive) products.

To establish such an innovative solution, it is key to align the several actors from different sectors: farmers, industrial technology providers, R&D, innovators, entrepreneurs. All of them from different backgrounds and economical areas makes it challenging.

Job Creation

10 direct jobs [1]

Socio - Economic

The solution can be operated in areas where olives are grown and processed. Farmers could set up a cooperation to establish such a plant and achieve higher value for their olive production, while reducing environmental impact. Operating the extraction plant requires educated and specialized personnel, so this solution offers opportunities for young people to stay in or return to rural areas.

Similar technology may be used for extraction of specific compounds from several other crops: Lupin, Crambe and Camelina for oil; Cardoon for chemicals; Camomile for aroma's and medicinal compounds; Rosemary for essential oils. An extraction plant flexible in its feedstock would offer farmers more rotation options to select crops for cultivation.

F. References

[1] Power4Bio Catalogue - Natac factsheet.

[2] https://power4bio.eu/wp-content/uploads/2020/04/POWER4BIO_D3.4_Best_practices_of_bio-based_solutions.pdf (Innovaoleo)

Funded by the European Union

C8. Business models based on Mechanical and thermomechanical disruption & fractionation

C8.1 Meadow grass silage based MECHANICAL TREATMENT AND HOT PRESSING producing grass fibre enhanced plastic granulates and natural insulation material (Biowert)

A. General

Title

Meadow grass silage based mechanical treatment and hot pressing producing grass fibre enhanced plastic granulates and natural insulation material (Biowert)

Keywords

Biorefinery; meadow grass; insulation material; grass fibre; plastic; bioplastic

Example user / provider of technology

https://biowert.com/

Contact person

Vera Schwinn, v.schwinn@biowert.com, Ochsenwiesenweg 4, D-64395 Brensbach / Germany, +49 6161 806 630

B. Feedstock

Main feedstock

Polyphenols and triterpenes (food additives)Meadow grass in Europe grows in spring and early summer, it can be harvested up to 4 times a year. At the usual 2 cuts per year about 50 ton/ha of fresh grass can be harvested. The seasonal characters can be different with other types of grasses and/or in other geographic area and/or under other climatic conditions.

Potential other feedstock

-

Required Feedstock Quality

The grass should be harvested before the panicle is pushed and ensiled at a dry matter content of 25-30 %. The ensiling makes it durable, so that it is available for processing all year round.

Feedstock price, trade spot and location

Price is negotiated directly with the suppliers. 140 €/ton dry matter at factory gate in Germany is a typical value.

C. Technology

Technology Name

Mechanical treatment and hot pressing of fibres

TRL

9

Description of Technology

- The cellulose fibres are separated from the grass using mechanical processing (presses, macerators) and warm water.
- Input of 8,000 ton/year grass at about 25% dry matter content (2,000 ton/year dry matter) [1]. An average of 500 kg of fibres can be obtained from 1 ton of dry matter.
- The grass juice (and further food residues) are fed to the company's own combined heat and power biogas plant. (also see technology entitled "Biogas plant producing electrical energy from grass juice and food residues")
  - The warm water used in step 1 is heated by the residual heat from this combined heat and power biogas plant.
  - The residual heat is also used for fibre drying.
- The fibres are converted into either a fibre reinforced composite, or into an insulation material.
- For fibre reinforced composite (AgriPlast) the grass fibres are compounded together with recycled (bio-based) plastic and a coupling agent into granules for injection moulding or extrusion applications [2].
- For insulation (AgriCell), about 4% Borax/boric acid is added as a fire protection aid, and made into (short) fibre for blow-in insulation of wall, roof and floor cavities [3].
- Patents include the maceration in different stages of the grass silage as well as the multi-step drying.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

2,500 ton/year of AgriPlast granules.

1,400 ton/year of AgriCell blow-in insulation fibre.

Investment Costs

Ca. 10 million €

Operational costs

-

D. Product(s)

Product Name(s)

- Fibre reinforced composite (AgriPlast) granules for injection moulding or extrusion applications.
- Fibre (AgriCell) for blow-in insulation of wall, roof and floor cavities.

Price, trade spot and location

- AgriPlast: 2.75 €/kg in Germany in 2019.
- AgriCell: 1.38 €/kg in Germany in 2019.

E. Impact

Environmental Benefits

Annual bio-based feedstock like grass has absorbed CO_2 from the atmosphere and stores when applied for a long time, e.g. in building and construction, thus posing a temporary negative greenhouse gas emission.

Challenges for Implementation

Market development for fibre-reinforced materials. Injection moulding and extrusion processes need to be adapted to the specificities of the grass fibre enhanced granulates. It takes 18-24 months to install and optimize the technology.

Job creation

-

Socio - Economic

The operation of the biorefinery and the biogas plant and feedstock production are located in a rural area, and requires several types of employees: farmers, operators, engineers, production manager, etc.

In regions where livestock farming is declining, the present innovation poses a new way of exploiting grassland. The production system could operate properly in structurally weak but agriculturally strong regions.

F. References

[1] https://www.ieabioenergy.com/wp-content/uploads/2019/07/IEA_grass-refinery_end.pdf

[2] https://biowert.com/products/agriplast

[3] https://biowert.com/products/agricell

[4] https://power4bio.eu/wp-content/uploads/2020/04/POWER4BIO_D3.4_Best_practices_of_bio-based_solutions.pdf

C8.2 Second-life materials based SHREDDING AND MIXING producing growing, insulating and construction material (Møllerup Brands)

A. General

Title

Second-life materials based SHREDDING AND MIXING producing growing, insulating and construction material (Møllerup Brands)

Keywords

hemp, eelgrass, end-of-life tyres, newspapers, wood, glass fibers, textile, polyester, micro greens, micro gardens, second life, insulating, construction, biomaterial

Example user / provider of technology

https://convert.as/

https://advancenonwoven.dk/

Contact person

- Convert: Peter Simonsen, pesi@kvadrat.dk, Møllerupvej 26 8410 Rønde / Denmark, +45 2023 0466
- Advance Non-woven: Claus Bonde Nielsen, cbc@advancenonwoven.com, Møllerupvej 26 8410 Rønde / Denmark, +45 8779 2900

B. Feedstock

Main feedstock

- Residues from agriculture (hemp production)
- Residues from aquatic biomass (eelgrass)
- Residues from forestry and forestry-based industry (wood)
- Other residues (tyres, paper, glass, textile, polyester)

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Shredding and mixing

TRL

9

Description of Technology

- The feedstock is shredded down to create more malleable fibres or granulates.
- The resulting building blocks are mixed to create a composite.
- The composite is crafted into a non-woven mat.
- The mat is pressed to acquire the desire compaction.

Key partners

- Feedstock providers
- Technology providers
- Converters
- Operation technicians
- Local administration
- Investors

Key resources

- Land
- Feedstock
- Technology
- Financial support
- R&D

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Biomaterials
- Plant pots
- Construction boards

Price, trade spot and location

-

E. Impact

Environmental Benefits

Each feedstock grants its own environmental benefits. Hemp and tyres residues are dealt with using these technologies, reducing the impact of said materials. The treatment of eelgrass prevents it from releasing the contained CO_2. On top of that, using the resulting materials minimizes the need for virgin materials. Where used, these materials support the DGNB certification.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

The hemp-derived material for micro gardens eases the access to horticulture to the broad audience, with the consequent mental and economic benefits. Besides, it is fully compostable.

The eelgrass-derived material insulation is comparable to that of mineral wool and it is fire-resistant, protecting both the environment and the people living in that building. Moreover, the costly removal of eelgrass from shores could now become a new source of income to the municipality.

F. References

[1] https://convert.as/

[2] https://advancenonwoven.dk/

C8.3 Forestry residue based MECHANICAL DISRUPTION producing pellets and chips for energy applications (MW Biomasse AG)

A. General

Title

Forestry residue based MECHANICAL DISRUPTION producing pellets and chips for energy applications (MW Biomasse AG)

Keywords

forestry residues, pelletisation, chipping, heat, energy

Example user / provider of technology

https://www.mwbiomasse.de/

Contact person

info@mwbiomasse.de, Salt stroke 10, 83737 Irschenberg / Germany, +49 8062 72894 60

B. Feedstock

Main feedstock

Residues from forestry and forest-based industry

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Mechanical treatment

TRL

9

Description of Technology

- The residues of forestry are mechanically disaggregated into wood chips.
- A fraction of those is further disrupted and reformed into pellets.

Key partners

- Landowners
- Feedstock providers
- Technology providers
- Operation technicians
- Logistics company

Key resources

- Land
- Feedstock
- Technology
- Logistics

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Wood pellets
- Wood chips

Price, trade spot and location

-

E. Impact

Environmental Benefits

- Climate change mitigation/adaptation
- Soil protection

Challenges for Implementation

-

Job Creation

-

Socio - Economic

The use of forestry residues reduces the probability of fires.

The company provides heat and energy consulting to help minimize expenses and environmental impact in homes and companies.

F. References

[1] https://www.mwbiomasse.de/

[2] LIVERUR Catalogue

C8.4 Wood residues based MECHANICAL DISRUPTION producing pellets energy applications (Biomassehof-Chiemgau)

A. General

Title

Wood residues based MECHANICAL DISRUPTION producing pellets energy applications (Biomassehof-Chiemgau)

Keywords

wood residues, sawing, forestry residues, pelletisation, chipping, heat, energy

Example user / provider of technology

https://www.biomassehof-chiemgau.de/

Contact person

info@biomassehof-chiemgau.de, Weidboden 3, 83339 Chieming / Germany, +49 086 693 567 20

B. Feedstock

Main feedstock

- Residues from forestry and forest-based industry
- Industrial wood waste

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Mechanical treatment

TRL

9

Description of Technology

- Waste wood products from industry, commerce and private households are collected, sorted, collated and sent for material and thermal recycling using the latest technology.
- Green waste is also used as feedstock. The woody component is filtered out via screening plants and chopped up. The remaining material components are intended for composting.
- Wood residues are mechanically disaggregated and reformed into pellets.

Key partners

- Feedstock providers
- Technology providers
- Operation technicians
- Logistics company

Key resources

- Land
- Feedstock
- Technology
- Logistics

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Wood pellets
- Compost

Price, trade spot and location

-

E. Impact

Environmental Benefits

70% of the feedstock is transformed into material recycling (primarily the Austrian chipboard industry), reducing the use of virgin materials and the environmental impact of their processing. The remaining 30% is used for thermal purposes, granting a bio-based substitute to petroleum-based technologies.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

The company also produces green electricity (solar panels) and biogas (see anaerobic digestion) for the local citizens, boosting the overall sustainability of the surrounding area.

F. References

[1] https://www.biomassehof-chiemgau.de/
[2] https://www.arjes.de/

C8.5 Machinery adaptation for PELLETISATION of lucerne (APS)

A. General

Title

Machinery adaptation for PELLETISATION of lucerne (APS)

Keywords

lucerne, pelletisation, feed

Example user / provider of technology

https://agroindustrialpascualsanz.es

Contact person

pascualsanzforrajes@hotmail.es, Calle del Sol 4, 50171, La Puebla de Alfinden / Spain, +34 976107117

B. Feedstock

Main feedstock

- Starch crops (lucerne)

Potential other feedstock

Any crop interesting as pellet.

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Mechanical treatment

TRL

9

Description of Technology

- The company has adapted their machinery to respond to the market conditions. It is designed to switch between forage production (April-November) to pellet production (December-March).

Key partners

- Technology providers
- Converters
- Operation technicians

Key resources

- Land
- Feedstock
- Technology
- Logistics

Capacity

-

Investment Costs

-

Operational Costs

-

D. Product(s)

Product Name(s)

- Lucerne hay
- Lucerne pellets

Price, trade spot and location

-

E. Impact

Environmental Benefits

The produced pellets are used as bioenergy.

Challenges for Implementation

-

Job Creation

-

Socio - Economic

This strategy optimizes the profitability of the company, while minimizing the extra investment needed for a parallel business line.

F. References

[1] https://agroindustrialpascualsanz.es

C8.6 Agricultural waste based MECHANICAL DISRUPTION producing pellets (Pelletierungs Genossenschaft)

A. General

Title

Agricultural waste based MECHANICAL DISRUPTION producing pellets (Pelletierungs Genossenschaft)

Keywords

meadow hay, corn cob, straw, husks, lucerne, pelletisation, heat

Example user / provider of technology

https://www.pelletierung.at/

Contact person

Alfred Kindler, info@pelletierung.at, Grazertorplatz 3, 8490 Bad Radkersburg / Austria, +43 664 96 377 30

B. Feedstock

Main feedstock

- Residues from agriculture
- Organic residues (corn cob from food consumption)

Potential other feedstock

Other residues from agriculture and additives can be subjected to a pelleting test to address their suitability.

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Mechanical treatment

TRL

9

Description of Technology

- Metals and sand are separated from the interesting portion of the feedstock.
- Said portion is grinded in a hammer mill.
- Outcome is fed to the drying system.
- Dried material is mixed in the desired proportions and pressed.
- Pellets are cooled.
- Dust and pellets are sorted using a sieve.
- Pellets are ready to be stored or transported to the end user.

Key partners

- Feedstock providers
- Technology providers
- Operation technicians
- Logistics company

Key resources

- Land
- Feedstock
- Technology
- Logistics

Capacity

1,500-2,000 kg pellets/hour

Investment Costs

-

Operational costs

-

D. Product(s)

Product Name(s)

- Pellets for litter, fuel, or feed

Price, trade spot and location

Around 270€/1,000 kg pellets, depending on the composition.

E. Impact

Environmental Benefits

Crop, feed and food wastes are recycled and given a second useful life. The employment of non-renewable energy resources is diminished. If pellets are used as feed, arable land can be sown with other interesting crops.

Challenges for Implementation

-

Job creation

-

Socio - Economic

The treatment of otherwise non-useful wastes is turned into a profitable business.

F. References

[1] https://www.pelletierung.at/

C8.7 Forestry residues based MECHANICAL DISRUPTION producing pellets (Elpis)

A. General

Title

Forestry residues based MECHANICAL DISRUPTION producing pellets (Elpis)

Keywords

fir, beech, pine, pelletisation, heat

Example user / provider of technology

https://www.elpis-mepe.gr/

Contact person

elpiscompany.elati@gmail.com, Kozani - Larissa National Highway km5, 50100 / Greece, +30 24610 24844

B. Feedstock

Main feedstock

- Residues from forestry and forest-based industry

Potential other feedstock

- Residues from forests of different composition
- Residues from agriculture

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Mechanical treatment

TRL

9

Description of Technology

- Feedstock is sorted.
- The outer layers of the materials are removed to ensure ash produced after combustion of the final product will consistently range below 5%.
- Prepared materials are mechanically broken down.
- Output is given a different form depending on the final product (mostly pellets, but also briquettes and charcoal).
- Final products are transported to the end user.
- The company guarantees products with a calorific value greater than 4800 calories.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company
- Investors

Key resources

- Feedstock
- Technology
- Logistics
- Financial support
- Political support

Capacity

-

Investment Costs

-

Operational costs

-

D. Product(s)

Product Name(s)

- Fuel (pellets)

Price, trade spot and location

-

E. Impact

Environmental Benefits

Apart from the environmental benefits of converting biological residues into a highly energetic product, Elpis reduces the impact of logistics by using 100% Greek materials.

Challenges for Implementation

-

Job creation

-

Socio - Economic

-

F. References

[1] https://www.elpis-mepe.gr/

C9. Business models based on Mechanical pulping

C9.1 Agricultural residue based MECHANICAL PULPING producing tableware and packaging material (Bio-Lutions)

A. General

Title

Agricultural residue based mechanical treatment and hot pressing producing tableware and packaging material (Bio-Lutions)

Keywords

Agricultural residues; tableware; packaging material; plant fibres; biodegradable

Example user / provider of technology

https://www.bio-lutions.com/

Contact person

-

B. Feedstock

Main feedstock

Agricultural residues

Potential other feedstock

Bagasse; Rice straw; Banana trunks; Sugarcane leaves; Tomato trunks; Cereal straw

Required Feedstock Quality

Strong fibres, not too fine (hardwood leaves), not too much like wood. Moisture content preferably in the range 10-15 wt.%.

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Mechanical treatment and hot pressing

TRL

9

Description of Technology

- Collection, drying and shredding of plant residues (e.g. tomato trunks, different types of straw, silphy, hemp etc. in Germany. And e.g. banana trunks, sugarcane leaves and bagasse, rice straw in India)
- Mechanical refining (patented process), without using heat or chemicals, into 'self-binding' micro and nano fibrillated fibcro® natural fibres. No components are extracted [1].
- The fibres are mixed with water and stirred into a pulp. The pulp is then pressed into shape (tableware or packaging material) and hot- pressed using bio-heat. The process requires 3.5 litres of water per 1 kg of product.

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

1,500 – 2,000 ton/year input in India; dry matter content not specified [2]. 400 – 850 ton/year output in India [3]. Bio-Lutions and PulPac (Dry Molded Fiber pioneer) are setting up a production facility in Germany, aiming at 72,000 ton/year input [4].

Investment Costs

8.3 million € [4]

Operational Costs

-

D. Product(s)

Product Name(s)

Disposable table ware and packaging items. Also other products are mentioned: Sporting goods, car panels, furniture, insulation for building and construction.

Price, trade spot and location

-

E. Impact

Environmental Benefits

Sustainable alternative to e.g. single-use non-biodegradable plastic tableware.

Challenges for Implementation

Facility has to be close to the feedstock sources (<60 km). Need for qualified workforce (expert knowledge in paper industry). Adequate infrastructure needed.

Job Creation

80 people work in India facility; in Europe this would be significantly less.

Socio - Economic

Valorisation of agricultural residues. Decentralized production possible. Raw material can be formed and coloured according to the user's needs.

F. References

[1] https://www.bioplasticsmagazine.com/en/news/meldungen/10-05-2017-Bio-Lutions-wins-Biobased-Material-of-the-Year-award.php

[2] https://www.bio-lutions.com/to-tackle-indias-growing-waste-problem-some-companies-are-changing-the-way-they-package-products/

[3] Power4Bio Catalogue - Bio-Lutions factsheet

[4] https://www.bio-lutions.com/category/press/

C10. Business models based on Combustion

C10.1 Oxydrogen COMBUSTION producing heat (ZP Victor Asenov)

A. General

Title

Oxydrogen COMBUSTION producing heat (ZP Victor Asenov)

Keywords

vegetables, greenhouse, heat, solar panels, water reuse, biomass waste, fertiliser

Example user / provider of technology

ZP Victor Asenov

Contact person

-

B. Feedstock

Main feedstock

- Solar energy
- Rain and well water

Potential other feedstock

-

Required Feedstock Quality

-

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Combustion

TRL

9

Description of Technology

- The electricity from solar panels and rain or well water are fed to a oxydrogen generator.
- Oxydrogen is a mixture of atomic oxygen and hydrogen at a ratio comparable to water. It is combusted, releasing water and 142,35 kJ heat/H gram.
- The greenhouse is heated 100% with renewable resources.

Key partners

- Technology providers
- Converters
  Local administration
- Investors

Key resources

- Land
- Technology
- Financial support
- R&D
- Political support

Capacity

0.6 hectares , 60 tonnes per hectare

Investment Costs

1.4 million euro

Operational Costs

-

D. Product(s)

Product Name(s)

- Vegetables

Price, trade spot and location

-

E. Impact

Environmental Benefits

Vegetable wastes produced in the greenhouse are sold to a nearby company to create composting and bio-fertilizers. The crops at ZP Victor Asenov are grown using said green fertilizers. If combustion heat is not enough, pellets from sunflower residues of local farmers are used. Overall, the environmental impact of production at the greenhouse has been minimized.

The sustainable all-year production of vegetables sold in the roundabouts reduces pollution due to food transport.

Challenges for Implementation

Financial support to kick off the main investments (such as the oxydrogen generator).

Job Creation

11 permanent employees, including people from a young generation of farmers and entrepreneurs.

Socio - Economic

The tightly intertwined relation of ZP Victor Asenov with other local businesses is an example of fruitful cooperation and benefits to the economy of the area.

F. References

[1] COOPID Success case – ZP Victor Asenov

C11. Business models based on Gasification

C11.1 Wood waste based THERMOLYSIS (GASIFICATION) producing renewable hydrogen (Hynoca)

A. General

Title

Wood waste based THERMOLYSIS producing renewable hydrogen (Hynoca)

Keywords

biomass, renewable hydrogen, Thermolysis

Example user / provider of technology

https://h2energy.ch/en/

https://www.h2gopower.com/

https://www.haffner-energy.com/

Contact person

Haffner Energy, contact@haffner-energy.com, 2 Place de la Gare, 51300 Vitry-le-François, France, +33 (0)3 26 74 99 10

B. Feedstock

Main feedstock

Wood waste

Potential other feedstock

Agricultural residues, recycled biomass

Required Feedstock Quality

-

Feedstock price, trade spot and location

90 €/tonne

C. Technology

Technology Name

Thermolysis

TRL

8

Description of Technology

- Hynoca exploits thermolysis, followed by thermochemical reactions like the steam reforming of natural gas.
- The first step is to transport and storage the feedstock (wood- based, agro- based and recycled- based biomass) then to decompose the biomass into thermolysis gas (initial flow of gas produced by the thermal decomposition of the biomass) and a biochar (carbonaceous solid product).
- The second step consists of treating the thermolysis gases in an equipment that will perform the cracking and hydrogen enrichment reactions by the "gas to water" reaction. This step is the key link in the destruction / cracking of long molecules, especially tar, to obtain a high energy syngas called "Hypergas" very rich in H_2 with the help of catalyst (ZnO).
- The following steps consist of separating, extracting and removing the residual CO_2 and CO from Hypergas and then purifying the hydrogen to a degree of purity of 99.97 % by means catalyst (CuO) and membranes.
- Finally, Hydrogen can be used for different applications as mobility, power generation or production of methane.
- Other Input Materials: catalyst

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

500 tonne/year

Investment Costs

5.4 million €

Funding Schemes: CAPEX

a. Financing: 2.7 M€ (0.9 M€ grant and 1.8 M€ repayable assistance)

b. Eligible 3.3 M€: 1 M€ Centrale Supélec, 0.3 M€ Communauté de Communes, 3.2 M€ Haffner Energy and 0.8 M€ SEM Vitry Energies.

Operational Costs

OPEX: Price of raw material; energy costs; labour costs.

Public Support: Investment funds EUREFI proposed by CAISSE DES DEPOTS and obtaining 1,7 M€ of PRI (Partenariat Régionaux d'Innovation) from BPI France et la région Grand-Est.

D. Product(s)

Product Name(s)

- Hydrogen
- Secondary products are hypergas and biochar

Price, trade spot and location

- Hydrogen: 10 €/kg

E. Impact

Environmental Benefits

Use of renewable resources. Carbon neutral conversion process.

Challenges for Implementation

-

Job Creation

This solution needs specific skilled workforce in order to be transferred to the rural environment. In addition, new jobs opportunities in regards to infrastructure, logistics and supply should be created.

Socio - Economic

Decentralized production: the plant can be built up and operated at almost any location, its size can be adjusted to the local needs (contribution to circular economy). Local and renewable raw materials used in the process.

Competitiveness of the solution - The main advantages are the production of hydrogen with high quality (degree of purity of 99.97 %) and ultra-competitive prices (lower by 20 to 60 % than those of other renewable H_2) achieving hydrogen selling price lower than 4 € / kg respect to the 10 €/kg of the current prices. Other important advantage is an energy efficiency rate exceeding 70 %.

Role of the biorefinery in the rural ecosystem - Local and renewable raw materials are used in the process as wood, agro-waste and recycled biomass. This location of the feedstock allows for the on-site production avoiding expensive logistics and boosting the industrial network in the region.

Contribution to social impact - The utilization of buildings and machinery needed in the process or the use of hypergas excess as an energy source for steam and heat production in farms and in auxiliary facilities can be taken into consideration.

De-centralized bioproducts production - The plant can be built up and operated at almost any location, its size can be adjusted to the local needs, achieving less dependency on large plant supply. Different challenges have to be overcome regarding to the operation cost and flexibility of the production.

Advantages for farmers - The production of hydrogen can be sized to the consumption and located where needed, so a centralized plant is not needed and local distribution of the product is improved. Others advantages would be the possible use of the secondary products generated as the biochar as soil amendment in the fields and the indirect incomes derived from the implementation of new ways of waste management.

F. References

[1] https://www.haffner-energy.com

[2] https://hydrogentoday.info/news/4534

[3] https://solarimpulse.com/companies/haffner-energy

[4] https://www.verif.com/bilans-gratuits/HAFFNER-ENERGY-813176823/

[5] https://www.transplo.com/FR/Vitry-le-François/1398295953810683/Haffner-Energy

[6] https://www.actu-environnement.com/ae/news/hydrogenerenouvelable-biomasse-33338.php4

[7] https://fuelcellsworks.com/news/france-green-hydrogen-in-2021-forstrasbourg-buses/

[8] https://infolocs.files.wordpress.com/2019/08/190826_cp_rhynoca_ok.pdf

[9] http://www.hydrogenfuelnews.com/france-to-demonstrate-theproduction-of-hydrogen-from-biomass/8536346/

[10] Power4Bio Catalogue - Hynoca factsheet

C12. Business models based on Torrefaction & carbonization

C12.1 Sewage Sludge based HYDROTHERMAL CARBONIZATION (HTC) producing bio-coal (TerraNova)

A. General

Title

Sewage Sludge based hydrothermal carbonization (HTC) producing bio-coal (TerraNova)

Keywords

Sewage sludges, hydrothermal carbonization, Biocoal, Phosphorous

Example user / provider of technology

https://terranova-energy.com

https://ingelia.com

https://www.c-green.se/

https://htcycle.ag/

https://www.suncoal.com

Contact person

TerraNova Energy GmbH, Marc Buttmann, marc.buttmann@terranova-energy.com, Schirmer Strasse 61, D-40211 Düsseldorf, Germany, +49 211 54413096

B. Feedstock

Main feedstock

Sewage Sludges.

Potential other feedstock

Forestry residues, agricultural residues, food residues, organic fraction (urban solid wastes)

Required Feedstock Quality

Dry matter content: minimum: 5 w-% and maximum: 30 w-%

Feedstock price, trade spot and location

-

C. Technology

Technology Name

Hydrothermal carbonization

TRL

9

Description of Technology

- Dewatered sewage sludge with a dry matter content of 5-30% is conveyed into the input heat exchanger. Then, the preheated sewage sludge is carbonized in an agitated reactor under the addition of catalyst for 3 hours at a temperature level of around 200°C.
- The resulting coal slurry is cooled down and dewatered to a dry matter content of 65-70%.
- The extracted water contains valuable nutrients like Phosphorous and Nitrogen that can be recovered as fertilizer.
- By means of fixation to Calcium Silicate Hydrate (CSH), the Phosphorous is bound and extracted in a filter press.
- The sludge water is not evaporated but mechanically extracted in a very energy efficient way saving up to 80 % energy compared to drying. Another advantage is that biomass with high water content can be used with this technology.
- Other Input Materials: heat, catalyst, power

Key partners

- Feedstock providers
- Converters
- Operation technicians
- Logistics company

Key resources

- Feedstock
- Technology
- Logistics
- R&D Development

Capacity

-

Investment Costs

2.1 million €

Operational Costs

28 €/ton input DM

D. Product(s)

Product Name(s)

- Biocoal: The slurry coal or bio-coal produced can be sold to heat and power plants, cement plants and waste-incineration plants and is used to generate neutral CO_2 energy.
- Phosphorus: Phosphorus is recovered as part of the process and can be used as particularly rich organic fertilizer.
- Side Product: Filtrate (rich in P and N)

Price, trade spot and location

- Biocoal: 500 €/tonne in Germany
- Economic value increase: 28 (€ output / ton input DM)

E. Impact

Environmental Benefits

- Phosphorous recovery
- Destruction and safe disposal of pollutants (e.g. toxins, heavy metals, organic compounds and pathogens)
- Reduction of disposal volume by 75%
- 80% less energy demand than drying.

Challenges for Implementation

Confidence in the current industrial plants. A challenge is the cost of the large number of equipment (CAPEX) and infrastructure needed to set-up the system.

Job Creation

Due to the fact this solution is easily implemented in rural areas to small scale, new jobs can be created by the cooperation of the farmers in the activities developed by other industrial partners.

Socio - Economic

Competitiveness of the solution - The TerraNova® Ultra process can be a solution to the energy demand from farms and to the limits of organic disposal on the agricultural lands becoming more and more restricted due to increasing environmental requirements. One of the competitive advantages of this technology is its flexibility to treat a large variety of sewage sludge/organic residues with high moisture content.

Role of the biorefinery in the rural ecosystem - This solution can use local residues (agricultural wastes) contributing to the cooperation with other industrial partners near to the farm. Solution can produce locally products useful to farmers with a high added value as fertilizers for lands or energy carriers for energy supply in the farm.

Contribution to social impact - The implementation of this solution in the rural environment can lead an improvement on living conditions of the rural communities, avoiding problems generated from the traditional disposal of sewage sludges and helping to generate a closed valorization value chain.

De-centralized bioproducts production - The adoption of this sewage sludges conversion technology in rural communities can help to guarantee the supply of low cost raw materials for primary production (less dependency). The operation cost in the farm (mainly the cost regarding the energy production) would be reduced with the use of the bio-coal and maybe with fertilizers formulated from nutrients recovered. The GHG emissions would be reduced in the same way.

Advantages for farmers - The implementation of an industrial collaborations between wastewater treatment plants, waste management companies and energy and fertilizer producers in order to apply the products and by-products from the HTC process would generate incomes for the farmers derived from the reduction of cost for the acquisition of raw materials, mainly fertilizers formulated from the recovery of nutrients (P and N), bio-coal for energy self-consume and HTC filtrate for co-digestion with other agricultural residues.

F. References

[1] Aqua and gas Journal (num 4). 2012. Hydrothermale Carbonisierung. Neue wege in der Klärschlammaufbereitung.

[2] Christian Remy, Jonas Warneke, Boris Lesjean (KWB),Julien Chauzy (Veolia DT), Christophe Sardet (Veolia Wasser).,2013. HTC- Check: Energiebilanz und Carbon footprint von Referenztechnologien und HTCProzess bei der Klärschlammentsorgung. HTC-Workshop

[3] Power4Bio Catalogue - TerraNova factsheet

Annex D: Catalogue of social innovations related to small-scale bio-based solutions

D1. L'Atelier Paysan

Description: This cooperative of small-scale farmers, employees, and agricultural development organizations is a social innovation dedicated to empowering farmers by disseminating agricultural knowledge and promoting technical and technological sovereignty. Through an open source resource platform for farm production tools, the collective aims to collectively develop tools adapted to the regional agro-ecological practices. This platform provides access to online resources, videos, trainings on construction and autonomy, and knowledge exchange sessions.

Activities: The cooperative supports farmer-led research and development, disseminates open source materials for organic farming, and leads training sessions to create self-sufficient farming systems. The tools developed are adapted to the context in which they are used in concrete terms. The cooperative also encourages farmers to think innovatively and come up with sustainable solutions to the problems they face.

Actors involved:

- Civil society : the Association Groupement des Agriculteurs Biologique du Finistère, the Association Agriculteurs Bio de Cornouaille, the Association Vignes Vivantes
- Industry: network of partners working on organic farmers (FNAB, FNCIVAM, FADEAR, RENETA).

Impact for bioeconomy development: The impact of this social innovation on bioeconomy development is significant, as it enhances collaboration among key rural actors and their involvement in decision-making, ensuring there is critical feedback on the technologies developed and promoted. The cooperative raises awareness and provides education and training sessions to build acceptance for technologies and nutrient recycling practices.

Social impact: In terms of social impact, the cooperative's efforts in disseminating knowledge and promoting technological sovereignty result in increased awareness and utilization of technologies, as well as access to online resources.

D2. Organic Food Valley (EkoLubelszczyzna)

Description: This social innovation project aims to develop a cooperative network between different actors involved in the production, processing, and marketing of organic food and eco-products/services.

Activities: By creating an eco-region in cooperation with local authorities, the project seeks to establish a platform that can promote and create organic food. The project also aims to enhance cluster cooperation among scientific institutions, innovation entities, and entrepreneurs in the organic industry. This will increase the competitiveness and innovation of cluster participants and contribute to the creation of a lively and active agricultural region.

Actors involved:

- Industry: producers of organic food and eco-products/ services, organic farmers
- Civil society: organizations of agricultural consulting and certification, other ecological organizations
- Academic & Research Institutions: Universities and research institutions.

Impact for bioeconomy development: In terms of impact for bioeconomy development, the project will increase the export of goods and services, preserve the environment and agricultural landscape, and enable the economic development of rural areas by diversifying and increasing the income of people living in those areas.

Social impact: The social impact of the project includes the generation of jobs and access to the network for all actors involved in the organic industry, including producers, farmers, services, ecological/organic shops, organizations of agricultural consulting and certification, and other ecological organizations.

D3. Rural HUB

Description: Rural HUB is a non-governmental organization that has created an innovative co-working space and educational complex in order to connect socially responsible individuals and organizations with traditional farmers. The organization offers comprehensive educational programs, social business design training, and sustainable farm development, among other activities. Its target groups are individuals of all ages living in rural areas who wish to start socially responsible and innovative individual or family businesses, young people, and women.

Activities: Rural HUB is committed to the development of the local community and uses its services and products to preserve nature, tradition, and households. It encourages and supports the development of the local community through the development of a unique touristic offer and specific domestic products and services. In addition, it prepares young people for green jobs and provides service learning opportunities.

Actors involved:

- Government agencies and public bodies: Centre for Socially Responsible Entrepreneurship, Municipality Sokobanja, Erste Bank a.d. Novi Sad, GIZ YEP
- Civil Society: villagers, new-comers.

Impact for bioeconomy development: Rural HUB's impact on bioeconomy development is significant. It promotes sustainable living through the ecovillage model across the country and region, and opens dialogue on sustainable living development policies and measures among relevant stakeholders. The organization provides sustainable development education workshops and trainings for the local community, develops human resources in ecovillage design and social business, and raises awareness of diverse aspects of sustainable living. Additionally, it supports the local community to apply different examples of eco-housing and appropriate eco-technology solutions, and establishes cooperation with the Vrmdza community. The organization also supports the building of eco-tourism facilities and accommodation capacities.

Social impact: Rural HUB's social impact is also noteworthy, as it provides financial support, generates jobs, and provides education and training opportunities for the local community. Overall, Rural HUB's efforts have resulted in the development of a sustainable and socially responsible ecosystem that promotes the preservation of nature and tradition while supporting the growth of innovative businesses and green jobs.

D4. ARDAC

Description: The reforestation and sustainable forest management project in a remote rural area aimed to address deforestation and local development. One of the innovative aspects of the project was the management of non-wood forest products from the biggest laurel forest in Lebanon.

Activities: A feasibility study and business plan for the extraction of laurel essential oil were developed, and specific equipment for the extraction of essential oil was designed and industrialized. Locals were trained on how to harvest laurel products sustainably and process them for oil extraction. In addition, socio-economic and environmental needs of residents were identified, and training workshops were designed and delivered in response to these needs. This included promoting job opportunities as part of an eco-tourism plan, and a number of inhabitants were trained on processing and marketing laurel products while also being involved in eco-tourism activities.

Actors involved:

- Government agencies & public bodies: Institute of the Environment (IoE)
- Academic & Research Institutes: University of Balamand (UOB)

Impact for bioeconomy development: The project had a significant impact on bioeconomy development, as it ensured the sustainable collection of laurel leaves and berries for the extraction of essential and crude oil, respectively. The specific equipment designed for the extraction of essential oil also contributed to the development of the bioeconomy. The project also contributed to sustainable forestry, including efficient and sustainable use of natural resources and the involvement of young people in sustainable rural activities. Additionally, the project provided job opportunities for poor villagers and jobless residents, thereby empowering vulnerable people and contributing to a secure society.

Social impact: The social impact of the project was also notable, as it generated jobs, utilized technology, and involved public participation. The project helped to improve the livelihoods of locals by providing them with new skills and job opportunities. The eco-tourism plan also provided an opportunity for locals to showcase their natural resources and cultural heritage while also generating income. Overall, the project was a success in addressing deforestation and local development while also contributing to the bioeconomy and social development.

D5. Gela Ochsenherz

Description: The Demeter farm in Lower Austria is an example of a partnership format in the social innovation context. This farm is collaboratively run by employees and a group of around 300 consumers, known as "harvest-sharers", who have founded an association to work together with the farm enterprise.

Activities: The consumers finance the operation of the farm enterprise and support it in other ways, such as voluntary work. This model allows the farm to detach from the constraints of the profit-driven market and to withstand risks of weather and markets with a diverse and labour-intensive form of agriculture. What's interesting about this model is that there is no price for individual products; instead, the members get their share of the harvest and can meet their requirements for vegetables in free weekly take-outs. This blurs the role of producer and consumer, as consumers may also help in production and distribution. The Demeter farm covers 4 hectares throughout the year with about 80 kinds of vegetables, herbs, and soft fruits. It almost exclusively uses saved seed, which means that the farm can maintain a high level of crop diversity and resilience.

Actors involved:

- Industry: farmers, producers
- Civil Society: consumers

Impact for bioeconomy development: The partnership format of the farm has several impacts on bioeconomy development, including the viability of the farm holding, job creation, and more resilience because of crop diversity.

Social impact: The social impact of this model includes access to networks, job generation, and public participation.

D6. Federatie Landbouw en Zorg - Network Care farming

Description: The organization is a foundation that aims to professionalize the agriculture sector and facilitate regional organizations in caring for farmers. As a foundation, it is likely a non-profit organization that receives funding from donations or grants.

Activities: One of the key activities of the organization is networking, which involves building relationships and connections with individuals and organizations in the same or related fields. By doing so, the organization can better understand the needs of stakeholders and facilitate cooperation among them. The organization also provides assistance and advice to stakeholders in the agriculture and rural sector, which can help them overcome challenges and make informed decisions. In addition to working with stakeholders in the agriculture and rural sectors, the organization also engages with individuals and groups outside of these sectors through public participation. This can include engaging with consumers, policymakers, and community organizations to raise awareness about the importance of agriculture and care and to promote sustainable practices. Another important activity of the organization is experimentation, which involves testing new ideas and approaches to address challenges and promote innovation. By doing so, the organization can identify new solutions and best practices that can benefit stakeholders in the agriculture and care sectors.

Actors involved:

- Industry: farmers
- Civil Society regional farm care organizations, client organizations
- Government agencies and public bodies.

Impact for bioeconomy development: The impact of this social innovation for bioeconomy development includes offering access to networks, sharing knowledge, and providing a social network sustaining the future of the farm and offering clients a better quality of life. By doing so, the organization can promote economic and social benefits for stakeholders and contribute to the growth and sustainability of the bioeconomy.

Social impact: The social impact of this innovation includes providing access to networks, assistance and advice, and public participation. By doing so, the organization can empower stakeholders in the agriculture and care sectors and promote greater awareness of their importance to society.

D7. Land Sharing for food and social good

Description: Land Sharing for Food and Social Good is a social innovation project that focuses on promoting and preserving traditional farming techniques to create sustainable, multifunctional farms that benefit the environment and the community. The project recognizes the value of these techniques and aims to reintroduce them into modern times through intergenerational cooperation between elderly farmers and unemployed people from towns. This cooperation helps to transfer knowledge about past techniques of multipurpose organic farming from older farmers to younger unemployed individuals, providing them with new skills and opportunities. This transfer of knowledge not only benefits the younger generation but also helps to preserve valuable farming techniques that may be lost without this intervention.

Activities: The project engages in various activities such as networking, training, teaching, production of goods, services delivery, social media, public participation, fundraising, project management, marketing, and promotion, as well as action-research.

Actors involved:

- Industry: InTerCer, local farmers
- Government agencies and public bodies: regional authorities
- Civil society: disadvantaged people

Impact for bioeconomy development: The impact of the project on bioeconomy development includes the transfer of knowledge related to organic agriculture practices, the creation of a new economic segment of social entrepreneurship, and the reintroduction of agriculture with a low carbon footprint. Additionally, the project contributes to nature conservation by promoting sustainable farming practices.

Social impact: The project also has a significant social impact by providing education and training, assisting and advising elderly farmers, and creating intergenerational cooperation between the older generation and the younger generation. Ultimately, the Land Sharing for Food and Social Good project seeks to improve the well-being of farmers, unemployed individuals, and the broader community by promoting sustainable farming practices and preserving traditional farming techniques.

D8. Mazi

Description: Mazi is a company that is taking the lead in the regeneration of degraded farmland in the Mediterranean through sustainable agriculture practices. This community-supported agroforestry farm is run by a diverse intergenerational team from multiple nationalities who share a passion for restoring the land and promoting a more holistic approach to farming. Mazi recognizes the importance of working with nature, not against it, and adopts the 'syntropic' model of agriculture. This method mimics nature's patterns in everything the farmers do, from farm design to crop choices, to ensure a diverse and resilient ecosystem that benefits both the environment and the community.

Activities: Through its community-supported model, Mazi connects directly with consumers and builds a strong network of support for its mission. Members receive fresh, locally-grown produce while providing financial and other forms of support to the farm. This not only helps to ensure financial sustainability but also fosters a sense of community and connection between the farm and its supporters. Mazi's innovative approach to sustainable agriculture combines traditional and modern practices to restore degraded farmland and promote the well-being of both people and the environment. Local farmers and volunteers are also actively involved in Mazi's activities, making it a collaborative effort for a better future.

Actors involved:

- Industry: local farmers
- Civil society: volunteers

Impact for bioeconomy development: The impact of Mazi on bioeconomy development is immense. By renewing existing resources and regenerating damaged ecosystems, Mazi is providing a local and healthy production system that promotes sustainability. Moreover, by introducing and promoting the 'syntropic' model of agriculture, Mazi is contributing to a larger movement towards ecological farming practices.

Social impact: Overall, Mazi's impact on society is not limited to just agriculture but also extends to the production system, and assistance and advice to local farmers and communities. Mazi truly represents a unique and inspiring approach to sustainable agriculture that is making a difference in the world.

D9. Integrated Ecosystemic value-enhancement of the Guadeloupe Forest Agrobiodiversity (VALAB)

Description: The Integrated Ecosystemic value-enhancement of the Guadeloupe Forest Agrobiodiversity (VALAB) is a project that aims to promote sustainable vanilla production while also preserving forest ecosystems and enhancing the livelihoods of forest users. It operates in a context where agricultural production in the forest undergrowth has been poorly addressed by research and development institutions and projects in Guadeloupe. VALAB recognizes the importance of balancing economic, ecological, and social considerations in agricultural practices. Through its focus on multifunctional value-enhancement, VALAB aims to reconcile vanilla production with forest conservation, recognizing the importance of maintaining the ecological balance of the forest ecosystem.

Activities: The project was developed by the Union of Guadeloupean agricultural vanilla producers (SYAPROVAG) as a more sustainable and diversified agricultural production model in the forest undergrowth after the failure of monocultural vanilla production in 2011. VALAB represents an innovative and necessary approach to sustainable vanilla production and forest conservation, promoting multifunctional value-enhancement and diversified agricultural production, and contributing to the well-being of forest users, local communities, and the environment in Guadeloupe.

Actors involved:

- Industry: SYAPROVAG (Union of Guadeloupean agricultural vanilla producers)

Impact for bioeconomy development: The impact of VALAB on bioeconomy development includes successful collective action by farmers to engage in the project, a shared vision of the forest to create added value to agricultural products from the forest, increased income for farmers, employment opportunities for rural youth, and maintenance or increase of the level of biodiversity in the forest.

Social impact: The social impact of VALAB includes income and jobs generation for forest users and local communities.

D10. Big Akwa - Fish farming in a new innovative way – symbiosis with pulp mills

Description: The social innovation "Big Akwa - Fish farming in a new innovative way - symbiosis with pulp mills" is a company that focuses on sustainable and resource-efficient food production through industrial symbiosis. The company combines resources between fish farming and pulp mills to achieve lower costs and higher efficiency while reducing negative climate and environmental impacts.

Activities: This social innovation has several activities, including food production using bio-based industrial side streams. The actors involved in this innovation include pulp and paper mills and technology companies.

Actors involved:

- Industry: pulp and paper mills, technology companies

Impact for bioeconomy development: This social innovation has significant impacts on bioeconomy development, as resource and energy efficiency are key focuses of this innovation. The technology can be paired with any pulp or paper mill, helping the local economy and providing a fresher sustainable product. Based on existing global pulp production capacity, the technology has the potential to farm 50,000 tons of sustainable fish in Sweden (5 times the actual aquaculture production) and 1.2 million tons globally at a reduced cost. The innovative technology has the potential to create more sustainable pulp and aquaculture business models.

Social impact: In terms of social impact, this innovation provides a more sustainable production system and utilizes innovative technology to achieve sustainable and efficient food production.

D11. Name: Agtira - Tomato farming in symbiosis with fish farming

Description: In terms of resource and energy efficiency, the closed-cycle system implemented by Agtira is highly beneficial. By using the water from the fish farm to nourish the greenhouse, the company is able to significantly reduce water consumption, which is an important resource in agriculture. Additionally, the fact that the system operates in a closed cycle means that there is no need to dispose of waste water or nutrients, which is both cost-effective and environmentally sustainable. The system also helps to reduce transport needs, as the produce can be grown on-site and sold directly to consumers in restaurants and grocery shops. This can help to reduce the carbon footprint associated with transportation and increase the freshness of the produce, which can lead to longer shelf life and lower food waste.

Activities: Circular food production - Agtira engages in circular food production, which means that they use the waste products from one process to feed another process, creating a closed loop of production.

Actors involved:

- Civil society: restaurant, grocery shops, actors in the food industry, consumers

Impact for bioeconomy development: Agtira's innovative closed-cycle system for growing tomatoes and fish has a significant impact on bioeconomy development. Firstly, the system is highly resource and energy-efficient, as waste products are used to nourish other parts of the system. Additionally, by growing food where the consumer is, Agtira reduces the need for fossil-based transport, which is better for the environment. The closed circulating systems used by Agtira also reduce water consumption by up to 95% compared to conventional cultivation, which is a huge benefit to the environment.

Social impact: In terms of social impact, Agtira's production system has a positive impact on the industry by reducing waste and increasing efficiency. The innovative use of technology to create a closed-cycle system for food production has the potential to change the way we think about food production and consumption. Consumers can benefit from having fresh, locally grown produce available year-round, and the potential to reduce food waste by harvesting and placing vegetables on the shelf the same day they are harvested. Overall, Agtira's innovative closed-cycle system has the potential to make a significant contribution to the development of a more sustainable and efficient bioeconomy.

D12. Collection of food waste

Description: The Örnsköldsvik municipality has implemented an innovative waste management system that prioritizes the recycling of food waste. In this system, each household collects their food waste separately, which is then picked up by the municipality's waste management company. The collected food waste is transported to a biogas plant in Härnösand, where it is recycled through digestion to extract vehicle gas in the form of biogas. This process is highly efficient as food waste contains a significant amount of energy. In fact, just 1 kg of food waste can drive a biogas car for almost 2 kilometres. Apart from producing biogas, the process also generates biofertilizer. By returning the biofertilizer to agricultural land, the cycle is closed, and the benefits of food waste are maximized. This means that the waste generated by households is not only effectively managed, but it also contributes positively to the agricultural sector. The Örnsköldsvik municipality's waste management system is not only environmentally sustainable, but it is also economically efficient. The production of biogas and biofertilizer from food waste is an innovative and practical solution to tackle the issue of waste management. The system has a positive impact on the environment and society by reducing the amount of food waste that ends up in landfills, generating renewable energy, and producing biofertilizer that can be used to enhance agricultural production.

Activities:
The main activity of Örnsköldsvik municipality is waste handling and energy recovery through the recycling of food waste.

Actors involved:
- Government agencies & public bodies: municipalities
- Civil Society: citizens

Impact for bioeconomy development: The recycling of food waste has a significant impact on the bioeconomy development. The process is highly resource and energy-efficient, and food waste contains a lot of energy that can be converted into biogas. The production of biogas and biofertilizer from food waste contributes positively to the agricultural sector and enhances agricultural production.

Social impact: The waste management system implemented by Örnsköldsvik municipality has a positive impact on the production system, food waste management, and energy generation. The system effectively manages waste and generates renewable energy and biofertilizer that can be used to enhance agricultural production. The system has the potential to reduce the environmental impact of waste management and contribute positively to the bioeconomy development.

D13. Cloughjordan EcoVillage

Description: Cloughjordan EcoVillage is a unique development that emphasizes sustainable living practices and community engagement.

Activities: As an educational community partnership, the ecovillage offers opportunities for research and educational visits to primary, post-primary, third level, and corporate groups. The ecovillage includes more than 50 low-energy homes and work units, a biomass-fueled district heating system, and a green enterprise center with high-speed broadband. The village also features a member-owned community farm and 50 acres of land for allotments, farming, and woodland.

Actors involved:

- Industry: Local farmers
- Civil Society: volunteers, citizens

Impact for bioeconomy development: One of the most significant impacts of Cloughjordan EcoVillage is its contribution to bioeconomy development. The ecovillage demonstrates an environmentally sustainable community model that is done in a collaborative and co-creative manner. The project facilitates quality academic research into the development of the ecovillage and contributes to harvesting valuable lessons from the community. The ecovillage's approach to sustainable living emphasizes localization as an alternative to consumer capitalism and prioritizes low carbon impact, zero waste, renewable energy, and organic food. The strong ethical worldview of the ecovillage is also an essential element of its impact on bioeconomy development.

Social impact: Furthermore, the social impact of Cloughjordan EcoVillage is significant. The project's production system emphasizes a collaborative approach that involves local farmers, volunteers, and citizens. The ecovillage's research activities contribute to the documentation of its development and the advancement of sustainable living practices. Overall, Cloughjordan EcoVillage is a pioneering example of how community-driven developments can contribute to bioeconomy development and sustainable living practices while enriching the social fabric of local communities.

D14. Shared composting

Description: Shared composting is an innovative approach to urban agriculture that is gaining popularity around the world. The "Root" Foundation, a Bulgarian organization focused on promoting sustainable development, is at the forefront of this movement. By working with beekeepers, permaculture farms, herbalists, biodynamic farmers, and environmental organizations, the foundation is able to restore and conserve biodiversity, the environment, and natural resources, with a particular focus on the soil.

Activities: Through its activities in architecture, agriculture, education, and culture, the foundation integrates environmental principles and values in the development and validation of different strategies, models, and technologies for sustainable development in cities and their peripheries. One of their notable achievements is the establishment of a Sustainable Practices Platform with 32,000 followers and 33 active users in 2020.

Actors involved:

- Industry: beekeepers, permaculture farms, craftsmen, herbalists, biodynamic farmers
- Civil Society: Environmental organizations

Impact for bioeconomy development: The foundation's impact on bioeconomy development is significant, as evidenced by its successful funding proposal for the "First steps to create a system for shared composting and growing edible plants in urban environments" project under the Europe Programme. This project has the potential to revolutionize urban agriculture and create new opportunities for sustainable development in cities.

Social impact: Aside from environmental impact, the "Root" Foundation has a significant social impact. It promotes public participation in sustainable development, provides education and training, and offers assistance and advice on various sustainable practices. The foundation also provides online resources to help people learn more about sustainable development and food waste management.

D15. Planeta Madera

Description: Planeta Mandera is an initiative that focuses on promoting sustainable forest management in Spain. The organization disseminates information about the benefits of utilizing forest resources in a sustainable manner and encourages the implementation of practices that support this goal.

Activities: One of the main activities of the initiative is to promote the use of wood throughout its entire life cycle, from the forest to the end consumer, in various industries such as sawmills, board and veneer industries, furniture manufacturing companies, pallets, containers and packaging, wooden doors or carpentry, biomass, and structural timber for construction.

Actors involved:

- Civil Society: UNEmadera, the Spanish Wood and Furniture Business Union

Impact for bioeconomy development: The impact of Planeta Mandera on bioeconomy development is significant. Sustainable forest management and the use of wood are essential tools to fight against the hollowing out of Spain, as they generate value and wealth in rural areas and prevent depopulation, as well as being an indispensable element to meet the Sustainable Development Goals (SDGs).

Social impact: In terms of social impact, Planeta Mandera promotes public participation by raising awareness about sustainable forest management and the importance of utilizing forest resources in a responsible manner. The organization also provides assistance and advice to those who are interested in implementing sustainable forest management practices.

D16. Apadrina un olivo

Description: Apadrina un olivo is an initiative that promotes the sponsorship of abandoned olive trees in the small town of Oliete, Teruel. Sponsors can visit their sponsored tree and receive a reward of 2 litres of olive oil each year. The initiative has successfully recovered over 10,000 olive trees in the last eight years with the support of more than 5,000 sponsors. This has created 10 job positions and attracted over 18,000 visits to Oliete.

Activities: Crowdfunding initiative encouraging people to 'adopt' an olive tree through a website with the options for a 'gift adoption', 'yearly adoption' and 'monthly adoption'. The stepparent christens the olive tree and receives photos periodically of it (through an app), and also information about the weather conditions of the area, of the work being done on it, etc. And also two litres of extra virgin olive oil from the olive trees part of the project. Besides, field trips are organised to visit the adopted olive trees promoting rural tourism in the area. The true owners of the olive trees receive the 10% of the harvest from the 6th year that the olive tree enters the project. It also runs volunteer days for people to help restore the olive trees as well as working closely with the ATADI organisation to provide days for those with learning disabilities to help restore the trees.

Actors involved:

- Industry: farmers
- Civil Society: citizens

Impact for bioeconomy development: The initiative has promoted the opening of an oil mill where people outside the project can bring their own olives and get their oil, securing the recovery of their own olive trees. This oil mill provides a local service, which promotes the development of the local economy.

Social impact: The initiative has raised awareness about the importance of preserving traditional farming practices and cultural heritage, as well as the potential for crowdfunding initiatives to support local initiatives and rural development.

D17. Haver til maver

Description: Haver til Maver is a non-profit organization that focuses on promoting sustainability, food culture, and health among children and young people in Denmark. They do this by providing school gardens where children can learn about gardening, outdoor cooking, and nature communication.

Activities: The program is an open outdoor school, where children and their teachers spend up to 8 full school days in the garden during the growing season. Each class has their own plot of land, where they plant, tend, and harvest their own crops. In addition to gardening, children engage in various activities within nature, the garden, and outdoor kitchens. These activities cover different subjects such as biology, reading, writing, mathematics, history, art, and more.

Actors involved:
- Civil Society: teachers, school managers, nature guides, chefs, volunteers, policy makers
- Industry: farmers

Impact for bioeconomy development: The impact of Haver til Maver is multi-factorial. School gardens provide children with life skills and help them understand the basics of nature and resources. They also offer an alternative learning environment for children who may not be motivated by traditional classroom teaching. Moreover, Haver til Maver promotes a different way of learning, playing, and living. When children grow, harvest, and cook together, they learn how to care for themselves, each other, and the planet in a safe and magical way. This has significant social impact on awareness raising, education/training, and public participation, with children developing a deeper appreciation for nature and the environment.

Social impact: Overall, Haver til Maver is an excellent example of how non-profit organizations can contribute to sustainable development by providing innovative programs that educate and empower children and young people.

D18. Too good to go

Description: Too Good To Go is a Danish success case in the fight against food waste. In just 6 years, 5 entrepreneurs have developed their business from an apartment in Copenhagen to include 1,400 business partners in 17 countries. The purpose of Too Good To Go is to reduce food waste worldwide. The concept is based on a service with a mobile application that connects customers to restaurants and stores that have surplus unsold food. Customers can buy whatever food the outlet considers surplus to requirements, without being able to choose ('lucky bags') at a much lower price than normal. The food on the app is priced at one-third its original price. The service covers major European cities and was introduced to North America in 2020. In 2022 Too Good To Go was the fastest-growing sustainable food app startup by number of downloads. Today, 47.5 million people have their app on their phone.

Activities: Fighting food waste via an app. To Good To Go is developing their list of activities to go beyond linking restaurants etc. with costumers, as they are developing a knowledge hub, has become a company that both politicians and companies listen to for good ideas to reduce food waste, recording videos about food waste to put on YouTube as well as making educational material and together with the dairy company Arla to create food waste schools.

Actors involved:
- Civil Society: restaurants, retail, grocery shops, hotels, manufacturers, consumers, policy makers

Impact for bioeconomy development: Reducing food waste is a crucial aspect of bioeconomy development, and it has a significant impact on the environment, society, and the economy. By reducing food waste, we can save resources, reduce greenhouse gas emissions, and create new opportunities for sustainable development. A reduction in food waste can also lead to the creation of new products and services, such as composting, biogas production, and new food products made from food waste. Additionally, by reducing food waste, we can reduce the demand for land, water, and other resources needed to produce food, which can free up these resources for other purposes, such as reforestation or renewable energy production.

Social impact: Reducing food waste has a significant impact on society. By reducing food waste, we can create new jobs, reduce costs for households, and improve access to nutritious food. Additionally, reducing food waste can help reduce hunger and food insecurity by redirecting food to those in need. By managing food waste more effectively, we can also reduce the negative impacts of waste on communities, such as odour and vermin. Finally, by reducing food waste and promoting sustainable development, we can create a more equitable and just society that benefits all.

D19. Kafsimo

Description: Kafsimo is a community-based project in Northern Greece that collects used coffee grounds from cafes and converts them into clean biofuel. Their aim is to reduce organic waste sent to landfills while also promoting inclusivity, employment, and sustainable consumption habits. With the goal of creating a prototype model for the collection and recycling of coffee waste, Kafsimo hopes to expand their impact to other regions and waste streams, encouraging citizens to change their coffee-drinking habits and promoting a fair and equitable economy. The project's slogan "Close the Circle" captures its focus on environmental, social, and economic sustainability.

Activities: The Kafsimo project collects used coffee grounds from coffee shops in Kilkis and Thessaloniki using an electric van and transports them to a specially designed greenhouse for dehydration and processing. The grounds are converted into biofuel pellets or briquettes using a formula and method perfected after months of experimentation and testing. The resulting biofuel can be used for heating in houses, local industries, and public spaces. The project also aims to address social issues by training and employing people from vulnerable groups, providing job opportunities, and developing their employability potential.

Actors involved:

- Participating coffee shops in Kilkis and Thessaloniki, which provide the used coffee grounds
- People from vulnerable groups who are trained and employed by the project
- Local industries and public spaces that use the biofuel for heating
- The wider community of Greece, which is encouraged to change their habits and reduce organic waste through the project's initiatives

Impact for bioeconomy development: The main environmental impact of the 'Kafsimo' project is the reduction of coffee waste that ends up in landfills, which pollutes the environment. By collecting coffee grounds from cafes and transforming them into biofuel pellets or briquettes, the project helps to reduce the reliance on fossil fuels and the atmospheric output associated with their use. The low-emissions vehicle used for transportation also contributes to a reduced environmental footprint. The project also raises awareness about environmentally friendly ways to consume coffee and other drinks, such as through Staramaki and reusable coffee cups. Overall, 'Kafsimo' promotes a circular economy model that reduces waste and environmental pollution while contributing to the bioeconomy.

Social impact: The Kafsimo project creates job opportunities and offers training in the green economy for vulnerable social groups, leading to economic independence and empowering them. This approach also promotes social integration. The Kafsimo team educates the public on the reuse and repurposing of organic waste, and conducts specialized training workshops with university students. This public engagement inspires active citizenship and highlights the potential for individuals to contribute to environmental and social transformation through local actions and small habit changes.

The project

MainstreamBIO is an Horizon Europe EU funded project, which sets out to get small-scale bio-based solutions into mainstream practice across rural Europe, providing a broader range of rural actors with the opportunity to engage in and speed up the development of the bioeconomy. Recognizing the paramount importance of bioeconomy for addressing key global environmental and societal challenges, MainstreamBIO develops regional Multi-actor Innovation Platforms in 7 EU countries (PL, DK, SE, BG, ES, IE & NL). The project aims to enhance cooperation among key rural players towards co-creating sustainable business model pathways in line with regional potentials and policy initiatives. MainstreamBIO supports 35 multi-actor partnerships to overcome barriers and get bio-based innovations to market with hands-on innovation support, accelerating the development of over 70 marketable bio-based products and services. Furthermore, the project develops and employs a digital toolkit to better match bio-based technologies, social innovations and good nutrient recycling practices with available biomass and market trends as well as to enhance understanding of the bioeconomy with a suite of educational resources building on existing research results and tools. To achieve these targets, MainstreamBIO involves 10 partners across Europe, coming from various fields. Thus, all partners combine their knowledge and experience to promote the growth of bioeconomy in a sustainable and inclusive manner.

Coordinator: Q-**PLAN INTERNATIONAL ADVISORS PC (Q-PLAN**)

Partner		Short Name
	Q-PLAN INTERNATIONAL ADVISORS PC	Q-PLAN
	MUNSTER TECHNOLOGICAL UNIVERSITY	MTU
	STICHTING WAGENINGEN RESEARCH	WR
	INSTYTUT UPRAWY NAWOZENIA I GLEBOZNAWSTWA, PANSTWOWY INSTYTUT BADAWCZY	IUNG
	RISE PROCESSUM AB	PROC
	AGRAREN UNIVERSITET - PLOVDIV	AUP
	FBCD AS	FBCD
	EURIZON SL	INNV
	DRAXIS ENVIRONMENTAL SA	DRAXIS
	WHITE RESEARCH SPRL	WHITE

CONTACT US info@mainstreambio-project.eu **VISIT** **www.mainstreambio-project.eu**

MainstreamBio @MainstreamBio MainstreamBio Project MainstreamBio Horizon Europe Project