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Midas

MARGINAL LANDS, INDUSTRIAL CROPS AND INNOVATIVE BIO-BASED VALUE CHAINS

Deliverable 5.2

Regional biomass-to-product pathways, system boundaries and process design

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Executive summary

A sustainable bioeconomy can be achieved by replacing non-renewable resources by sustainably sourced biomass and by developing production systems that are able to close material and energetic cycles (Dietz et al. 2018). A promising perspective on this bioeconomy transformation takes advantage of industrial crops grown on marginal lands to produce high-value-added bio-based products. The idea behind this sustainable feedstock production on marginal lands is that shifting bio-based production systems to these areas can address sustainability issues in a spatial context and avoid competition with food production and direct and indirect land-use change problems (Muscat et al. 2022). This approach has the potential to strengthen the growing bio-based industry, reduce land use competition, increase farmer incomes, and increase the value of marginal land (Elbersen et al. 2017).

The EU Horizon 2020 project MIDAS (Grant agreement ID: 101082070) was established with the ambition of building innovative regionally adapted value chains and webs to support a sustainable bioeconomy. In MIDAS different promising industrial crops are grown in innovative cropping systems with annual and perennial crops (intercropping, agroforestry) on marginal land (WP2; WP3). These crops can support the bio-based industry by providing low indirect land-us change (low-ILUC) feedstock for numerous conversion technologies for bio-based applications and products (WP4). WP5 aims to design sustainable value chains and webs with biomass stemming from farming systems tested in different case studies (WP3). The MIDAS project goes beyond the farm scale and considers the entire value chain in site-adapted biomass-to-product pathways.

Many different industrial crops, cropping systems and bio-based products are considered in the MIDAS project. Considering together crop production systems in different regions, marginality conditions and stakeholders led to the identification of 129 biomass-to-product pathways, which were presented in a superstructure approach (Deliverable 5.1). With this approach we were able to show the **technological potential** for every industrial crop grown on marginal land in MIDAS.

To further shape the process towards bio-based value chains and web concepts we need to select regionally suitable site-specific biomass-to-product(s) pathways. This report “Regional biomass-to-product pathways, system boundaries and process design” (Deliverable 5.2) represents the results of this selection process (task 5.2.1).

For this Deliverable we identified **a regional implementation potential** for all technologically possible pathways. We therefore designed a **superstructure-based multi-criteria evaluation approach** to identify suitable pathways for every case study region from a broad perspective while including relevant stakeholders and their exptertise.

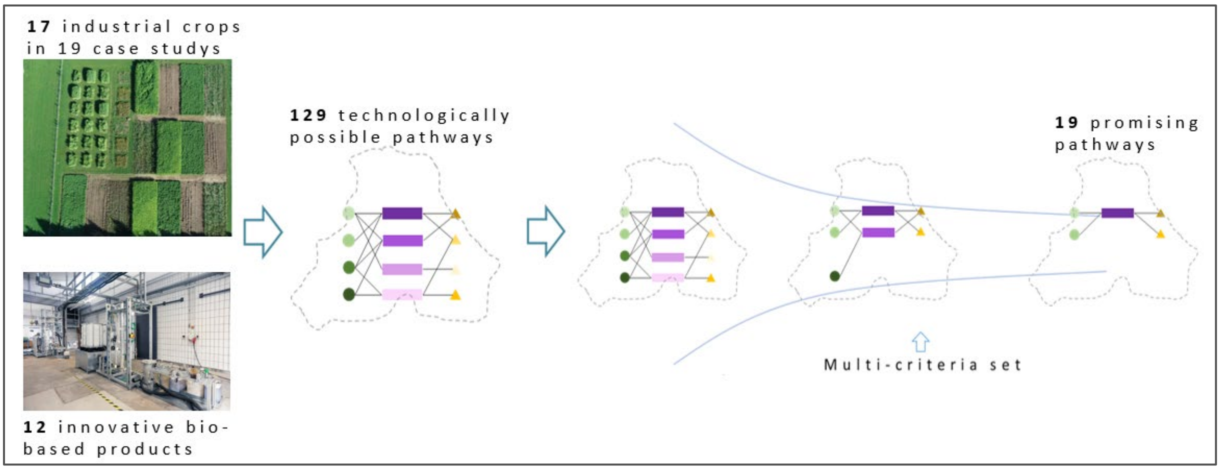

Figure 1 Identification process for promising biomass-to-product pathways in MIDAS (Pictures: University Hohenheim/ von Cossel; Kovalenko)

Accordingly, we operationalized a multi-criteria set by means of quantitative and qualitative proxy indicators and incorporated context-dependent factors at regional level, to assess the technologically possible biomass-to-product pathways. For this early-stage assessment we identified criteria and categorized them according to Vargas-Carpintero et al. (submitted) into three categories — feasability, viability and desirability — in order to assess the crop suitability in the region as well as the crop suitability for the different conversion technologies.

Based on the assessment results, expertise of stakeholders and the additionally collected contextualized information we selected promising biomass-to-product pathways, i.e su with a regional implementation potential, for every region. We hereby identified **19 promising biomass-to-product pathways** (Figure 1). The following table (Table 1) highlights the components of these pathways for every region.

Table 1 Selected (industrial) crops and bio-based products for every case study region which can be combined to biomass-to-product pathways with high implementation potentials. Scoring results from the early-stage assessment in bold; P=Perennial; A= Annual; TBI=to be investigated.

	Region	Cropping System (WP3)	**Selected industrial crop(s)** (cycle) & scoring result (WP3)	**Innovative bio-based products** & scoring result (WP4)
1	Northern Spain, Soria	Intercropping	Lavender (P) - **0.74**	Bio-based phytosanitary products (Bioherbicides) – **0.575**
			Safflower (A) - **0.66**	*Seedcake:* Agricultural biostimulants - **0.69**
2	Northern Spain, Soria	Agroforestry	Siberian Elm (P) - **0.55**	MDF Boards – **0.75**
3	Central Italy, Monterotondo (Rom)	Agroforestry	Poplar (P) – **0.72**	Biochar – **0.78**
4	Western Greece, Lexaina/Ilia	Intercropping	Switchgrass (P)	Graphene & Nanocarbons – **0.46**
5	North- western Greece, Vonitsa	Intercropping	Castor (A)	*Seed:* Biodegradable in soil mulch films – **0.675**
				Seedcake: Phenol-formaldehyde type adhesives for particelboards – **0.6**
6	Central Greece, Litoxhoro (Katerini)	Agroforestry	Sorghum (A)	Particleboards – **0.7**
7	Central Greece, Stylida (Fthiotida)	Agroforestry	Safflower	*Seed:* Biodegradable in soil mulch films – **0.71**

				Seedcake: Phenol-formaldehyde type adhesives for particelboards - **0.6**
8	Northern Czech Republic, Ahnikov	Intercropping	Hemp (A) – **0.53**	Particleboards – **0.7**
9	Northern Poland, Swierznica	Agroforestry	Poplar (P) – **0.75**	Biochar – **0.78**
10	Southern France, Le Cailar	Intercropping	Guayule (P) – **0.72**	Latex for gloves, Adhesives and coatings as covering material for particleboards (latex-covered wood-based panels – **0.92** *Bagasse*: Biochar (**0.68**), MDF Boards (**0.75**), Particelboards (**0.71**)
11	Northern Serbia, Zabalj	Intercropping	Sorghum (A) - **0.66**	Particleboards – **0.67**
12	Central Spain, Fuentidueña de Tajo (Madrid)	Intercropping	Guayule (P) – **0.53**	Natural rubber for Tires – **0.75** *Resins*: Adhesives and coatings as covering material for particleboards
13	Southern Italy, Santa Maria La Fossa (Campania)	Intercropping	Cardoon (A) – **0.625**	*Seed:* Biodegradable biolubrificants – **0.66** *Seedcake*: Agricultural biostimulants – **0.69**
14	Central Italy, Terni (Umbria)	Intercropping	Safflower (A) – **0.6**	*Seed*: Biodegradable biolubrificants – **0.66** *Seedcake*: Agricultural biostimulants – **0.69**
15	Central Hungary, Gödöllö	Intercropping and agroforst	Miscanthus (P) - **0.67**	Particleboards – **0.67**
16	Central Hungary, Gödöllö	Intercropping and agroforstry	Poplar (P) – **0.67**	Biochar – **0.78**
17	Southern Germany, Eningen unter Achalm	Intercropping	Crambe (A) – **0.5**	Seed: Biodegradable biolubrificants **-TBI** Seedcake: Phenol-formaldehyde type adhesives for particelboards – **0.6**
18	Northern Italy, Bologna	Intercropping	Hemp (A) – **0.69**	Particleboards – **0.7**
19	Southern Italy, Catania (Sicily)	Intercropping	Cardoon (A) – **0.6**	*Seed*: Biodegradable in soil mulch films – **0.71** *Seedcake*: Agricultural biostimulants – **0.69**

Complementary to the selection, we provide detailed and contextualized information for every biomass-to-product pathway (chapter 6). At first regionalized information is given highlighting climate and soil data as well as information about current land uses in the case study region. Additionally, we provide initial information about the agricultural production like the propagation method, sowing and plant density, fertilization and information related to the harvest for every selected (industrial) crop. Furthermore, information regarding the production of innovative bio-based products is given which relates to the feedstock logistic, processing (scale, TRL, etc.) and market (target, competitors, outlook, etc.).

Instead of focusing on one product and one value chain, we apply an initial value web perspective to explore interlinkages between single value chains and identify possibilities for the creation of regional bio-based value webs, incorporating the principle of cascading use of biomass.

The information gathered for this Deliverable are the basis for further investigation in WP5 and the creation of regional value web concepts as well as practical and policy recommendations and strategies for their implementation. This will include LCSA in T5.3 and modelling for biodiversity restoration potential (LARCH) in T5.4.

Table of contents

List of Figures

List of Tables

1. Introduction

The transition to a sustainable bioeconomy depends - from a resource use perspective - on the sustainable production and utilization of renewable resources (e.g. biomass). A sustainable bioeconomy can be achieved by replacing non-renewable resources by using renewable biomass and changing consumption and production patterns while closing material and energy cycles (i.e., circular economy), and increasing biomass utilization (i.e., cascade use) (Diaz-Chavez et al. 2020; Lewandowski 2015). To ensure their positive impact at the social, economic and environmental levels, the impacts and trade-offs that may arise in biomass production and in the manufacture of bio-based products need to be anticipated and resolved in a meaningful way (Staffas et al. 2013). A promising perspective on this bioeconomy transformation takes advantage of the extensive, regionally diverse opportunities (Dietz et al. 2018).

The EU Horizon 2020 project MIDAS (Grant agreement ID: 101082070.) was established with the ambition of building on the development of innovative regionally adapted value chains and webs by growing selected non-edible (industrial) crops on marginal lands to produce low-ILUC feedstock for bio-based applications following the biorefinery concept (circular biomass use).

To achieve this, the MIDAS project aims:

- to understand and map the actual marginal lands in Europe (now, in 2030 & 2050) for low ILUC feedstock production (WP1).
- to optimize selected industrial crops adapted to marginal lands through modern biotechnology tools and tailored agronomic practices towards low ILUC cropping systems (WP2; WP3).
- to develop case studies of low-ILUC cropping systems (intercropping & agroforestry) on marginal agricultural land on farm level for present and future farming systems (WP3).
- to develop innovative bio-based products (namely biochemical, composites, and elastomers) trough various biomass conversion technologies following a biorefinery concept and the circular use of biomass (WP4).
- to design innovative resource efficient bio-based value chains and webs and to perform integrated sustainability assessment, including impacts on biodiversity (field & landscape level) (WP5).
- to develop business plans to foster circularity at farm level by engaging the farming community, industrial actors and academia through the projects' Case Studies (WP6)

In MIDAS different promising industrial crops are grown in innovative cropping systems (intercropping, agroforestry) with annual and perennial crops on marginal land (WP2; WP3).

Marginal land: "Lands having limitations which in aggregate are severe for sustained application of a given use and/or are sensitive to land degradation, as a result of inappropriate human intervention, and/or have lost already part or all of their productive capacity as a result of inappropriate human intervention and also include contaminated and potentially contaminated sites that form a potential risk to humans, water, ecosystems, or other receptors" (Elbersen et al. 2017).

These crops can cope well with water scarcity/stress and they have been proven to be effective to reducing soil erosion. They can support the bio-based industry by providing low-ILUC feedstock for numerous bio-based applications (biochemical, biomaterials, elastomers) including bioenergy while optimizing the circular biomass use (WP4). The MIDAS project goes beyond the farm scale and considers the entire value chain through site-adapted biomass-to-product pathways.

Biomass-to-product(s) pathways are combinations of a particular type of biomass, the biomass treatment and conversion processes and one or more products by it.

The value chain approach of WP5 is demonstrated by integrating biomass, stemming from farming systems tested in different case studies (WP3) as starting point and the mapping of potential biomass processing steps that deliver the innovative bio-based products (WP4) into possible bio-based value chains and webs concepts. For this, the selection of suitable biomass-to-product(s) pathways is a required step.

Bio-based value chains are the full range of activities and the sequence of processes and stakeholders involved from biomass production to the conversion through different technologies into material and energetic products (Kaplinsky and Morris 2001; Lewandowski 2015; Zörb et al. 2018).

The WP5 activities are structured around five Tasks: The identification and screening of all potential biomass-to-product(s) pathways by combining the selected industrial crops (WPs 2 & 3) grown in innovative regional cropping systems in regional case studies (WP3) and the bio-based products that are developed in WP4 (Task 5.1). Then, these identified biomass-to-product(s) pathways will be assessed (Task 5.2) to estimate their suitability and potential contribution to a sustainable bioeconomy at regional level applying a multi-criteria framework to identify combinations with promising regional implementation potential. Furthermore, for these most promising biomass-to-product(s) pathways Life-cycle-sustainability assessments (LCSA) will be carried out including their biodiversity impact and restoration potentials (Task 5.3; Task 5.4). Finally, sustainable bio-based value web concepts will be designed applying all information generated and recommendations for their implementation will be developed (Task 5.5). This deliverable presents the results of Task 5.2 the assessment and identification of promising biomass-to-product pathways.

In the MIDAS project the starting point for designing innovative value chain concepts is the identification of potential biomass-to-product pathways. There are multiple technologically possible conversion routes for the selected industrial crops. In order to summarize these pathways, a biomass use superstructure was developed and presented in Deliverable 5.1 highlighting a variety of possible combinations of each crop and conversion technology. Accordingly, the objective of this Deliverable was to identify and screen promising biomass-to-product pathways and regionalize the information. We therefore conducted an early-stage assessment based on a superstructure-based multi-criteria screening approach including all relevant stakeholders in MIDAS.

This report on "Regional biomass-to-product pathways, system boundaries and process design" (Deliverable 5.2) represents the results of work of task 5.2.1 (Grant Agreement no.

101082070). The goal of this report is to provide a system description of those value chains that were selected in MIDAS as having a high implementation potential and therefore are relevant for further in-depth analysis (sustainability assessment).

The report is structured as follows: at first the concept of bio-based value chains and webs as well as the data collection and methodological approach is explained (chapter 2,3). Next, we present the results from our **superstructure-based multi-criteria screening approach** (chapter 4) and highlight the selected biomass-to-product pathways (chapter 5). Afterwards we describe the selected pathways in detail with regionalized information while taking an initial value web perspective (chapter 6). We finish with an outlook of future work related to the MIDAS project (chapter 7).

2. Concept of bio-based value chains and webs

As shown in Deliverable 5.1, bio-based value chains are usually represented in a simplified structure that entails biomass production and supply, conversion processes and final use. A bio-based value chain is defined as the sequence of value adding activities from biomass production to bio-based products along with its opportunities for value generation, including economic, social and ecological values (Lewandowski 2015). The value chain results from the interaction of all connected actors and productive activities involved in the process of adding value, as well as the supporting and institutional activities that allow the value creation (Fig. 2) (Donovan et al. 2015). The possibility of using biomass in diverse forms, using by-products for additional value generation (i.e. cascading use of biomass) and setting multi-feedstock and multi-product systems from biomass (e.g. biorefineries) indicate that bio-based value chains are beyond linear systems. Consequently, the term biomass-based value web was introduced in the context of bioeconomy as an extension of the value chain concept to embrace the multiple biomass use pathways and the manifold products that can be derived from one biomass raw product (Virchow et al. 2016; Scheiterle et al. 2017).

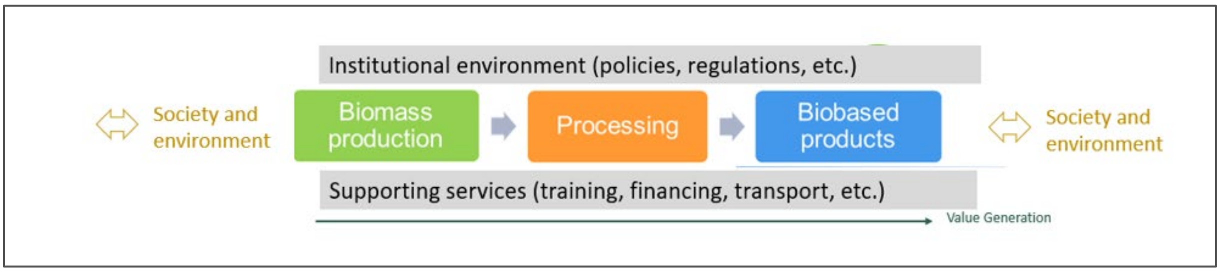

Figure 2 Simplified value chain web concept (Authors)

The bio-based value web framework allows for a system, integrative, and multi-dimensional approach. Bio-based value webs interlink several bio-based value chains into one network. Instead of focusing on one single product and value chain, bio-based value webs allow biomass-to-product pathways to be integrated into a system. Moreover, they allow to look at the product mix that can be produced at regional level (Virchow et al. 2016). As a multi-dimensional framework, the bio-based value web contributes to the integration of ecological, social, economic, and governance aspects, as well as relationships between actors (Vargas-

Carpintero et al. 2022, Zörb et al. 2018). The application of the value web framework contributes to unveil social and regional contexts that influence the performance of these systems (Virchow et al. 2016; Scheiterle et al. 2018).

In the case studies of the MIDAS project, the application of the bio-based value web framework allows the specific analysis of single biomass-to-product pathways from the studied crops and derived value chains from a systems perspective, considering together techno-economic, ecological and social aspects. In this way, value chains and webs concepts as well as recommendations for their development, tailored to the context, can be suggested. For instance it is essential to design and develop cropping systems that fit the location-specific circumstances in order to offset marginality and promote sustainable agriculture and biomass supply of the analysed crops (Pancaldi und Trindade 2020).

3. Methodological approach and data collection

The objective of MIDAS is to develop innovative bio-based value chains and webs concepts from sustainably produced biomass cultivated in marginal lands. The value chain components of this approach are the biomass production in innovative cropping systems (WP2, WP3) and the biomass processing into bio-based products that are being developed in WP4. The process of developing innovative value chains and webs concepts started by combining these value chain components to identify all potential biomass-to-product pathways in a 'biomass use superstructure' approach. The biomass use superstructures are flowsheets that show all the process alternatives for MIDAS feedstocks resulting in biomass-to-product pathways. This biomass use superstructure approach is widely used for biorefinery design and analysis (Elyasi et al. 2021; Gu et al. 2022; Del Álvarez Castillo-Romo et al. 2018; Kim et al. 2013; Ng et al. 2018). Adapting this approach to the context of MIDAS allowed us to show the overall **technological potential** for every industrial crop tested in MIDAS. In total **129 potential biomass-to-product pathways** have been identified in Deliverable 5.1 and summarized in different superstructures.

To further shape the process towards bio-based value chains and webs we need to identify **a regional implementation potential** of these pathways. We therefore adapted and applied a stepwise **superstructure-based multi-criteria evaluation approach (Fig. 3).**

This process starts with the identification of suitable pathways for every case study region from a considering relevant criteria for their evolution into bio-based value chains while including relevant stakeholders. A circular and sustainable bioeconomy requires stakeholder engagement in order to develop a shared understanding of the productive systems, allowing to look at bio-based value chains and webs from an integral perspective (Lokesh et al. 2018; Vargas-Carpintero et al. 2022).

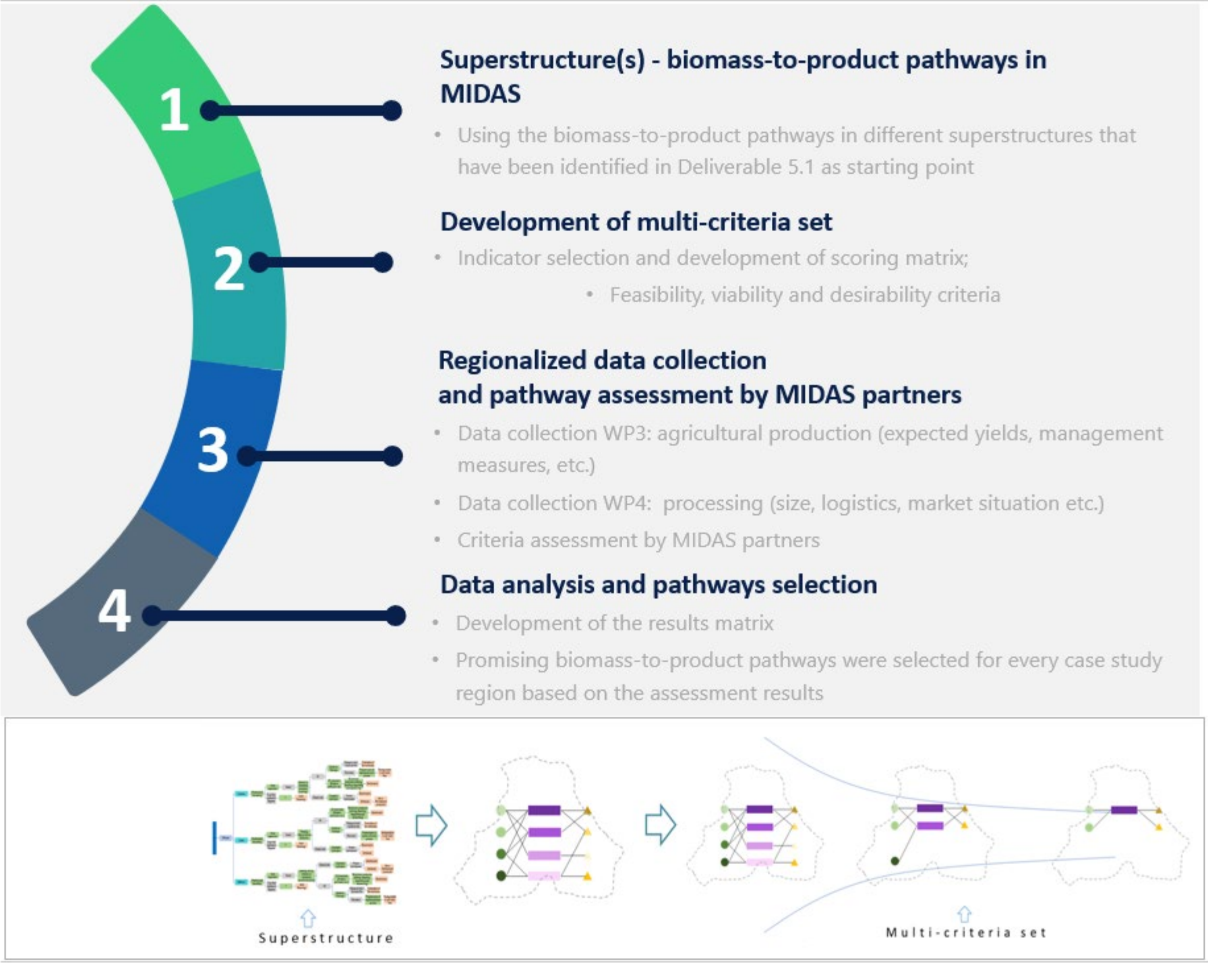

Figure 3 Methodological approach for the mapping and evaluation of biomass-to-product pathways (MIDAS Deliverable 5.2) (Adapted from Vargas-Carpintero et al. (Submitted)

Using the biomass use superstructures as a starting point (1st step in Fig. 3), we operationalized a multi-criteria set for an early-stage assessment of the different biomass-to-product pathways (2nd step in Fig. 3). Based on Vargas-Carpintero et al. (Submitted) we determined different criteria including qualitative proxy indicators and incorporating context dependent factors at regional level for an assessment of the implementation potential of technologically possible biomass-to-poduct pathways identified in Deliverable 5.1.

The evaluation of the defined proxy indicators and criteria was based on the input provided by project partners involved in WP3 and WP4. Additionally, we collected contextualized information about each region, crop, agricultural production, conversion technology and product (3rd step in Fig. 3). The required data were primarily accessed through stakeholder consultation using user-friendly templates (data entry sheets) and interviews with research partners in WP3 and industry partners in WP4. Also, literature sources were used to fill data gaps. The collected information was validated, analyzed and refined during joint project (4th step in Fig. 3). For more information regarding the data collection see Deliverable 5.1.

This multi-criteria set as well as the contextualized information collected was used as a basis to identify **a regional implementation potential** of the different biomass-to-product pathways in the case study regions and to select promising pathways based on stakeholder expertise (detailed explanations can be found in the following sub-chapter).

Multi-criteria assessment for the selection of promising biomass to product pathways

To select promising biomass-to-product pathways at an early stage of value chain design prior to in-detail design and assessment, a multi-criteria framework was used. In this way, those biomass-to-product(s) pathways identified in D5.1 were preliminary assessed in D5.2 (Fig. 4).

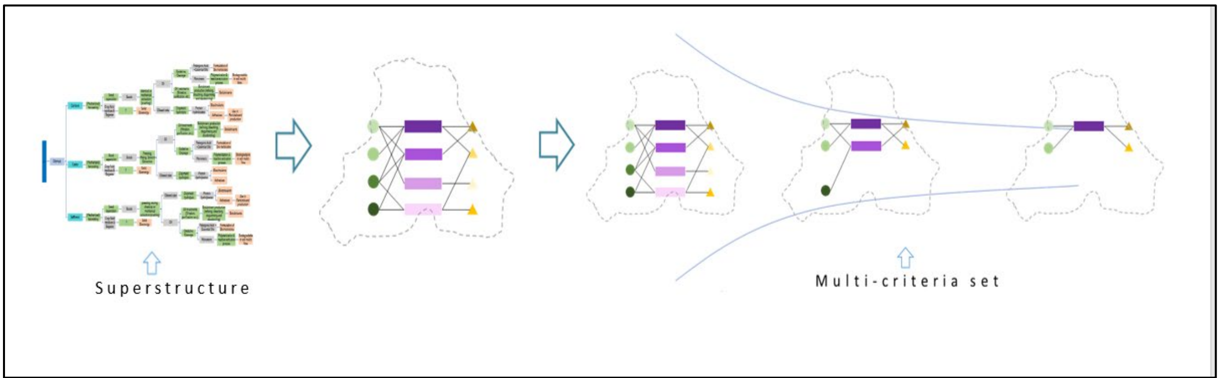

Figure 4 Screening logic to identify promising biomass-to-product pathways (Adapted from Vargas-Carpintero et al. (Submitted))

By means of the multi-criteria set, all identified biomass-to-product(s) pathways were assessed to check their implementation potential. The criteria that were applied for the initial assessment can be categorized according to Vargas-Carpintero et al. (Submitted) into three categories:

- a) Criteria belonging to **Feasibility** include various aspects related to the production system and its interaction with the biophysical and environmental context. It includes characteristics related to the crop and its ecosystem, such as resource availability, crop suitability, seasonality, biodiversity as well as characteristics of the processing route.
- b) Criteria included in the **Viability** category aim to check the potential of the production system against various techno-economic aspects including for example biomass access, technical knowledge in biomass production, crop quality and usability, scalability, infrastructure (e.g. access to energy etc.), labour availability, production costs, resource efficiency, product diversity, market access and the existence of supporting processes, among others.
- c) Criteria included in the **Desirability** category include normative aspects related to the social dimension and the institutional context such as technology acceptance, impacts on human health, safety, value delivered for local development, product quality, product acceptance and regulatory framework, etc.

The use of this adapted multi-criteria framework provides a qualitative check list that allows the identification of promising biomass-to-product(s) pathways. The criteria were associated to simple questions with qualitative values that were normalized and quantified by a score between 0 and 1. The average score of all indicators' values was calculated to generate the ranking of the crops, processing route and bio-based products assessed, giving a same level of importance to each criteria and dimension. This scoring logic was developed based on the expertise of the authors and aligned with the design objectives of the bio-based value chains and webs in the context of the MIDAS project, e.g. biomass locally sourced, cultivation in marginal lands, value generation through high added value products. A value of 1 in the applied criteria represents a best-case scenario for the evaluated biomass-to-product pahtway. A list of all criteria, associated questions as proxy indicators and evaluation scales can be found in the following chapters.

4. Identification of promising biomass-to-product pathways

In the following chapter an overview of the criteria selected for the early-stage assessment is presented. The tables include the criteria, questions related to the criteria and their respective scoring logic for each dimension (feasibility, viability, desirability). These criteria were selected to fit the purpose of this project. Data availability and management as well as practicability of these criteria were crucial for their selection. During the duration of the project this multi-criteria approach will be further developed and extended.

The presented results are based on stakeholder opinion (data entry sheet, interviews and discussions during project meetings) of the respective partners (WP3 & WP4). At first, the criteria and results used to assess the biomass production in innovative cropping systems (WP3) are shown, indicating the suitability of growing the crop in the region. Afterwards the criteria and results used to assess the processing and innovative bio-based products are presented (WP4), indicating the`suitability of the conversion technology and crop). At last a table (8) is shown which combines the results in a matrix (WP3 &WP4). This matrix was used to identify promising biomass-to-product pathways for every case study region.

However, for some of these biomass-to-product pathways components not enough data could be collected for this deliverable. These components are partially regarded as promising by the partners and will in some cases be further investigated during the MIDAS project.

Through an understanding of the available information from each of the value chain components (agricultural crop production WP3, processing and bio-based products WP4), it was possible to identify biomass-to-product pathways with **a regional implementation potential** in a specific region.

Biomass production in innovative cropping systems (WP2, WP3) – assessing the case studies in MIDAS

The following table highlights the criteria and their respective questions used to assess the suitability of growing the different industrial crops in the case study region as well as the scoring logic (Table 4). In total 19 criteria divided into the abovementioned dimensions (feasability, viability, desirability) were used. WP3 Partners were asked to answer the questions based on their knowledge and expertise related to the regional conditions.

Table 1 Criteria, respective questions and scoring logic for the initial assessment of biomass-to-product pathways (crop suitability in the region) – Criteria are related to the industrial crops grown in innovative cropping systems (case studies WP3) looking at their feasability, viability, and desirability.

Feasability criteria		Questions related to the criteria	Scoring				
			0	0.25	0.5	0.75	1
1	**Availability of the crop in the region**	Has the proposed crop been already established in the region?	*No*		*only in scientific trials*		*Yes*
2	**Seasonality**	Months of biomass availability during the year	*biomass type is available ≤3 months per year*		*biomass type is available >3 months and ≤9 months per year*		*biomass type is available >9 months and ≤12 months per year*
3	**Invasiveness**	Does the crop represent a risk of invasiveness?	*there is low risk of potential invasiveness of according to scientific evidence*				*if there is a high risk of potential invasiveness of according to scientific evidence*
4	**Nativeness**	Is the plant native in the region?	*No*				*Yes*
5	**Biodiversity promotion**	Does the plant promote biodiversity?	*No, there is scientific evidence of negative influence on flora and fauna*				*Yes, there is scientific evidence of positive influence on flora and fauna*
6	**Crop suitability related to the regional climate (temperature, precipitation etc.)**	Is the crop adapted to the climatological conditions of the region?	*No*		*Required adaptations (e.g. shading)*		*Yes*
7		Does the crop requires irrigation for its cultivation in the region?	*Yes*		*Only in extreme drought conditions*		*No*
Viability criteria							
8	**Agronomic practices**	Experience with agricultural management of the proposed industrial crops	*No knowledge, no practical application yet*	*Theoretical knowledge but no practical application yet*	*Known, apllication limited (only specific stakeholders e.g., scientific institutions)*	*Known, regular application by scientific institutions and by some farmers*	*Known, regular application by regional farmers over longer time period*
9	**Availability of plant material/ genetic material**	Is it possible to have access to planting material for cultivating the crop comercially?	*There is no developed planting material*		*There is no availability of planting material at commercial level*		*There is planting material commercially available*
10	**Market for the product**	Is there an existing application for the crop in the region?	*No application has been identified in the region*		*At least one application at research level*		*At least one application at commercial level*
11	**Crop technical suitability**	Is the crop suitable to the targeted application and processing technology?	*Does not deliver needed fraction*	*Delivers needed fraction; technological requirements and quality requirements not met*	*Delivers needed fraction; technological requirements or quality requirements not met*	*Delivers needed fraction; technological requirements met; quality good*	*Delivers needed fraction; technological requirements met; quality very good*

12		Is the crop quality stable over time?	*biomass requires immediate energy-intensive (pre-) processing or pre-treatment*				*biomass is easy to be transported and can be stored for long periods after harvest without energy-intensive pre-treatment processes*
13	**Incentives**	Is the cultivation of the crop benefitted by external incentives, such as subsidies?	*No*				*Yes*
14	**Productivity**	Is the crop's yield known?	*No*	*Yes, only at research level under optimal conditions*		*Yes, at research level under optimal and marginal conditions*	*Yes, both optimal and marginal conditions at commercial level*
Desirability criteria							
15	**Biomass acceptance**	Do farmers from the region generally know the crop?	*No*				*Yes*
16		Are farmers from the region interested in cultivating the crop?	*No*				*Yes*
17	**Product value**	Is the product meeting local needs and demands? (e.g. Food, energy, feed, materials for local industry/companies)	*No*				*Yes*
18		Is it an edible crop by humans?	*Yes*		*Part of the crop is edible*		*No*
19	**Human health**	Are there special health risks associated to the cultivation of the crop?	*No*				*Yes*

These questions were included in the data entry sheet for collecting data from WP3 partners. The summarized results for the crop suitability assessment in the case study regions can be seen in Table 5. The values represent the average of all assessed criteria.

For some of these crops not enough data was available to assign specific values. These crops are in some cases still regarded as promising by WP3 partners and will be further investigated during the MIDAS project.

As some case studies are not fully established yet (as of October 2023) due to various difficulties the following information is provisional and subject to change.

Suitable crops for each region are labelled green. Crops for which moderate limitations are expected in the study region, are shown in yellow. Crops where severe limitations are expected are marked in red.

Table 2 Results from the inirial assessment of the crop suitability for the region (WP3) –promising industrial crops for regional cropping systems

City	*Region*	**Case study design**	*Crop Name*	*Cycle*	*Screening result*
Soria	**Northern Spain**	intercropping	Lavender	Perennial	0.7368
			Crambe	Annual	0.4705
			Safflower	Annual	0.6578
			Melilotus	Annual	0.5
		agroforestry	Elm	Perennial	0.5
			Crambe	Annual	0.6842
			Safflower	Annual	0.5882
			Melilotus	Annual	0.4558
Monterotondo (Rome)	**Central Italy**	agroforestry	Poplar	Perennial	0.7236
			Crambe	Annual	0.4166
			Safflower	Annual	0.3684
Lexaina/Ilia	**Western Greece**	intercropping	Miscanthus	Perennial	TBI
			Castor	Annual	TBI
			Safflower	Annual	TBI
			Sorghum	Annual	TBI
Vonitsa	**North-Western Greece**	intercropping	Switchgrass	Perennial	TBI
			Castor	Annual	TBI
			Safflower	Annual	TBI
			Sorghum	Annual	TBI
Litoxhoro/Katerini	**Central Greece**	agroforestry	Poplar	Perennial	TBI
			Castor	Annual	TBI
			Safflower	Annual	TBI
			Sorghum	Annual	TBI
Stylida / Fthiotida	**Central Greece**	agroforestryryagroforestry	Paulonia	Perennial	TBI
			Castor	Annual	TBI
			Safflower	Annual	TBI
			Sorghum	Annual	TBI
Ahníkov	**Northern Czech Republic**	Intercropping	Miscanthus	Perennial	0.5263
			Sorghum	Annual	0.4736
			Hemp	Annual	0.5263
			Safflower	Annual	0.4473
Świerznica, Stegna Municipality	**Northern Poland**	agroforestry	(Black) Poplar	Perennial	0.75
			Dactylis	Annual	0.9531
Montpellier	**Southern France**	intercropping	Guayule	Perennial	0.625
			Sorghum	Annual	TBI
			Hemp	Annual	TBI

Žabalj	Northern Serbia	intercropping	Miscanthus	Perennial	0.5294
			Safflower	Annual	0.5833
			White Mustard	Annual	0.6052
			Sorghum	Annual	0.6578
Fuentidueña de Tajo (Madrid).	Central Spain	Intercropping	Guayule	Perennial	0.5263
			Safflower	Annual	0.75
			Hemp	Annual	0.6578
Terni, Umbria	Central Italy	intercropping	Cardoon	Perennial	0.625
			Safflower	Annual	0.5468
			Castor	Annual	0.0277
Santa Maria La Fossa, Campania	Southern Italy	intercropping	Cardoon	Perennial	0.6333
			Safflower	Annual	0.5937
			Castor	Annual	0.0277
Gödöllő	Central Hungary	intercropping	Miscanthus	Perennial	0.67
			Hemp	Annual	0.58
			Carinata	Annual	0.58
			Sorghum	Annual	0.62
		agroforestryry	Poplar	Perennial	0.67
			Hemp	Annual	0.58
			Carinata	Annual	0.58
			Sorghum	Annual	0.62
Eningen unter Achalm	Southern Germany	Intercropping	Miscanthus	Perennial	0.5526
			Hemp	Annual	0.5789
			Melilotus	Annual	0.5833
			Crambe	Annual	0.5
Bologna	Northern - central Italy	intercropping	Miscanthus	Perennial	0.4473
			Hemp	Annual	0.6973
			Safflower	Annual	0.6315
			Crambe	Annual	0.4078
Catania	Southern Italy	intercropping	Cardoon	Perennial	0.6052
			Hemp	Annual	0.6710
			Safflower	Annual	0.4868
			Castor	Annual	0.5277

Legend:

(0,6-1) Highly Suitable; No or only minor limitations

(0,35-0,59) Moderately Suitable; Some productivity limitations or limitations related to the context

(0-0,34) Minimally Suitable; Severe limitations

TBI = To be investigated (theoretically possible, data missing)

Innovative bio-based products – assessing the applications (WP4) in MIDAS

The following table highlights the criteria, respective questions and scoring logic used to assess the different conversion technolgies and innovative bio-based products (suitability of conversion technology and crop) (Table 6). In total 14 criteria divided into the abovementioned categories (feasability, viability, desirability) were used. 11 of these criteria relate directly to the processing, while 3 criteria specifically adress the crop suitability, assessing if the crop provides the required feedstock for each technology (Viability2 criteria). Suitable crops for the respective processes were identified and assessed by WP4 partners. The partners were asked to answer the questions based on their knowledge and expertise.

Table 3 Criteria, respective questions and scoring logic for the initial assessment of biomass-to-product pathways –Criteria are related to the processing technology (feasability, viability1, desirability) and potential feedstock types (viability2) for the innovative bio-based applications (WP4)

Feasability criteria		Questions related to the criteria	Scoring				
			0	0.25	0.5	0.75	1
1	**Residues**	Are there hazardous waste generated in the conversion process?	yes		Partially		no
		Are non-organic wastes (e.g. Plastic) produced in the conversion process?	yes		Partially		no
		Is organic waste recycled in the process (e.g., waste water, biomass)?	no		Partially		yes
2	**Resource need**	Is the energy demand for the process self-supplied?	No		Partially		Yes
Viability1 criteria							
3	**Market**	Is there an available market for the product?	*No*		*In early-stage development*		*Yes, established*
		Market potential for the product - Public interest in the product?	*Low*		*Medium*		*High*
		Are there similar bio-based products in the market?	*No*		*Yes, being introduced*		*Yes, fully established*
4	**Biomass conversion**	What is the biomass conversion rate into the final product?	*<10%*		*<50%*		*>90%*
5	**Resource use**	Are inputs (e.g. Catalizers) recovered and re-used in the process?	*No*		*Partially*		*Fully*
6	**Processing decentralization**	Can the process be operated in small-scale and decentralized processing systems?	*No*		*Only pre-treatment*		*Fully*
7	**Incentives**	Are there external incentives for the production of the targeted product?	*No*				*Yes*
Desirability criteria							
8	**Product value**	Does the targeted application replaces a fossil-based product/material?	*No*				*Yes*
9	**Regulatory framework**	Is there a reguatory framework specific for the targeted application?	*No*				*Yes*

10	**Social acceptance**	Is the processing technology socially accepted?	*No*				*Yes*
		Is there consumers acceptance for the targeted application?	*No*				*Yes*
11	**Safety**	Are there safety hazards in the process?	*Yes*				*No*
		Does the product cause health problems (e.g. Toxicity, irritation)?	*Yes*				*No*
		Are there safety hazards in the product?	*Yes*				No
Viability2 criteria (related to all potential feedstocks)							
12	**Feedstock supply**	Is the feedstock currently used for other applications?	*Yes*				*No*
		Expertise for processing the feedstock	*No knowledge, no practical application yet*	*Theoretical knowledge but no practical application yet*	*Theoretical knowledge; some experiemental application*	*Good knowledge, regular application (<1year experience)*	*Known, regular application over longer time period (>1 year)*
13	**Valorization potential**	Is the crop suitable to the targeted application and processing technology?	*Does not deliver needed fraction*	*Delivers needed fraction; technological requirements and quality requirements not met*	*Delivers needed fraction; technological requirements or quality requirements not met*	*Delivers needed fraction; technological requirements met; quality good*	*Delivers needed fraction; technological requirements met; quality very good*
14	**Product diversity**	Are manifold products obtained from the biomass input?	*No*		*at least 2*		*More than 2*

These questions were included in the data entry sheet for collecting data from WP4 partners. The summarized results for the crop suitability for the innovative bio-based products can be seen in Table 7. The values represent the average of all assessed criteria.

For some of these crops not enough data was available to assign specific values. These crops are in some cases still regarded as promising by WP4 partners and will be further investigated during the MIDAS project.

Suitable crops for delivering feedstock for each product are labelled green. Crops for which moderate limitations are expected are shown in yellow. Crops where severe limitations or low interest for the respective conversion pathway is predominant are marked in red.

Table 4 Results from the inirial assessment of the crop suitability for bio-based applications (WP4) - promising industrial crops for innovative bio-based products in MIDAS

Products	Technology	Raw material	Crop Name	Screening result
Biodegradable biolubrificants	Biolubricant formulation	Vegetable oil (Oilcrops)	Cardoon	0.66
			Castor	0.6
			Safflower	0.66
			Crambe	TBI
Biodegradable in soil mulch films	Enzymatic hydrolysis (protease)	Seed cake (Oilcrops)	Cardoon	0.69
			Castor	0.6
			Safflower	0.69
Agricultural biostimulants	Chemical and biotechnological processes	Vegetable oil (Oilcrops)	Cardoon	0.71
			Castor	0.67
			Safflower	0.71
Phenol-formaldehyde type adhesives for particelboards	Addition and polymerisation reactions	Protein from seed cake	Oilcrops	0.6
		Protein from Bagasse	Guayule (Bagasse)	TBI
Covering materials for particleboards	Various methods under development	Resins; Latex	Guayule	0.63
Latex for Gloves	Water-based extraction (continous)	Latex	Guayule	0.92
Tires	Sequential extraction process	Rubber	Guayule	0.75
Bio-based phytosanitary products (Bioherbicides)	Oxidative cleavage and formulation	Pelargonic acid (PA) derived from vegetable oils in formulation with essential oils	Cardoon	0.575
			Castor	TBI
			Safflower	0.575
Particleboards	Particleboard production with replacement of woody biomass	Lignocellulosic biomass, bagasse	Hemp	0.7
			Miscanthus	0.68
			Sorghum	0.66
			Guayule (Bagasse)	0.71
MDF Boards	MDF Board production with natural binders	Lignocellulosic biomass; bagasse	Siberian Elm	0.75
			Guayule (Bagasse)	0.75
Graphene & Nanocarbons	Two novel thermocatalytic reactor technology	Lignocellulosic biomass and Canadian biomass residues	Switchgrass	0.46
			Guayule	0.46
			Willow	0.46
			Poplar/Willow mixture	0.46
Biochar & Wood Vinegar	Carbonization demo plant (slow pyrolysis)	Bagasse; Woody biomass (chips)	Hemp	0.76
			Guayule (Bagasse)	0.78
			Miscanthus	0.73
			Sorghum	0.73
			Siberian Elm	0.76

			Poplar	0.78

Legend:

(0,6-1) Very Good candidate

(0,35-0,59) Good candidate; Technically possible, further investigation necessary

(0-0,34) Low interest

TBI = To be investigated (theoretically possible, data missing)

Identifying suitable combinations - matching the assessment results of WP3 and WP4 in MIDAS

In the following table (8) we show all possible combinations in a matrix while also highlighting the results from the early-stage assessment. For every case study region, we show the site-specific crop suitability in the region (results WP3) and their suitability for the processing into different bio-based products (results WP4).

For some of these combinations not enough data could be collected to assign specific values. These combinations are in some cases still regarded as promising by the partners and will be investigated during the MIDAS project.

The selected combinations of industrial crop and innovative bio-based product are labelled in green.

Table 5 Results from the initial assessment - On the left: crop suitability in the region based on the assessment of feasability, viability and desirability in the case studies (WP3); On the right: Crop suitability for the different applications based on the assessment of feasability, viability and desirability (WP4). Marked in green: Selected industrial crops (WP3) and respective bio-based product for further analysis in MIDAS (biomass-to-product pathways)

Regional assessment: crop suitability in the region related to context - results from the inital assessment (WP3)			Bio-based products (WP4); crop suitability for the different applications - results from the initial assessment											
			Bio-lubrifi-cants	Biostim-ulants	Biodegra-dable in soil mulch film	Phenol for-malde-hy-detyp adhesives	Covering for wood-based panels	Gloves and covering	Tires (Rub-ber)	Bioher-bicides	Par-ticle-boards	MDF Boards	Nano-carbons	Bio-char
Northern Spain, Soria (CIEMAT Inter-cropping)	Lavender	0.74	-	-	-	-	-	-	-	TBI	-	-	-	-
	Crambe	0.47	TBI	TBI	TBI	0.6	-	-	-	TBI	-	-	-	-
	Safflower	0.66	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
	Melilot	0.5	-	-	-	-	-	-	-	-	TBI	TBI	-	TBI
Northern Spain, Soria (CIEMAT Agro-forst)	Crambe	0.5	TBI	TBI	TBI	0.6	-	-	-	TBI	-	-	-	-
	Safflower	0.66	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
	Melilot	0.5	-	-	-	-	-	-	-	-	TBI	TBI	-	TBI
	Elm	0.55	-	-	-	-	-	-	-	-	TBI	0.75	-	0.76
Central Italy, Mon-tero-tondo (CREA Intercropping)	Poplar	0.72	-	-	-	-	-	-	-	-	TBI	TBI	0.46	0.78
	Crambe	0.41	TBI	TBI	TBI	0.6	-	-	-	TBI	-	-	-	-
	Safflower	0.36	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
Western Greece, Lex-aina/Ilia (CRES Intercropping)	Switchgrass		-	-	-	-	-	-	-	-	TBI	TBI	0.46	TBI
	Castor		0.6	0.66	0.675	0.6	-	-	-	TBI	-	-	-	-
	Safflower		0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
	Sorghum		-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
North- western Greece, Vonitsa (CRES Intercropping)	Miscanthus		-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
	Castor		0.6	0.66	0.675	(0.6)	-	-	-	TBI	-	-	-	-
	Safflower		0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
	Sorghum		-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
Central Greece, Li-tox-horo (Katerini) (CRES Agro-forst)	Poplar		-	-	-	-	-	-	-	-	TBI	TBI	0.46	0.78
	Castor		0.6	0.66	0.675	0.6	-	-	-	TBI	-	-	-	-
	Safflower		0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
	Sorghum		-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
Central Greece, Stylida (Fthiotida)	Paulonia		-	-	-	-	-	-	-	-	TBI	TBI	TBI	TBI
	Castor		0.6	0.66	0.675	0.6	-	-	-	TBI	-	-	-	-
	Safflower		0.66	0.69	0.71	(0.6)	-	-	-	0.575	-	-	-	-
	Sorghum		-	-	-	-	-	-	-	-	0.67	TBI	-	0.73

	(CRES Agro-forst)														
	Northern Czech Re-pub-lic, Ahnikov (CzecHemp In-tercropping)	Miscanthus	0.53	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
		Sorghum	0.47	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
		Safflower	0.44	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Hemp	0.53	-	-	-	-	-	-	-	-	0.7	-	-	0.76
	Northern Po-land, Swierz-nica (ECF In-tercropping)	Poplar	0.75	-	-	-	-	-	-	-	-	TBI	TBI	0.46	0.78
		Grasses (dac-tylis, festuca, timothy and bromus)	0.95	-	-	-	-	-	-	-	-	-	-	-	?
	Southern France, Le Cailar (GuaTecs Inter-cropping)	Guayule (Baga-sse)	0.72	-	-	-	-	0.625	0.92	0.75		*(0.71)*	*(0.75)*	0.46	*(0.68)*
		Sorghum		-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
		Hemp		-	-	-	-	-	-	-	-	0.7	TBI	-	0.76
	Northern Ser-bia, Zabalj (IFVC Inter-cropping)	Miscanthus	0.54	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
		Safflower	0.58	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		White mustard	0.6	-	-	-	-	-	-	-	-	TBI	TBI	TBI	TBI
		Sorghum	0.66	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
	Central Spain, Fuen-tidueña de Tajo (Ma-drid) (ITAP In-tercropping)	Guayule (*Baga-sse*)	0.53	-	-	-	-	0.625	0.92	0.75		*(0.71)*	*(0.75)*	0.46	*(0.68)*
		Safflower	0.75	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Hemp	0.66	-	-	-	-	-	-	-	-	0.7	TBI	-	0.76
	Southern Italy, Santa Maria La Fossa (Nova-mont Inter-cropping)	Cardoon	0.625	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Safflower	0.55	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Castor	0.03	0.6	0.66	0.675	0.6	-	-	-	TBI	-	-	-	-
	Central Italy, Terni (Umbria) (Novamont In-tercropping)	Cardoon	0.633	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Safflower	0.6	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Castor	0.03	0.6	0.66	0.675	0.6	-	-	-	TBI	-	-	-	-
	Central Hun-gary, Gödöllö	Miscanthus	0.67	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
		Hemp	0.58	-	-	-	-	-	-	-	-	0.7	TBI	-	0.76
		Carinata	0.58	TBI	TBI	TBI	TBI	-	-	-	TBI	-	-	-	-

	(Soltub Inter-cropping)	Sorghum	0.62	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
	Central Hungary, Gödöllö (Soltub Agro-forestryry)	Poplar	0.67	-	-	-	-	-	-	-	-	TBI	TBI	0.46	0.78
		Hemp	0.58	-	-	-	-	-	-	-	-	0.7	TBI	-	0.76
		Carinata	0.58	TBI	TBI	TBI	TBI	-	-	-	TBI	-	-	-	-
		Sorghum	0.62	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
	Southern Germany, Eningen unter Achalm (UHOH Inter-cropping)	Miscanthus	0.55	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
		Hemp	0.57	-	-	-	-	-	-	-	-	0.7	TBI	-	0.76
		Melilot	0.58	-	-	-	-	-	-	-	-	TBI	TBI	-	TBI
		Crambe	0.5	TBI	TBI	TBI	0.6	-	-	-	TBI	-	-	-	-
	Northern Italy, Bologna (UNIBO Intercropping)	Miscanthus	0.45	-	-	-	-	-	-	-	-	0.67	TBI	-	0.73
		Hemp	0.69	-	-	-	-	-	-	-	-	0.7	TBI	-	0.76
		Safflower	0.53	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Crambe	0.4	TBI	TBI	TBI	0.6	-	-	-	TBI	-	-	-	-
	Southern Italy, Catania (Sicily) (UNICT Inter-cropping)	Cardoon	0.6	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Hemp	0.67	-	-	-	-	-	-	-	-	0.7	TBI	-	0.76
		Safflower	0.48	0.66	0.69	0.71	0.6	-	-	-	0.575	-	-	-	-
		Castor	0.52	0.6	0.66	0.675	0.6	-	-	-	TBI	-	-	-	-

TBI = To be investigated

5. Promising biomass-to-product pathways in MIDAS

The superstructures in Deliverable 5.1 highlight the technological potential for every industrial crop tested in MIDAS. In total **129 potential biomass-to-product pathways** have been identified in Deliverable 5.1 and summarized in different superstructures showing the technological potential.

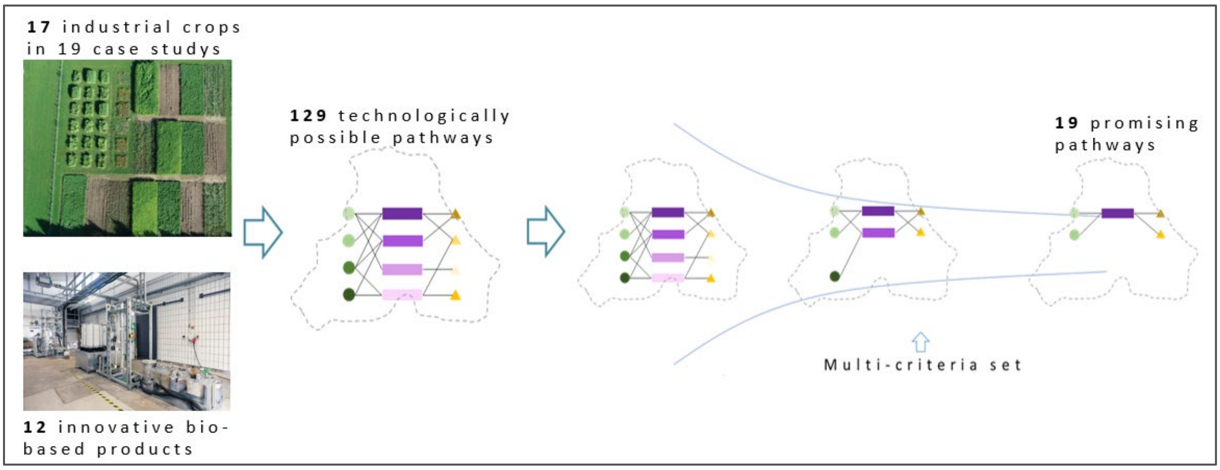

Figure 1 Identification process for promising biomass-to-product pathways in MIDAS (Pictures: University Hohenheim/ von Cossel; Kovalenko)

The identification of **a regional implementation potential** for biomass-to-product pathways requires to include various other aspects like the inclusion of local stakeholders and contextualized information. The results of the early-stage analysis (chapter 4) give a first indication of the site-specific crop suitability in the region related to the biomass production and their suitability for the processing into different bio-based products.

As crop suitability differs depending among other things on marginality, soil characteristics and climate and biomass conversion on biomass type, quality and availability contextualized information and stakeholder expertise are relevant factor to identify a regional implementation potential. Therefore, we collected regionalized information about the climate, crops, agricultural production, conversion technologies and products for this Deliverable. The data was primarily accessed through stakeholder consultation using user-friendly templates (data entry sheets) and interviews with research partners in WP3 and industry partners in WP4. Also, literature sources were used to fill data gaps.

To reduce the number of technologically possible biomass-to-product pathways to regionally promising site-specific pathways, we then used the scoring results from the early-stage assessment (chapter 4), stakeholder expertise and the contextualized information collected to select promising biomass-to-product pathways for every case study region. Different drivers led to the selection of **19 promising combinations of industrial crop(s) and suitable innovative bio-based product(s)** for every case study region (Table 1). These are the building blocks for the generation of value chain and webs concepts in MIDAS. The following table summarises the region, cropping system, selected industrial crop(s) and selected innocative bio-based product.

Table 1 Selected (industrial) crops and bio-based products for every case study region which can be combined to biomass-to-product pathways with high implementation potentials. Scoring results from the early-stage assessment in bold; P=Perennial; A= Annual; TBI=to be investigated.

	Region	**Cropping System (WP3)**	**Selected industrial crop(s)** (cycle) & scoring result (WP3)	**Innovative bio-based products** & scoring result (WP4)
1	Northern Spain, Soria	Intercropping	Lavender (P) - **0.74**	Bio-based phytosanitary products (Bioherbicides) – **0.575**
			Safflower (A) - **0.66**	*Seedcake:* Agricultural biostimulants - **0.69**
2	Northern Spain, Soria	Agroforestry	Siberian Elm (P) - **0.55**	MDF Boards – **0.75**
3	Central Italy, Monterotondo (Rom)	Agroforestry	Poplar (P) – **0.72**	Biochar – **0.78**
4	Western Greece, Leaxina/Ilia	Intercropping	Switchgrass (P)	Graphene & Nanocarbons – **0.46**
5	North- western Greece, Vonitsa	Intercropping	Castor (A)	*Seed:* Biodegradable in soil mulch films – **0.675**
				Seedcake: Phenol-formaldehyde type adhesives for particelboards – **0.6**
6	Central Greece, Litoxhoro (Katerini)	Agroforestry	Sorghum (A)	Particleboards – **0.7**
7	Central Greece, Stylida (Fthiotida)	Agroforestry	Safflower	*Seed:* Biodegradable in soil mulch films – **0.71**
				Seedcake: Phenol-formaldehyde type adhesives for particelboards - **0.6**
8	Northern Czech Republic, Ahnikov	Intercropping	Hemp (A) – **0.53**	Particleboards – **0.7**
9	Northern Poland, Swierznica	Agroforestry	Poplar (P) – **0.75**	Biochar – **0.78**
10	Southern France, Le Cailar	Intercropping	Guayule (P) – **0.72**	Latex for gloves, Adhesives and coatings as covering material for particleboards (latex-covered wood-based panels – **0.92**
				Bagasse: Biochar (**0.68**), MDF Boards (**0.75**), Particelboards (**0.71**)
11	Northern Serbia, Zabalj	Intercropping	Sorghum (A) - **0.66**	Particleboards – **0.67**
12	Central Spain, Fuentidueña de Tajo (Madrid)	Intercropping	Guayule (P) – **0.53**	Natural rubber for Tires – **0.75**
				Resins: Adhesives and coatings as covering material for particleboards
13	Southern Italy, Santa Maria La Fossa (Campania)	Intercropping	Cardoon (A) – **0.625**	*Seed:* Biodegradable biolubrificants – **0.66**
				Seedcake: Agricultural biostimulants – **0.69**
14	Central Italy, Terni (Umbria)	Intercropping	Safflower (A) – **0.6**	*Seed*: Biodegradable biolubrificants – **0.66**
				Seedcake: Agricultural biostimulants – **0.69**
15	Central Hungary, Gödöllö	Intercropping and agroforst	Miscanthus (P) - **0.67**	Particleboards – **0.67**
16	Central Hungary, Gödöllö	Intercropping and agroforstry	Poplar (P) – **0.67**	Biochar – **0.78**
17		Intercropping	Crambe (A) – 0.5	Seed: Biodegradable biolubrificants - **TBI**

	Southern Germany, Eningen unter Achalm			Seedcake: Phenol-formaldehyde type adhesives for particelboards – **0.6**
18	Northern Italy, Bologna	Intercropping	Hemp (A) – **0.69**	Particleboards – **0.7**
19	Southern Italy, Catania (Sicily)	Intercropping	Cardoon (A) – **0.6**	*Seed*: Biodegradable in soil mulch films – **0.71**
				Seedcake: Agricultural biostimulants – **0.69**

These components give an overview of the configuration options with a good **regional implementation potential** and highlight the range of possibilities and opportunities to create regional bio-based value chain and web concepts in the MIDAS project. In the following chapter these 19 pathways are described in more detail, presenting the contextualized information gathered about each region, crop, agricultural production, conversion technology and product.

6. Detailed description of selected MIDAS value chains and webs

The selected components (Table 1) can be summarized in **19 different biomass-to-product pathways**. Different drivers led to the selection of these pathways including i.a. suitability of crop in the region, suitability of crop for conversion technology and stakeholder expertise.

To further develop these pathways towards value chain and web concepts we need to include regionalized information. During the early-stage assessment we collected provisional data related to the region, agricultural production and processing into bio-based products for every selected pathway. Additionally, we identified potential value web components, propose ways to increase the circularity of every selected pathway(s) and opportunities through the identification of possible valorization strategies for the resulting by-products.

In the following section we present this information for every selected biomass-to-product pathway. This information can be seen as a starting point for further in-depth analysis in WP5 (e.g., LCSA) and the creation of value chain and web concepts.

As some case studies are not fully established yet (as of October 2023) due to various difficulties the following information is provisional and subject to change.

The following section highlights the structure that we followed to describe every selected pathway in this chapter:

Biomass-to-product pathways

In this part the main drivers for their selection as well as the value chain and web components from feedstock production to products (biomass-to-product pathways) are shown in graphical form.

Colour-code for biomass-to-product pathways

The components are color-coded into region, crop category, feedstock, process, intermediate and product. The main product is marked in **bold**. Potential components of a MIDAS value web are also highlighted (*italic*) in this structure (see explanation below).

Regional information

In this part contextual information about the region of biomass production is shown based on stakeholder expertise (WP3 partners). The information relates to the climate, soil characteristics, marginality, land use and land availability in the region as well as predominant farming systems in the area. Since a broad range of regions with different climatic conditions are under investigation in MIDAS, crop requirements and their suitability vary significantly among these regions. This part gives a first glimpse of these differences. If there were more than one pathway for the same region, this was indicated by a number in the heading (e.g. (1); (2)).

Agricultural production

This part provides information regarding the biomass production in innovative cropping systems during the MIDAS field trials based on stakeholder expertise (WP3 partners). Since a broad range of crops are investigated in MIDAS (perennial and annual crops, lignocellulosic, oil and speciality crops), cultivation and harvesting practices as well as their requirements vary significantly among the regions. Information from the MAGIC crop database (Monti 2021) was used as starting point. This information was then updated and adapted to the regional setting by WP3 partners.

Innovative bio-based products

This part covers the biomass conversion into different applications and products in MIDAS based on stakeholder expertise (WP4 partners). The bio-based product and its conversion technology is described and information regarding logistics, scale, by-products, TRL, product composition and lifetime, market, customer group as well as a market outlook is given.

Market potential

In this part initial information regarding the market size, market potential and drivers for future developments for the respective bio-based product is given based on stakeholder expertise (WP4).

Value web perspective

As previously stated the goal of MIDAS is to create innovative regional value chain and web concepts. The possibility of using biomass in diverse forms, using by-products for additional value generation (i.e. cascading use of biomass) and setting multi-feedstock and multi-product systems from biomass (e.g. biorefineries) indicate a bio-based value web approach (chapter 2). Especially, at the handling, processing and trading level, the feedback loops and cascading effects for utilizing and reutilizing biomass can link or merge value chains.

In this section a preliminary value web perspective is given based on the authors expertise. We highlight potential components for the creation of a regional value web concept in MIDAS, preliminary linking different MIDAS pathways and including potential cascading uses. This section herby presents potential synergy opportunities in the MIDAS project that could be investigated in future work.

Northern Spain (1) - Soria: Formulation of Bio-based phytosanitary products (Bioherbicides) from Essential Oils (Lavender) and Pelargonic Acid (Safflower)

For the production of Bio-based phytosanitary products (Bioherbicides) Safflower and Lavender are cultivated and converted trough different process steps (Fig. 5). Lavender and Safflower were identified as highly suitable crops for the region which indicates a regional implementation potential. Additionally, an increased interest for organic farming products is projected to drive the market for Bioherbicides in the future making this value chain an attractive option for further study in MIDAS.

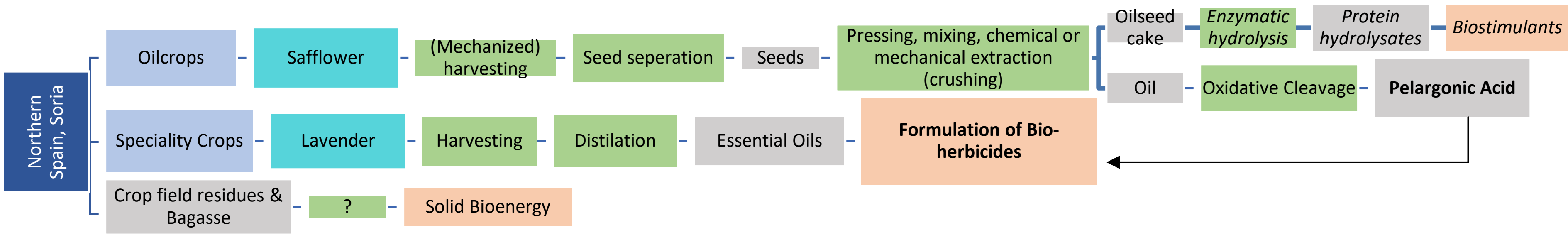

Figure 5 Value chain and web - Northern Spain (1); Soria

Regional information

Table 6 Regional information case study Northern Spain (1) - Soria

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Soria	Northern Spain	Warm and temperate (cfb) - moderately cold winters; cool summer nights)	10,7° C; 450-525 mm; 1050m altitude;	1% organic matter, pH 6-7, high stonnines, sandy soil	Adverse Climate (dryness); Low soil fertility	Wheat/barley in rotation with sunflower and fallow. Legumes are being introduced in rotations but this is not most common case by now.	175.000 ha of marginal agricultural land in the provice of Soria (NUTS 3)	Typically rainfed annual crops

Agricultural production:

CIEMAT is producing perennial and annual crops in an intercropping field trial. From the initial assessment Lavender and Safflower has been identified as a promising crop for the region.

Table 7 Information regarding crop cultivation CIEMAT - Northern Spain (1)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Lavender	Perennial	Cuttings/Seeds	moldboard plowing, cultivator pass, rolling	-	9375/ha for lavender strips (2885 plants/ ha for the whole plot)	-	Only for survival if very dry season and if posible	Summer	mechanized	800 - 1200 kg harvested biomass	-	Oil	10-15 kg oil/ha/y
Safflower	Annual	Seed	Plowing Harrowing Hoening	14-24 kg/ha	400.000/ 500.000 plants/ha	From second year: 60-110 N/y 30 P/y 40 k/y	No	Summer	Combine harvester	Seed: 1,5 - 3 t/ha dm	Seeds: Silos	Seeds	Seed: 1,5 - 3 t/ha dm

Lavender thrives in warm summer and cold winter climates, yielding around 1000 kg ha^{-1} of dry flowers and about 300-400 kg ha^{-1} of seeds. The plant's ecological flexibility allows it to thrive in various regions, but requires a temperature of 10-15 ◦C for germination. Lavender harvest begins in the second year after flowering, taking two to three years to reach full productivity. Essential oil extraction is typically done through hydrodistillation and steam distillation. Lavender essential oil is a highly sought-after product due to its versatility in various applications, including the use of flowers, leaves, and stalks in distillation processes, and its potential for creating various products, making it a versatile and versatile ingredient (Crișan et al. 2023). In MIDAS the essential oil from Lavender is combined with pelargonic acid extracted from Safflower to formulate Bioherbicides.

Innovative bio-based product:
Novel biodegradable in soil bio herbicides formulations based on bio-based pelargonic acid derived from the vegetable oils (Safflower) and the essential oils (Lavender) produced by CIEMAT will be developed and characterised by NOVAMONT. Bioherbicides are herbicides consisting of phytotoxins, pathogens, and other microbes used as biological weed control. Pelargonic acid is an efficient burndown weed control active ingredient, which acts by contact on the leaf surface**,** resulting in rapid tissue desiccation

Table 8 Information regarding innovative bio-based products – Bioherbices; Biostimulants

	Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Bio-based phytosanitary products (Bioherbicides	Lorry/truck in big bags	Oxidative Cleavage of vegetable oil	50kg/Batch	TBI	Azelai Acid	Protected by IP right	1/2 years (TBI starting from the ingredients)	Agriculture, Europe	B2B[1]	TBI	TBI	TBI
Agricultural Biostimulants	*Lorry/truck in big bags*	*50l/batch reactor*	*TBI*	*Waste water*	*7*	*Covered by IP protection*	*TBI*[2]	*Agriculture, Europe*	*B2B*	*TBI*	*TBI*	*TBI*

Market potential

The global **bioherbicides market** has grown at an annualized average rate of revenue growth (CAGR) of 14.5% from 2016 to reach 1.4 bn€ by 2021. Increasing preferences for organic farming producers along with rising consumption of eco-friendly weed control products is projected to drive the market further in the near future.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using the seedcake from Safflower for the production of Agricultural Biostimulants (Novamont).

[1] B2B = Business to Business
[2] TBI = To be investigated

Northern Spain (2) - Soria: Medium-Density-Fibre (MDF) Boards from Woody Biomass (Siberian Elm)

For the production of Medium-Density-Fibre Boards Siberian Elm is cultivated and converted trough different process steps (Fig. 6). MDF Boards from Siberian Elm has been identified as highly suitable processing pathways indicating a regional implementation potential. Additionally, an strong market for wood-based panels in Europe makes this value chain an attractive option for further study in MIDAS.

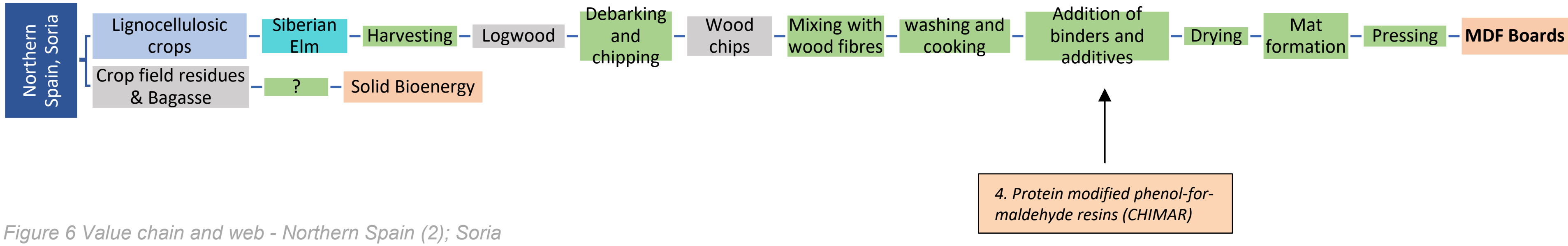

Figure 6 Value chain and web - Northern Spain (2); Soria

Regional information

Table 9 Regional information case study Northern Spain (2) - Soria

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Soria	Northern Spain	Warm and temperate (cfb) - moderately cold winters; cool summer nights)	10,7° C; 450-525 mm; 1050m altitude;	1% organic matter, pH 6-7, high stonnines, sandy soil	Adverse Climate (dryness); Low soil fertility	Wheat/barley in rotation with sunflower and fallow. Legumes are being introduced in rotations but this is not most common case by now.	175.000 ha of marginal agricultural land in the provice of Soria (NUTS 3)	Typically rainfed annual crops

Agricultural production:

CIEMAT is producing perennial and annual crops in an agroforestryry field trial. From the initial assessment Elm has been identified as a promising crop for the region.

Table 10 Information regarding crop cultivation CIEMAT (2) - Northern Spain

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertili-zation	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Elm	Perennial	Seed	moldboard plowing, cultivator pass, rolling	-	4688 plans/ha in elm strip and 1442 planst/ha in the whole plot, distances between plants 2x1 m	None	Only for survival if very dry sea-son and if possi-ble	Winter	mecha-nized	2-3 Mg dm/ha/y (DM)	-	Lignocellulose	2-3 Mg dm /ha/y (DM)

Innovative bio-based product:

Valbopan (CHIMAR) will produce coloured medium density fiberboards (MDF). Woody biomass (Siberian elm) together with natural resins will be tested to establish whether, alone or in combination, they could offer any improvement to the physicochemical features of currentl produced products. MDF Boards with new adhesives and different particles will be tested as well as changing press temperatures; addition of hardeners and addition of adhesives.

Table 11 Information regarding innovative bio-based products – MDF Boards

Feedstock lo-gistics	Processing scale	Amount of product output per year	By-prod-ucts	Pro-cess-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known com-petitors	Market out-look 2030	Societal trends that influence mainstreaming
Truck	50kg/Batch	TBI[3]	dust, bark (used for heating), water	-	Wood chips, binder, addi-tives,	TBI	Wood Fibre Boards (Eu-rope)	-	TBI	TBI	TBI

[3] TBI = To be investigated

Market potential

The wood-based panel industry is strong in Europe as **Particleboards** and **MDF-Boards** have high volume shares, at 30.7 and 12.0 million m^3 in 2020 respectively. The technology and services used in MIDAS account for over 10% of the annual global production.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using protein modified phenol-formaldehyde resins (CHIMAR) as binder in the production of MDF-Boards. These resins can be produced by using seedcake which is a by-product from oil extraction (e.g., Bioherbicides, Biodegradable in soil mulch films etc.).

Central Italy (1) - Monterotondo (Rom): Biochar from Woody Biomass (Poplar)

For the production of Biochar woody biomass (Poplar) is cultivated and converted trough different process steps (Fig. 7). Poplar was identified as highly suitable crops with strong expertise about the cultivation in the region which indicates a regional implementation potential. Additionally, the Biochar market is projected to grow making this value chain an attractive option for further study in MIDAS.

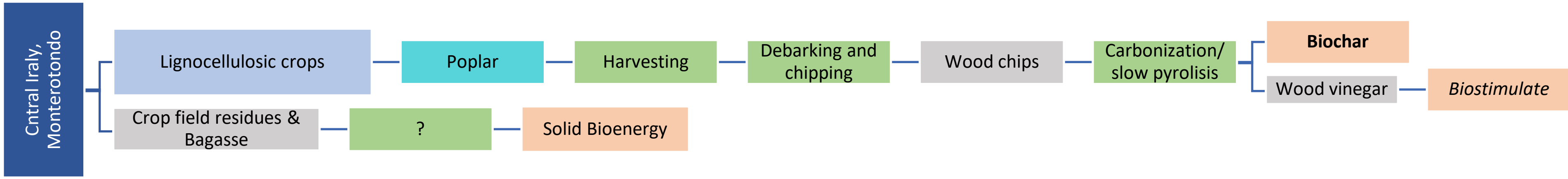

Figure 7 Value chain and web - Central Italy (1); Monterotondo

Regional information

Table 12 Regional information case study Central Italy (1); Monterotondo

City	*Re-gion*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classifi-cation	*Annual tempera-ture & precipita-tion, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Montero-tondo (Rome	Italy	Warm and tem-perate (cfb) - moderately cold winters; cool summer nights)	mean annual tem-perature 16 c°, about 600 mm of rain and altitude of 165 m.a.s.l.	Clay loam soil (sand 21%, silt 44%, clay 35%); O.M. 2.23%, Tot N 0.153%, pH 8.0 Mg 290 ppm, K 220 ppm, Ca 3700 ppm, EC 0.135mS,	Excessive wetness	Perennial crops (Poplar)	7.0 ha (estimate)	rotations sytems

Agricultural production:

CREA is producing perennial and annual crops in an agroforestry field trial. From the initial assessment Poplar has been identified as a promising crop for the region.

Table 13 Information regarding crop cultivation CREA - Central Italy (1)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Poplar	Perennial	Stem cuttings of different size, seedlings from seeds or tissue cultures, root cuttings.	-	-	Plants per ha :800 - 2000	50 - 100 Kg N /ha	-	All season ussualy leaveless –winter-spring-autum	harvester, motor-manual, special self moving chipper	10-15t/ha (expected)	woods chips	energy wood, chips pellets, boards and furniture	4-10 Mg DM/y, 250-450 m3 /ha for 15-20 years,

Poplar is a plant species which grows rapidly that is being identified as a promising feedstock for BBVCs. It is possible to operate poplar forests as biomass production ecosystems with low energy input, resulting in significant improvements to habitat quality for flora and fauna, erosion control, and reduced fertilizing and spraying requirements (Meyer et al. 2021).

Innovative bio-based product:

RE-CORD will produce Biochar which is the solid product from lignocellulosic biomass thermochemical conversion such as slow pyrolysis together with gas and a liquid phase (Bio-oil). Solid biomass is introduced into a carbonization demo plant where it is pyrolized. The biochar is collected by gravity in a sealed vessel. Biochar is a highly porous material with a wide range of possible uses, including sustainable agriculture, as it improves the water holding capacity and the organic matter content in soil, in particular in marginal lands and regions where rain is scarce, and irrigation is difficult for a number of environmental or economic reasons.

Table 14 Information regarding innovative bio-based products – Biochar

Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming

Road	100kg/h (inlet) - rotary kiln, continuous	5 to 10 tons /year - demonstrative purposes	wood vinegar	7	88,5% Carbon	100 years	Agricultural amendments and fertilizers (organic or conventional) - Biodegradable mulch films	Farms - Biodegradable mulch film producers - Organic amendment producers	Many	expected CAGR 2020-2023 + 68%	Production capacity

Market potential

According to the European Biochar Industry Consortium, approximately 21,000 tons of biochar were manufactured in Europe in 2020. The **biochar** market size, already generating 1.8 bn€ revenue in 2021, is expected to advance at a CAGR of over 10% during 2021–2030. Biochar's importance is expected to grow as a Carbon Capture Use and Storage (CCUS) market is expected to have a turnover of 500 M€ in 2026.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using Biochar as a bio-based substitute of Carbon Black masterbatch in the production of biodegradable in soil mulch films.

Also using the wood vinegar which is a by-product in the Biochar production could improve circularity. Wood vinegar is an aqueous fraction of condensates which contains approximately 30% of acetic acid and can be used as a Biostimulate.

Western Greece (1), Lexaina (Ilia): Carbon nanofilaments (CNF) from woody biomass (Switchgrass) and use as polymers additives in resins

For the production of Carbon nanofilaments and Graphene woody biomass (Switchgrass) is cultivated and converted trough different process steps (Fig. 8). Carbon nanofilaments from Switchgrass has been identified as highly suitable processing pathways indicating a regional implementation potential. Additionally, the use of biomass from marginal land potentially enables lower costs in production of nanocarbons making this value chain an attractive option for further study in MIDAS.

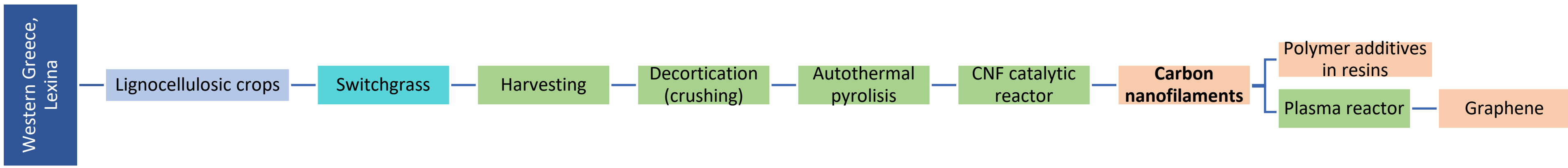

Figure 8 Value chain and web - Western Greece (1); Lexaina

Regional information

Table 15 Regional information case study Western Greece (1); Lexaina

City	***Region***	***Climate***		***Soil characteristics***	***Marginality***	***Regional information***		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Lexaina	Greece	Hot-summer mediterranean climate (csa)	-	sandy soil (>68%), alkalic (8.1), low organic matter (1.12%).	Limitations in rooting (a. Unfavourable soil texture);	Annual winter and spring crops like cereals, corn, watermelon, melon, etc.	TBI	Rotation schemes with winter and spring annual crops

Agricultural production:

CRES is producing perennial and annual crops in an intercropping field trial. From the initial assessment Switchgrass has been identified as a promising crop for the region.

Table 16 Information regarding crop cultivation CRES - Western Greece (1)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Switchgrass	Perennial	Seed		10 kg seeds/ha, the distances between the rows were 79 cm	50-150	50-100 Kg N/y 80-100 kg P (only at establishment) 80-100 kg K (only at establishment)	300 mm	Summer to spring	Baled straw	Expected 10 t/ha		Lignocellulose	15 Mg/ha/y (DM)

Innovative bio-based product:

Carbonaceous nanomaterials are extensively investigated due to their remarkable performance including mechanical, electrical, and thermal properties. In particular, the use of nanomaterials can offer extraordinary structural and functional properties of polymers that can be tailored for broad application in many fields. UDS produces bio-carbon nanofilaments and graphene (Bio-CNF&G) by using a kg-lab scale process unit based on two novel thermo-catalytic reactor technologies.

Table 17 Information regarding innovative bio-based products – Nanofilaments and graphene

Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Truck	Semi-batch operation, kg-lab scale (thermal reactor), pilot plant scale pyrolyzer (up	100 kg/year	Syngas; feed for various chemical reactors to produce liquid hydrocarbons, Liquid hydrocarbons: A raw feed	4-6.	60% NFC, 40% graphene	to be explored, it will be determined through its use efficiency and final	Polymers, dyes, resins, rubbers	B2B	Upon our knowledge there are no commercial users or competitors in this area.	This is part of the overall project. Our results will feed other Work Packages (WPs)	Bio-sourced products

	to 3 kg/hr), 300 hours/year		for further separation and valorization, Char: Adsorbent, fertilizer			product robustness and lifetime.				focusing on Techno-Economic Analysis (TEA).	

Market potential

CNF (**carbon nanofilaments**) is still an emerging market as Nanofibers represented a market of about 0.4 bn€ in 2019. Forecasts indicate an annual growth rate of approximately 30% from 2022 to 2027. Currently the production costs of present technologies limit their use.
The use of biomass and CO_2 as a carbon source potentially enables low-cost entrants making it feasible to offer this product at a competitive price. Additionally this positions the process as an environment-friendly option.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using carbon nanofilaments in the production of tires.

Western Greece (2), Vonitsa: Biodegradable in Soil Mulch films and phenol-formaldehyde type adhesives from Oilcrops (Castor)

For the production of Biodegradable in Soil Mulch films and phenol-formaldehyde type adhesives, Oilcrops (Castor) are cultivated and converted trough different process steps (Fig. 9). Biodegradable in Soil Mulch films from Castor has been identified as highly suitable processing pathways indicating a regional implementation potential. Additionally, the importance of biodegrabdable soil mulch film is growing due to i.a. an increasing growth in sustainable agriculture making this value chain an attractive option for further study in MIDAS.

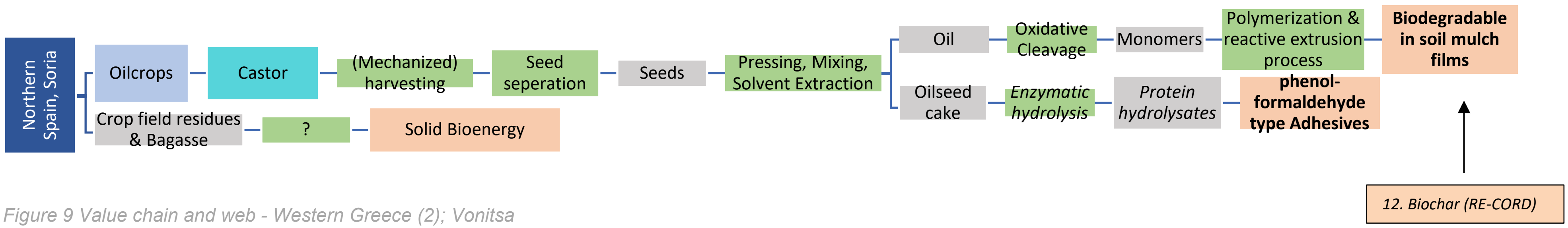

Figure 9 Value chain and web - Western Greece (2); Vonitsa

Regional information

Table 18 Regional information case study Western Greece (2); Vonitsa

City	*Re-gion*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classifica-tion	*Annual tempera-ture & precipita-tion, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming sys-tems*
Vonitsa	Gre-ece	warm and temper-ate, dry summers; wet winters (csa)	16,6 °C; 1200-1700mm;	sandy soil (>68%), alkalic (8.1), low or-ganic matter (1.12%).	Limitations in rooting (a. Un-favourable soil texture);	Annual winter (winter cerelas) and spring crops (corn, sorghum, sunflower)	TBI	Rotation schemes with cereals and oilseeds; sorghum is being grown as ani-mal feed

Agricultural production:

CRES is producing perennial and annual crops in an intercropping field trial. From the initial assessment Castor has been identified as a promising crop for the region.

Table 19 Information regarding crop cultivation CRES - Western Greece (2)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield	Storage and durability	Main product	Potential production
Castor	Annual	Seed		15-20 kg seeds/ha	6-10		400 mm	Summer to early fall	Combined threshing	2.5 to 3 t/ha		Oil	3-5 Mg/ha/y (seeds), 6-10 Mg/ha/y (straw

There are many chemical applications for castor oil due to its high content of ricinoleic acid (RA). Regardless of the fact that the castor plant is well-suited to the European environment, castor oil production is concentrated in a few countries (primarily India, China, and Brazil) (Zanetti et al. 2017). The EU oleochemical sector accounts for one-quarter of global castor oil production (Zanetti et al. 2017). Castor oil is extracted from seeds through pressing. After supplementary detoxification by chemical means, the cake can be used for Biostimulants and Adhesives production. Additionally, it can be used as a natural fertilizer and for the production of biochar (Dimian et al. 2019).

Innovative bio-based product:

Novamont will convert vegetable oils through proprietary chemical and biotechnological processes, into purified monomers that will be used in polymerization and reactive extrusion processes in order to obtain biodegradable and compostable biomaterials suitable to be transformed trough film-blowing into biodegradable in soil mulch films. Mulch film will be characterized through rheological, mechanical, hydrolytic stability and in soil biodegradability EN17033 and will be tested on fields carried out in WP2 & 3
CHIMAR will develop phenol-formaldehyde type adhesives for particleboards by replacing part of phenol by proteins extracted from seed cake left behind by oil extraction.

Table 20 Information regarding innovative bio-based products – Biodegradable in soil mulch films, phenol-formaldehyde adhesives, Biochar

	Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Biodegradable in Soil	Truck /Lorry in Big Bags	Different Sizes from Lab to Industrial scale	TBI	Pelargonic Acid	From 4 to 9	Protected by IP right	~1year	Agriculture; Europe	B2B	Novamont is producer of Biomaterials, mulch film are pro-		

Mulch films										duced by converters. Biomaterials competitors are BASF, FKUR,		
phenol-formaldehyde type adhesives	Truck	Lab sacle	N/A	none	6	phenol, formaldehyde, water, NaOH, protein	1 month	construction, furniture	wood-based panels industry	other institutes/companies developing know-how for thermosetting polymers	21.17 billion USD	increased request of wood-based panels and all other applications of phenolic resins
Biochar	*Road*	*100kg/h (inlet) - rotary kiln, continuous*	*5 to 10 tons /year - demonstrative purposes*	*wood vinegar*	*7*	*88,5% Carbon*	*100 years*	*Agricultural amendments and fertilizers (organic or conventional) - Biodegradable mulch films*	*Farms - Biodegradable mulch film producers - Organic amendment producers*	*Many*	*expected CAGR 2020-2023 + 68%*	*Production capacity*

Market potential

Global **mulch film** market is expected to reach 4.4 bn€ in 2024, growing at a CAGR of 6.8% between 2018 and 2024. In Europe (86 kton/year), only 3 % of the total amount of plastic mulches is currently biodegradable. Thanks to its ability to address drawbacks of conventional products such as high film disposal cost (between 50 to 250 €/kg), chemical effects of plastic pollution in soil, and the increasing growth in sustainable agriculture, the importance of **biodegrabdable soil mulch film** is growing.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using the seedcake for the production of phenol-formaldehyde type adhesives. In a sub-task Biochar form RE-CORD could tested as bio-based substitute of Carbon Black masterbatch in the production of biodegradable in soil mulch films.

Central Greece (1), Litoxhoro (Katerini): Particleboards from Woody Biomass (Sorghum)

For the production of Particleboards woody biomass (Sorghum) is cultivated and converted trough different process steps (Fig. 10). Particleboards from Hemp has been identified as highly suitable processing pathways indicating a regional implementation potential. Additionally, a strong market for wood-based panels in Europe makes this value chain an attractive option for further study in MIDAS.

Figure 10 Value chain and web - Central Greece (1); Litoxhoro

Regional information

Table 21 Regional information case study Central Greece (1); Litoxhoro

City	Region	Climate		Soil characteristics	Marginality	Regional information		
		Köppen-Geiger climate classification	Annual temperature & precipitation, altitude			Land use in the region	Land availability (marginal land)	Regional farming systems
Litoxhoro	Greece	warm and temperate, dry summers; wet winters (csa)	16,6 °C; 1200-1700mm;	TBI	Low fertility of soil	TBI	TBI	TBI

Agricultural production:

CRES is producing perennial and annual crops in an agroforestryry field trial. From the initial assessment Sorghum has been identified as a promising crop for the region.

Table 22 Information regarding crop cultivation CRES - Central Greece (1)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Sorghum	Annual	Seed	soil preparation disc plow trailer, pre-sowing preparation with seedbed cultivator	10	250 000	100-120 kg N, 60-90 kg P2O5 and 60-80 kg K2O per hectar		Summer to early fall	Combine Harvester	8-10 t seed; 5 t/ha biomass	big bags for seed, bale for biomass	Starch, protein; Lignocellulos	

Innovative bio-based product:

CHIMAR will manufacture particleboards for various purposes (furniture, objects, wall finish-es etc). MIDAS biomass will use to replace wood in the production of particleboards. The replacement will start from low levels (e.g. 20-30%) and it will be gradually increased. The target is a 100% replacement of wood.

Table 23 Information regarding innovative bio-based products – Particleboards

Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Truck	lab scale (pilot plant)	Not applicable	-	TRL 6	Composite of lignocellulosic biomass and an adhesive	TBI	Furniture, constructions	Wood-bsed panels industry	Other companies that develop know-how in the field	34 USD million	Growing demand for eco-friendly building materials, increasing investment in construction industry, rising popularity of do-it-yourself (DIY) projects

Market potential

The wood-based panel industry is strong in Europe as **Particleboards** and **MDF-Boards** have high volume shares, at 30.7 and 12.0 million m^3 in 2020 respectively. The technology and services used in MIDAS account for over 10% of the annual global production.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using adhesives and coatings from CHIMAR as well as covering material from Latex (CHIMAR/GuaTecs) for the production of particleboards.

Central Greece (2), Stylida (Fthiotida): Biodegradable in Soil Mulch films and phenol-formaldehyde type adhesives from Oilcrops (Safflower)

For the production of Biodegradable in Soil Mulch films and phenol-formaldehyde type adhesives, Oilcrops (Safflower) are cultivated and converted trough different process steps (Fig. 11). Biodegradable in Soil Mulch films from Safflower has been identified as highly suitable processing pathways indicating a regional implementation potential. Additionally, the importance of biodegrabdable soil mulch film is growing due to i.a. an increasing growth in sustainable agriculture making this value chain an attractive option for further study in MIDAS.

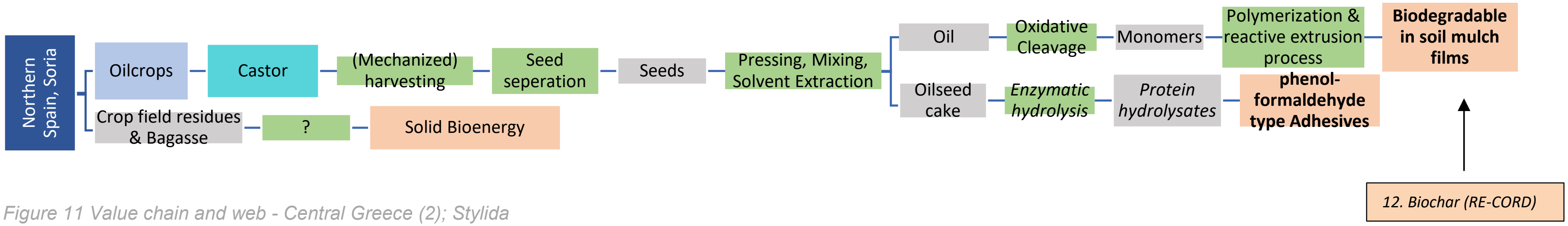

Figure 11 Value chain and web - Central Greece (2); Stylida

Regional information

Table 24 Regional information case study Central Greece (2); Stylida

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Stylida	Greece	Mediterranean climate (csa)		> 50% sandy, saline area	Adverse chemical composition of soil; Adverse terrain	TBI	TBI	TBI

Agricultural production:

CRES is producing perennial and annual crops in an agroforestryry field trial. From the initial assessment Safflower has been identified as a promising crop for the region.

Table 25 Information regarding crop cultivation CRES - Central Greece (2)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Safflower	Annual	Seed	Plowing Harrowing Hoening	14-24 kg/ha				Summer	Combine harvester	Seed: 1,5 - 3 t/ha dm (expected)	Seeds: Silos	Seeds	Seed:1,5 - 3 t/ha dm

Innovative bio-based product:

Novamont will convert vegetable oils through proprietary chemical and biotechnological processes, into purified monomers that will be used in polymerization and reactive extrusion processes in order to obtain biodegradable and compostable biomaterials suitable to be transformed trough film-blowing into biodegradable in soil mulch films. Mulch film will be characterized through rheological, mechanical, hydrolytic stability and in soil biodegradability EN17033 and will be tested on fields carried out in WP2 & 3
CHIMAR will develop phenol-formaldehyde type adhesives for particleboards by replacing part of phenol by proteins extracted from seed cake left behind by oil extraction

Table 26 Information regarding innovative bio-based products – Biodegradable in soil mulch films, phenol-formaldehyde adhesives, Biochar

	Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product life-time	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Biodegradable in Soil Mulch films	Truck/Lorry in Big Bags	Different Sizes from Lab to Industrial scale	TBI	Pelargonic Acid	From 4 to 9	Protected by IP right	~1year	Agriculture; Europe	B2B	Novamont is producer of Bio-materials, mulch film are produced by converters. Biomaterials competitors are BASF, FKUR,		

phenol-formaldehyde type adhesives	Truck	Lab sacle	N/A	none	6	phenol, formaldehyde, water, NaOH, protein	1 month	construction, furniture	wood-based panels industry	other institutes/companies developing know-how for thermosetting polymers	21.17 billion USD	increased request of wood-based panels and all other applications of phenolic resins
Biochar	*Road*	*100kg/h (inlet) - rotary kiln, continuous*	*5 to 10 tons /year - demonstrative purposes*	*wood vinegar*	*7*	*88,5% Carbon*	*100 years*	*Agricultural amendments and fertilizers (organic or conventional) - Biodegradable mulch films*	*Farms - Biodegradable mulch film producers - Organic amendment producers*	*Many*	*expected CAGR 2020-2023 + 68%*	*Production capacity*

Market potential

Global **mulch film** market is expected to reach 4.4 bn€ in 2024, growing at a CAGR of 6.8% between 2018 and 2024. In Europe (86 kton/year), only 3 % of the total amount of plastic mulches is currently biodegradable. Thanks to its ability to address drawbacks of conventional products such as high film disposal cost (between 50 to 250 €/kg), chemical effects of plastic pollution in soil, and the increasing growth in sustainable agriculture, the importance of **biodegrabdable soil mulch film** is growing.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using the seedcake for the production of phenol-formaldehyde type adhesives. In a sub-task Biochar form RE-CORD could tested as bio-based substitute of Carbon Black masterbatch in the production of biodegradable in soil mulch films.

Northern Czech Republic, Ahnikov: Particleboards from Woody Biomass (Hemp)

For the production of Particleboards woody biomass (Hemp) is cultivated and converted trough different process steps (Fig. 12). Particleboards from Hemp has been identified as highly suitable processing pathways indicating a regional implementation potential. Additionally, hemp has been identified as highly suitable crop for the region making this value chain an attractive option for further study in MIDAS.

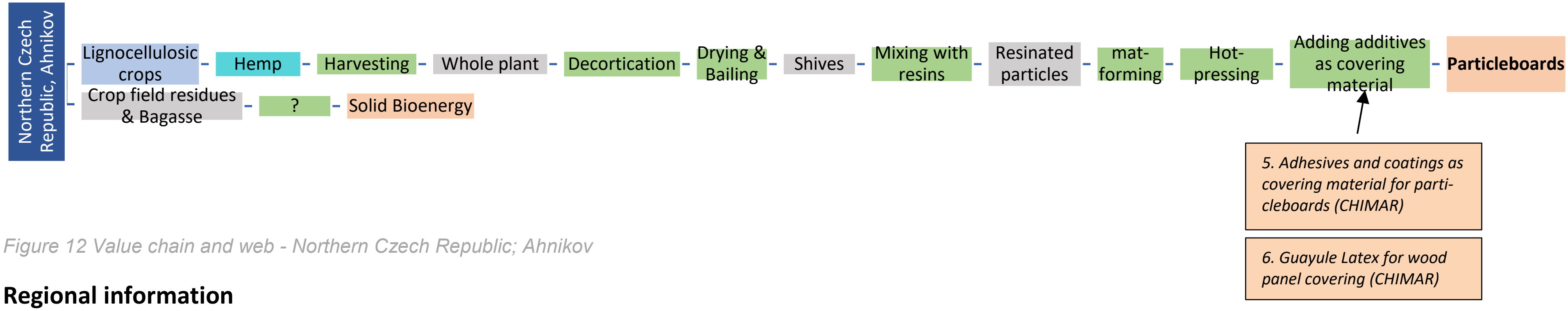

Figure 12 Value chain and web - Northern Czech Republic; Ahnikov

Regional information

Table 27 Regional information case study Northern Czech Republic

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Malkov (Ahníkov)	Chomutov, Czech Republic	mild, and generally warm and temperate (Cfb)	Average annual temperature °C: 8 – 9; Average rainfall (mm): 500 - 600 Altitude: 363 m.a.s.l.; Sum of temperatures above 10 °C: 2600 – 2800; Probability of dry growing seasons in %: 20 – 30;Moisture security in the growing season: 2 - 4	anthropogenic soils damaged by mining activities. The topsoil was removed and replaced with a layer of engineered soil. The content of organic matter and nutrients was low, but this was improved by a heavy application of digestate from the neighboring biogas plant, which raised the content of nutrients and humus to medium to high values. The acidity is weak. Medium to light soil, stony, skeleton content up to 25%. Hydropedological characteristics: high	Adverse chemical composition of soil. Low fertility of soil.	Permanent grassland or forest	about 1200	very low fertility soils

				infiltration and permeability - from 0.20 mm/min; low water retention capacity - up to 100 l/m2; low usable water capacity - up to 79 l/m2.				

Agricultural production:

CZECHEMP is producing perennial and annual crops in an intercropping field trial. From the initial assessment Hemp has been identified as a promising crop for the region.

Table 28 Information regarding crop cultivation CzecHemp - Northern Czech Republic

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Hemp	Annuall	Seed	plough, harrow	25-35 kg/ha (seed); 40-60 kg/ha (fiber or biomass)	30 kg / ha (30-75 (seed); 150-250 (fiber)	100-150 kg N, 26-44 kg P and 80-140 kg K per hectare	no irrigated	Summer to Fall	Combine harvesting grain and straw. Double-cut combine above-ground biomass.	-	Green biomass or straw can be stored in bales or chips. It is demanding on the harvesting technique due to the large fiber content.	Oil and grain for food or feed and/or lignocellulosic biomass for technical and energetic use, or fibers production.	1.0-1.5 Mg/ha (seeds), 7-12 Mg/ha (dry stems)

Innovative bio-based product:

CHIMAR will manufacture particleboards for various purposes (furniture, objects, wall finish-es etc). MIDAS biomass will use to replace wood in the production of particleboards. The replacement will start from low levels (e.g. 20-30%) and it will be gradually increased. The target is a 100% replacement of wood.

Table 29 Information regarding innovative bio-based products – Particleboards

Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Truck	lab scale (pilot plant)	Not applicable	there are no byproducts	TRL 6	Composite of lignocellulosic biomass and an adhesive	TBI	Furniture, constructions	Wood-bsed panels industry	Other companies that develop know-how in the field	34 USD million	Growing demand for eco-friendly building materials, increasing investment in construction industry, rising popularity of do-it-yourself (DIY) projects

Market potential

The wood-based panel industry is strong in Europe as **Particleboards** and **MDF-Boards** have high volume shares, at 30.7 and 12.0 million m^3 in 2020 respectively. The technology and services used in MIDAS account for over 10% of the annual global production.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using adhesives and coatings from CHIMAR as well as covering material from Latex (CHIMAR/GuaTecs) for the production of particleboards.

Northern Poland, Swierznica: Biochar from Woody Biomass (Poplar)

For the production of Biochar woody biomass (Poplar) is cultivated and converted trough different process steps (Fig. 13). Biochar from Poplar has been identified as highly suitable processing pathways. Additionally, an expected growing market interest for Biochar in Europe makes this value chain an attractive option for further study in MIDAS.

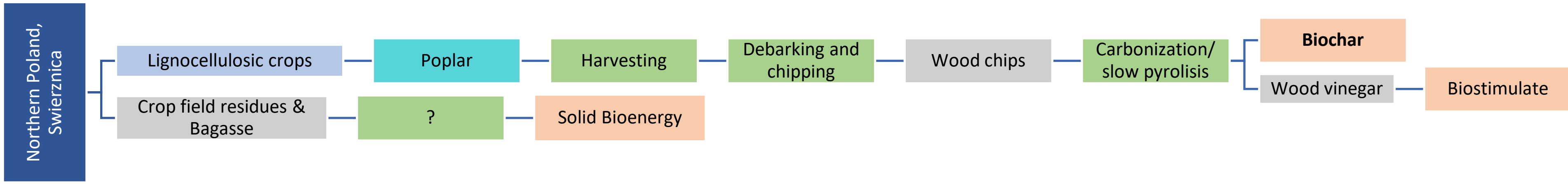

Figure 13 Value chain and web - Northern Poland, Swierznica

Regional information

Table 30 Regional information case study Northern Poland; Swierznica

City	***Region***	***Climate***		***Soil characteristics***	***Marginality***	***Regional information***		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Świerznica, Stegna Municipality	Northern Poland	mild, and generally warm and temperate (Cfb)	9,2°C; 700-750mm	Alluvial lands - very high variability in soil conditions across field; in general, very sandy soil with very low soil organic content matter; the field contains places, where only sand is present.	Adverse chemical composition of soil; low fertility of soil	Intensive production of cereals (wheat, barley, triticale), canola, sugarbeets, and potatoes with regions of intense dairy production and vegetables for processing (corn and peas for canning).	Due to various conditions (mainly too wet and in some places too sandy) estimated at approximately 12-18% of agricultural land in the area.	The dominant farming system in the region is very intensive cereal-rapeseed production (with tillage, sometimes without the use of the plough). Some farms have sugarbeets and/or potatoes integrated into their operations. The farm European Carbon Farmers is cooperating with to run its demo plot in Poland is unique for this

								region and the rest of Poland, as it specializes in hay production only.

Agricultural production:

EuropeanCarbonFarmers is producing perennial and annual crops in an agroforestryry field trial. From the initial assessment Poplar has been identified as a promising crop for the region.

Table 31 Information regarding crop cultivation ECF - Northern Poland

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
(Black) Poplar	Perennial	Seed	Shallow disking (two times - one time each in different directions of the field) with topsoil preparation by power harrow.	25-35 kg/ha (seed); 40-60 kg/ha (fiber or biomass)	600 trees for three rows of trees (200 each = approximately 40 trees per tree sub-row).	None	N/A	Poplar harvested every couple of years depending on end use and growth conditions.	Bale straw or chips	no experience yet, 5-8t/ha (estimate)	All of the biomass stored, protected away from the weather conditions (rain, snow, etc.) as presented here: https://www.arc2020.eu/letter-from-the-farm-welcome-to-ciasnocha-family-farm/	energy wood, chips pellets, boards and furniture	4-10 Mg DM/y, 250-450 m3 /ha for 15-20 years,

Poplar is a plant species which grows rapidly that is being identified as a promising feedstock for BBVCs. It is possible to operate poplar forests as biomass production ecosystems with low energy input, resulting in significant improvements to habitat quality for flora and fauna, erosion control, and reduced fertilizing and spraying requirements (Meyer et al. 2021).

Innovative bio-based product: RE-CORD

Biochar is the solid product from lignocellulosic biomass thermochemical conversion such as slow pyrolysis together with gas and a liquid phase (Bio-oil). Solid biomass is introduced into a carbonization demo plant where it is pyrolized. The biochar is collected by gravity in a sealed vessel.

Biochar is a highly porous material with a wide range of possible uses, including sustainable agriculture, as it improves the water holding capacity and the organic matter content in soil, in particular in marginal lands and regions where rain is scarce, and irrigation is difficult for a number of environmental or economic reasons.

Table 32 Table 17 Information regarding innovative bio-based products – Biochar

Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Road	100kg/h (inlet) - rotary kiln, continuous	5 to 10 tons /year - demonstrative purposes	wood vinegar	7	88,5% Carbon	100 years	Agricultural amendments and fertilizers (organic or conventional) - Biodegradable mulch films	Farms - Biodegradable mulch film producers - Organic amendment producers	Many	expected CAGR 2020-2023 + 68%	Production capacity

Market potential

According to the European Biochar Industry Consortium, approximately 21,000 tons of biochar were manufactured in Europe in 2020. The **biochar** market size, already generating 1.8 bn€ revenue in 2021, is expected to advance at a CAGR of over 10% during 2021–2030. Biochar's importance is expected to grow as a Carbon Capture Use and Storage (CCUS) market is expected to have a turnover of 500 M€ in 2026.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using Biochar as a bio-based substitute of Carbon Black masterbatch in the production of biodegradable in soil mulch films.

Also using the wood vinegar which is a by-product in the Biochar production could improve circularity. Wood vinegar is an aqueous fraction of condensates which contains approximately 30% of acetic acid and can be used as a Biostimulate.

Southern France, Le Cailar: Latex from Speciality Crops (Guayule) for Gloves and covering materials

For the production of Latex, Guayule is cultivated and converted trough different process steps (Fig. 14). Latex from Guayule has been identified as highly suitable processing pathway indicating a regional implementation potential. Additionally, a strong expertise in the cultivation of Guayule in the region makes this value chain an attractive option for further study in MIDAS.

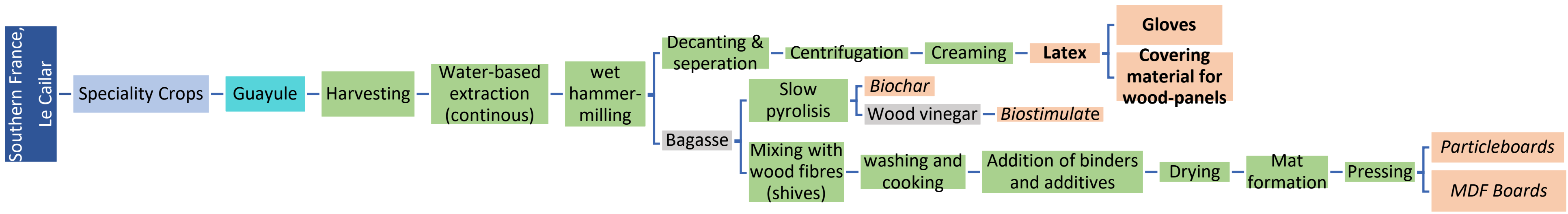

Figure 14 Value chain and web - Southern France, Le Cailar

Regional information

Table 33 Regional information case study Southern France; Le Cailar

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Le Cailar	Southern France (Occitanie Department Gard)	Mediterranean, warm and temperate (csa)	15°C; 650-750mm;	Soil texture : clay Soil Ph : 8,5 Topsoil depth : 30cm SOM : 1,6% Very low phosphorus availability (40mg/kg) Poor biological activity Low structural stability	Unfavorable soil texture and stoniness, shallow rooting depth, Adverse chemical composition of soil	On useful agricultural area : 52% wineyards, 17% cattle breeding, 12% arable and industrial crops, 11% legume crops, 9% arboriculture	23400 ha for Gard department	29% of farms are Organic farms 36% of farms are working with short selling circuits (excluding wine)

				Very high risk of asphyxia				

Agricultural production:

GuaTecs is producing perennial and annual crops in an intercropping field trial. From the initial assessment Guayulue has been identified as a promising crop for the region.

Table 34 Information regarding crop cultivation GuaTecs - Southern France

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Guayule	Perennial	Plantlets	Tilling. Deep landfill work.	Plantlets	40.000	210 N kg/ha; standard 40 N kg/ha	The water requirement to be implemented is not yet known.	The first year 0, the following year gives production.	Mechanical and manual.	-	Short duration. Fast transfer.	rubber, latex	200 kg CES

Innovative bio-based product:

GuaTecs will be extracting unique allergy-free latex from guayule cultivated, paying attention to achieve the reproducibility of product quality (especially latex stability, film properties) via process adjustment. Large scale samples will be provided for evaluation of gloves manufactured under industrial conditions (by Piercan a first-ranked European manufacturer). In addition, GUATECS will supply latex to CHIMAR for testing it as covering material for wood-based panels (eg particleboards, MDF, etc).

Table 35 Information regarding innovative bio-based products – Latex for gloves and covering material, bagasse for particleboards, MDF Boards, Biochar

	Feed-stock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product life-time	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Latex for gloves	Truck	1 latex liter / hour	pilot production	Resin & Bagasse	5	water-based polyisoprene dispersion	TBI	european medical glove market	B2B	no	30-100 Meuros	allergenicity, and sovereignty
Latex for covering material	Truck	Lab scale	N/A	none	4/5	TBI	TBI	construction, furniture	wood-based panels industry	other institutes/companies developing know-how		eco-friendly furniture and floorings with less VOCs and from renewable materials
Bagasse for Particleboards	*Truck*	*lab scale (pilot plant)*	*Not applicable*	*there are no by-products*	*TRL 6*	*Composite of lignocellulosic biomass and an adhesive*	*TBI*	*Furniture, constructions*	*Wood-bsed panels industry*	*Other companies that develop know-how in the field*	*34 USD million*	*Growing demand for eco-friendly building materials, increasing investment in construction industry, rising popularity of do-it-yourself (DIY) projects*
Bagasse for MDF Boards	*Truck*	*50kg/Batch*	*TBI*[4]	*dust, bark (used for heating), water*	*-*	*Wood chips, binder, additives,*	*TBI*	*Wood Fibre Boards (Europe)*	*-*	*TBI*	*TBI*	*TBI*
Bagasse for Biochar	*Road*	*100kg/h (inlet) - rotary kiln, continuous*	*5 to 10 tons /year - demonstrative purposes*	*wood vinegar*	*7*	*88,5% Carbon*	*100 years*	*Agricultural amendments and fertilizers (organic or conventional) - Biodegradable mulch films*	*Farms - Biodegradable mulch film producers - Organic amendment producers*	*Many*	*expected CAGR 2020-2023 + 68%*	*Production capacity*

[4] TBI = To be investigated

Market potential

The worldwide latex market (synthetic and natural) is at 150 bn€ (paint, paper, adhesive). Approximately 1 bn€ of this market will be accessible for the **guayule latex** (dipping, textile coating, foam). Europe accounts for 17% of this market and 1/3 of the European market relates to high-value applications (surgical gloves, and medical devices).

The global **wood adhesives** market exhibits high growth potential and is projected to reach a market size of 6.5 bn€ by 2026 at a CAGR of 5.12 %. CHIMAR estimated market share in wood adhesive technology market is equal to 33% on a global level. Important market drivers represent the expansion of the construction industry as well as the demand for sustainable, eco-friendly products. Thus, bio-based adhesives from green materials are expected to provide profits in long run.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using the Bagasse for Biochar, Particelboard and MDF Board production. Also using the latexy as covering material for Particleboards could improve circularity.

Northern Serbia, Zabalj: Particleboards from Woody Biomass (Sorghum)

For the production of Particleboards, Sorghum is cultivated and converted trough different process steps (Fig. 15). Sorghum was identified as highly suitable crop for the region which indicates a regional implementation potential. Additionally, a strong market for wood-based panels in Europe makes this value chain an attractive option for further study in MIDAS.

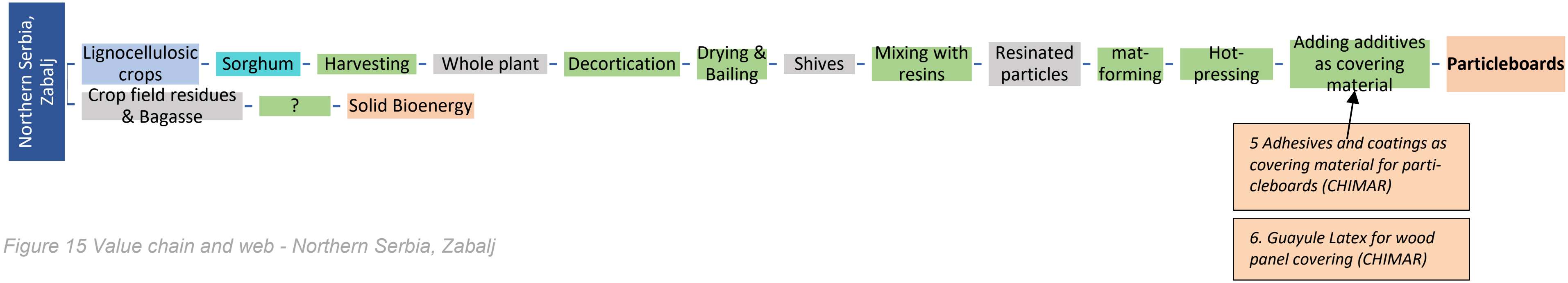

Figure 15 Value chain and web - Northern Serbia, Zabalj

Regional information

Table 36 Regional information case study Northern Serbia, Zabalj

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Žabalj	Northern Serbia	Warm and temperate climate (cfa)	12,7° C; 650-700 mm	According to domestic, national classification: order - halomorphic (saline) soil, class - Asa-C-CG, type - solonchak According to WRB: Soil Group Solonchaks Generally: solonchaks on small areas and in association with other soil types	Excessive wetness, low soil fertility, unfavorable chemical conditions, Limitations in rooting; adverse terrain	barley, wheat, corn, sunflower, rapeseed, soybean.	There are about 100,000 ha of saline soils (solonchaks and solonetz) in Vojvodina	Private family-owned small field plots dominate here, while the rest are privatized previously state-owned plots. Conventional agriculture dominates this area substantially with very little organic farming, if any. Mineral fertilizers are used in relatively small rates and according to well-established schemes, whereas organic fertilizers are applied scarcely. Organic matter loss is

								the dominant soil degradation process.

Agricultural production:

IFVC is producing perennial and annual crops in an intercropping field trial. From the initial assessment Sorghum has been identified as a promising crop for the region.

Table 37 Information regarding crop cultivation IFVC - Northern Serbia

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield (expected)	Storage and durability	Main product	Potential production
Sorghum	Annual	Seed	soil preparation disc plow trailer, pre-sowing preparation with seedbed cultivator	10	250 000	100-120 kg N, 60-90 kg P2O5 and 60-80 kg K2O per hectar		Summer to early fall	Combine Harvester	8-10 t seed; 5 t/ha biomass	big bags for seed, bale for biomass	Starch, protein; Lignocellulos	

Innovative bio-based product:

CHIMAR will manufacture particleboards for various purposes (furniture, objects, wall finish-es etc). MIDAS biomass will use to replace wood in the production of particleboards. The replacement will start from low levels (e.g. 20-30%) and it will be gradually increased. The target is a 100% replacement of wood.

Table 38 Information regarding innovative bio-based products – Particleboards

Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Truck				TRL 6		TBI					

	lab scale (pilot plant)	Not appli-cable	there are no byprod-ucts		Composite of lignocellulo-sic biomass and an adhe-sive		Furniture, construc-tions	Wood-bsed panels in-dustry	Other com-panies that develop know-how in the field	34 USD mil-lion	Growing de-mand for eco-friendly building materials, in-creasing invest-ment in con-struction indus-try, rising popu-larity of do-it-yourself (DIY) projects

Market potential

The wood-based panel industry is strong in Europe as **Particleboards** and **MDF-Boards** have high volume shares, at 30.7 and 12.0 million m^3 in 2020 respectively. The technology and services used in MIDAS account for over 10% of the annual global production.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using adhesives and coatings from CHIMAR as well as covering material from Latex (CHIMAR/GuaTecs) for the production of particleboards.

Central Spain, Fuentidueña de Tajo: Rubber and resins for Tyres from Speciality Crops (Guayule)

For the production of rubber and resins, Guayule is cultivated and converted trough different process steps (Fig. 16). Natural rubber from Guayule has been identified as highly suitable processing pathway for tyre production indicating a regional implementation potential. Additionally, a strong expertise in the extraction of rubber from Guayule in the region makes this value chain an attractive option for further study in MIDAS.

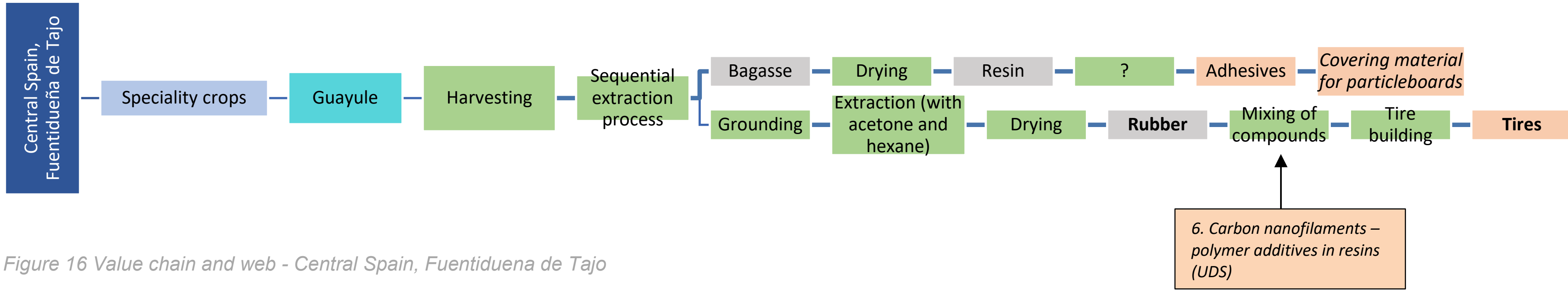

Figure 16 Value chain and web - Central Spain, Fuentiduena de Tajo

Regional information

Table 39 Regional information case study Central Spain; Fuentiduena de Tajo

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Fuentidueña de Tajo (Madrid).	Central Spain	Mediterranean, mild, and generally warm and temperate (csa) (semi-arid cold agro-climatic zone).	14.8 °C; 300- 400 mm.	Gypsiferous (>70%)	Low fertility of soil, Adverse climate (dryness).	Irrigated and rainfed cereals.	4.000	Irrigated and rainfed cereals.

Agricultural production:

ITAP is producing perennial and annual crops in an intercropping field trial. From the initial assessment Guayulue has been identified as a promising crop for the region.

Table 40 Information regarding crop cultivation ITAP - Central Spain

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertiliza-tion	Water (if irri-gated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Guayule	Peren-nial	Plantlets	Tilling. Deep land-fill work.	Plant-lets	40.000	210 N kg/ha; standard 40 N kg/ha	The water requirement to be imple-mented is not yet known.	The first year 0, the following year gives produc-tion.	Mechani-cal and manual.	10 t/ha (fm) (ex-pected)	Short du-ration. Fast trans-fer.	rubber, latex	5.5 -15 Mg/ha/y (biomass); 0.32 - 1.9Mg/ha/y (rubber).

Innovative bio-based product:

In a sequential extraction process, guayule will be extracted at large scale (UCLM), with the purpose of obtaining rubber for the manufacture of tires. As in the case of resins, UCLM will optimize the rubber extraction conditions for large-scale extraction (500 L batch), selecting the most suitable solvent or solvents. Manufactured tyres by NOKIAN will be tested under real life conditions.

Table 41 Information regarding innovative bio-based products – Rubber for tires, resins for adhesives and covering material

	Feed-stock lo-gistics	Processing scale	Amount of product output per year	By-prod-ucts	Pro-cess-TRL	Product composition	Prod-uct life-time	Targeted market	Customer group (B2B/B2C)	Known com-petitors	Market outlook 2030	Societal trends that influence main-streaming
Rubber for tyres	Truck	500L/Batch (NA at the moment)	(NA at the moment)	Bagasse	7	tyre made of rubber compounds, steel and textile com-ponents	at least 6 years	(NA at the moment)	both	Bridgestone,	(NA at the mo-ment)	sustanainability of raw materials, lo-gistics, deforesta-tion
Resins for adhesives and cover-ing material	*Truck*	*Lab sacle*	*N/A*	*none*	*6*	*phenol, for-maldehyde, water, NaOH, pro-tein*	*1 month*	*construc-tion, furni-ture*	*wood-based panels in-dustry*	*other insti-tutes/compa-nies develop-ing know-how for thermoset-ting polymers*	*21.17 billion USD*	*increased request of wood-based panels and all other applications of phenolic resins*

Market potential

The **tyre industry** alone absorbs about 76% of all the **natural rubber** produced globally. Natural Rubber is recognised as a Critical Raw Material by the EU. The European Tyre Industry (86 Plants across Europe, 200,000 people directly employed, up to 800,000 jobs provided indirectly) depends exclusively on the oligopoly of the 3 largest producers (91%, Indonesia, Malaysia, Thailand). Having a value chain that produces natural rubber in Europe could alleviate the current situation.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using carbon nanofilaments in the production of tires. Also resins could be used for the production of adhesives and covering material.

Southern Italy (1), Santa Maria La Fossa (Campania): Biodegradable biolubrificants and agricultural biostimulants from Oil-crops (Cardoon)

For the production of biodegradable biolubrificants and agricultural biostimulants, oilcrops (Cardoon) are cultivated and converted trough different processing steps (Fig. 17). Both products produced from Cardoon have been identified as highly suitable processing pathways indicating a regional implementation potential. Additionally, Cardoon has been identified as highly suitable crop for the region making this value chain an attractive option for further study in MIDAS.

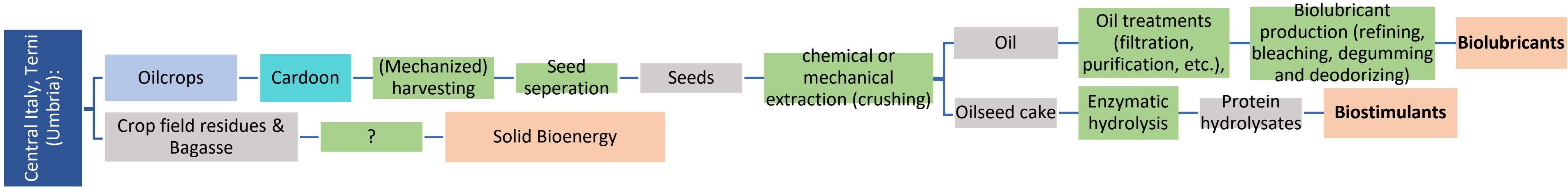

Figure 17 Value chain and web - Southern Italy (1); Santa Maria La Fossa

Regional information

Table 42 Regional information case study Southern Italy (1); Santa Maria La Fossa

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Santa Maria La Fossa, Campania	Southern Italy	warm and temperate climate (csa)	15,8°C: 1000 mm	Loam (<50%); OC 0,62 g/kg; pH 7,9; N 0,25 g/kg; K 22 mg/kg; P 310 meq/100g	Excessive wetness b. Limited soil drainage Adverse climate (b. Dryness)	Wheat; Corn; Alfaalfa; Broccoli; Tomato; Lettuce; Strawberry; Peach trees; Hazeltun; Chestnut; Wine grapes; Olive trees;	Tbd	The region is characterized to have a lot of cropping systems. Green house cropping system with horticultural crops with 2 or 3 sowing during the year (e.g lettuce). Open field cropping system with one or two crops per

								year (e.g. winter forage and corn in the summer) or orchards.

Agricultural production:

Novamont is producing perennial and annual crops in an intercropping field trial. From the initial assessment Cardoon has been identified as the most promising crop.

Table 43 Information regarding crop cultivation Novamont - Southern Italy (1)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Cardoon	Perennial	Seed or suckers	Plowing Harrowing Hoening	3 kg/ha	80000 plants/ha	From second year: 50 N/y 60-70 P/y 100-150 k/y	No	Summer	Seed: Combine harvester; Biomass: baler machine	Seed: 1 - 1,5 t/ha dm Lignocellulose biomass: 10-15 t/ha dm	Seeds: Silos Biomass: bales	Lignocellulose biomass, seeds	Seed: 1 - 1,5 t/ha dm Lignocellulose biomass: 10-15 t/ha dm

Innovative bio-based product:

Novamont (ELPE) will convert vegetable oils into new biodegradable biolubricants, to be used for lubrication of agricultural machinery as UTTO with improved performance. Particular attention will be paid to the selection of the additives, which must guarantee biodegradability and non-toxicity. An innovative protocol will be defined for the obtainment of protein hydrolysates from the seed cake left after by oil extraction performed by NOVAMONT towards use in new formulations of low impact biostimulants for application at various crops

Table 44 Information regarding innovative bio-based products – Biolubricants, Biostimulants

	Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence

												mainstream-ing
Biolubfri-cants	Truck/Lorry Big Bags	5ton/batch	TBI	NA	4	Protected by IP right	1/2 year (TBI de-pending on the pro-cesses)	hydraulic oils, UTTO	B2B	Traditional UTTO	TBI	-
Biostimu-lants	Truck/Lorry Big Bags	50l/batch re-actor	TBI	Waste water	7	Covered by IP pro-tection	TBI	Farmers	B2B	TBI	-	-

Market potential

The global **biolubricants** market exceeded 1.7 bn€ in 2015 (630 ktons) and is expected to witness growth at 5.4% CAGR over the period 2016-2024 due to the superior product characteristics such as constant viscosity, high flash points, biodegradability and lower emission levels.
The global **biostimulants** market was valued at 1.7 bn€ in 2017 and is expected to register a CAGR of12.5% during the period 2018-2023. Europe is the largest regional market for biostimulants, accounted for a share of around 42.5%.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using the seedcake for the production of Agricultural Biostimulants (Novamont).

Central Italy (2), Terni (Umbria): Biodegradable Biolubrificants and agricultural Biostimulants from Oilcrops (Safflower)

For the production of Biodegradable Biolubrificants and agricultural Biostimulants, Oilcrops (Safflower) are cultivated and converted trough different processing steps (Fig. 18). Both products produced from Safflower have been identified as highly suitable processing pathways indicating a regional implementation potential. Additionally, Safflower has been identified as highly suitable crop for the region making this value chain an attractive option for further study in MIDAS.

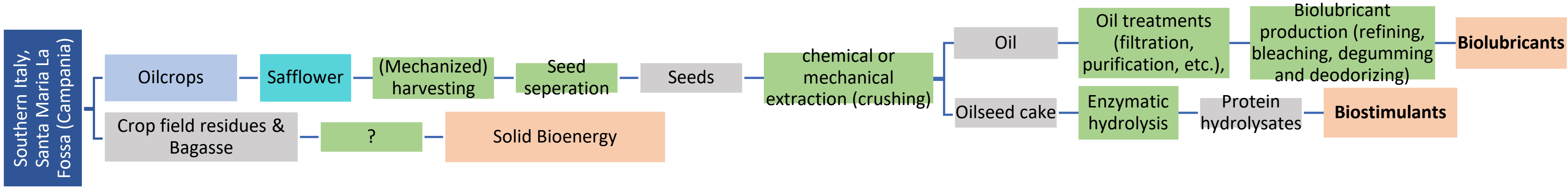

Figure 18 Value chain and web - Central Italy (2); Terni

Regional information

Table 45 Regional information case study Central Italy (2); Terni

City	Region	Climate		Soil characteristics	Marginality	Regional information		
		Köppen-Geiger climate classification	Annual temperature & precipitation, altitude			Land use in the region	Land availability (marginal land)	Regional farming systems
Terni, Umbria	Central Italy	warm and temperate climate (csa)	13,6°C; 1000mm	Silt Loam; SOC (2,63 %), N (0,15 %), P (17 ppm)	Adverse climate (b. Dryness)	Barley; Fava bean; Sunflower; Alfalfa; Wheat; Corn; Wine grapes; Olive trees; Tobacco;	Tbd	Annual cropping; One crop for year (e.g. wheat; tobacco; barley)

Agricultural production:

Novamont is producing perennial and annual crops in an intercropping field trial. From the initial assessment Safflower has been identified as the most promising crop.

Table 46 Information regarding crop cultivation Novamont - Central Italy (2)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield	Storage and durability	Main product	Potential production
Safflower	Annual	Seed	Plowing Harrowing Hoening	14-24 kg/ha	400.000/ 500.000 plants/ha	From second year: 60-110 N/y 30 P/y 40 k/y	No	Summer	Combine harvester	Seed: 1,5 - 3 t/ha dm (expected)	Seeds: Silos	Seeds	Seed: 1,5 - 3 t/ha dm

Innovative bio-based product:

Novamont (ELPE) will convert vegetable oils into new biodegradable biolubricants, to be used for lubrication of agricultural machinery as UTTO with improved performance. Particular attention will be paid to the selection of the additives, which must guarantee biodegradability and non-toxicity. An innovative protocol will be defined for the obtainment of protein hydrolysates from the seed cake left after by oil extraction performed by NOVAMONT towards use in new formulations of low impact biostimulants for application at various crops.

Table 47 Information regarding innovative bio-based products – Biolubrificants, Biostimulants

	Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Biolubfricants	Truck/Lorry Big Bags	5ton/batch	TBI	NA	4	Protected by IP right	1/2 year (TBI depending on the processes)	hydraulic oils, UTTO	B2B	Traditional UTTO	TBI	-
Biostimulants	Truck/Lorry Big Bags	50l/batch reactor	TBI	Waste water	7	Covered by IP protection	TBI	Farmers	B2B	TBI	-	-

Market potential

The global **biolubricants** market exceeded 1.7 bn€ in 2015 (630 ktons) and is expected to witness growth at 5.4% CAGR over the period 2016-2024 due to the superior product characteristics such as constant viscosity, high flash points, biodegradability and lower emission levels.
The global **biostimulants** market was valued at 1.7 bn€ in 2017 and is expected to register a CAGR of12.5% during the period 2018-2023. Europe is the largest regional market for biostimulants, accounted for a share of around 42.5%.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using the seedcake for the production of Agricultural Biostimulants (Novamont).

Central Hungary (1), Gödöllö: Particleboards from Woody Biomass (Miscanthus)

For the production of Particleboards woody biomass (Miscanthus) is cultivated and converted trough different process steps (Fig. 19). Miscanthus was identified as highly suitable crop for the region which indicates a regional implementation potential. Additionally, a strong market for wood-based panels in Europe makes this value chain an attractive option for further study in MIDAS.

Figure 19 Value chain and web - Central Hungary (1) - Gödöllö

Regional information

Table 48 Regional information case study Central Hungary (1); Gödöllö

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Gödöllő	Central Hungary	warm and temperate climate (csa)	15,8°C: 1150mm	0-30 cm topsoil; pH 6,76 (H2O), sandy-loam (31 KA), CaCO3 0,0 %, humus% 1,32 (low provision) NO3+NO2 55 mg kg-1 (low provision), P2O5 371.1 mg kg-1 (medium provision), K2O 184,0 mg kg-1 (medium provision)	adverse climate (dryness), adverse chemical composition as heterogenic soil, adverse terrain conditions	the most cultivated are the winter wheat, winter barley, sunflower, corn and rape		crop farming and mixed farming systems

Agricultural production:

SOLTUB is producing perennial and annual crops in an intercropping and agroforestryry field trial. From the initial assessment Miscanthus has been identified as a promising crop for the region.

Table 49 Information regarding crop cultivation Soltub - Central Hungary (1)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irri-gated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Miscanthus	Peren-nial	Rhizome, micropropa-gat ion	deep	1!m2	800 pc /1000 m2	0 - 50 kg N/y; 40 kg P/y; 80 kg K/y	no	February to March; or Octo-ber (Bio-gas)	Baled straw or Chips	1t/per harvest for 1000m 2	multia-nual	Lignocellu-lose	40 Mg DM/ha/y

As a perennial grass, miscanthus has proven to be a very promising feedstock for the manufacturing of bio-based products (van der Cruijsen et al. 2021). It uses nitrogen, water, and sunlight efficiently, besides being able to be harvested annually for a period of 25 years. Additionally, it increases soil permeability and microbial activity while lowering bulk density. As a consequence, there is a chance to rehabilitate the land while still using it to produce biomass (Wagner et al. 2017).

Innovative bio-based product:

CHIMAR will manufacture particleboards for various purposes (furniture, objects, wall finish-es etc). MIDAS biomass will use to replace wood in the production of particleboards. The replacement will start from low levels (e.g. 20-30%) and it will be gradually increased. The target is a 100% re-placement of wood.

Table 50 Information regarding innovative bio-based products – Particleboards

Feedstock lo-gistics	Processing scale	Amount of product output per year	By-prod-ucts	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known com-petitors	Market outlook 2030	Societal trends that influence main-streaming
Truck	lab scale (pilot plant)	Not appli-cable	-	TRL 6	Composite of lignocellulo-sic biomass	TBI	Furniture, construc-tions	Wood-bsed panels in-dustry	Other com-panies that develop	34 USD million	Growing demand for eco-friendly building materials,

					and an adhesive				know-how in the field		increasing investment in construction industry, rising popularity of do-it-yourself (DIY) projects

Market potential

The wood-based panel industry is strong in Europe as **Particleboards** and **MDF-Boards** have high volume shares, at 30.7 and 12.0 million m^3 in 2020 respectively. The technology and services used in MIDAS account for over 10% of the annual global production.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using adhesives and coatings from CHIMAR as well as covering material from Latex (CHIMAR/GuaTecs) for the production of particleboards.

Central Hungary (2), Gödöllő: Biochar from Woody Biomass (Poplar)

For the production of Biochar woody biomass (Poplar) is cultivated and converted trough different process steps (Fig. 20). Poplar was identified as highly suitable crops in the region which indicates a regional implementation potential. Additionally, the Biochar market is projected to grow making this value chain an attractive option for further study in MIDAS.

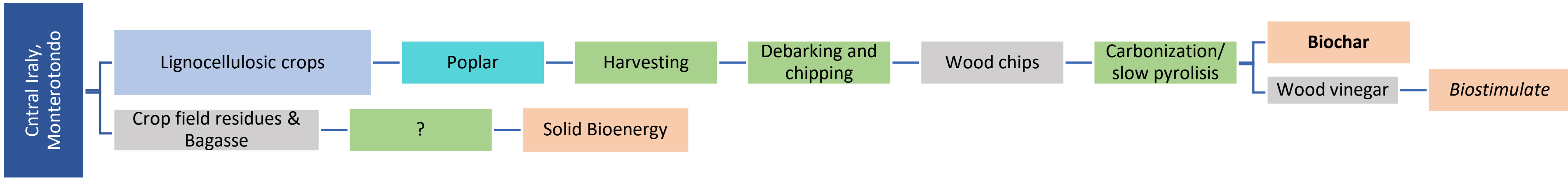

Figure 20 Value chain and web - Central Hungary (2) - Gödöllö

Regional information

Table 51 Regional information case study Central Hungary (2); Gödöllö

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Gödöllő	Central Hungary	warm and temperate climate (csa)	15,8°C: 1150mm	0-30 cm topsoil; pH 6,76 (H2O), sandy-loam (31 KA), CaCO3 0,0 %, humus% 1,32 (low provision) NO3+NO2 55 mg kg-1 (low provision), P2O5 371.1 mg kg-1 (medium provision), K2O 184,0 mg kg-1 (medium provision)	adverse climate (dryness), adverse chemical composition as heterogenic soil, adverse terrain conditions	the most cultivated are the winter wheat, winter barley, sunflower, corn and rape		crop farming and mixed farming systems

Agricultural production:

SOLTUB is producing perennial and annual crops in an intercropping and agroforestryry field trial. From the initial assessment Miscanthus has been identified as a promising crop for the region.

Table 52 Information regarding crop cultivation Soltub - Central Hungary (2)

Crop Name	*Cycle*	Propaga-tion	Soil prepara-tion	Sow-ing den-sity	Plant density	Fertiliza-tion	Water (if irri-gated)	Harvest pe-riod	Harvesting method	total Yield)	Storage and durability	Main product	Poten-tial pro-duction
Poplar	Perennial	plantlets	deep	2/m2	1000 pc /1000m2 (twin rows)	no	no	one or two harvest during the 4 year	manual	1t/per har-vest for 1000m2	multianual, may be once during the 4 year	lignocel-lulose	-

Poplar is a plant species which grows rapidly that is being identified as a promising feedstock for BBVCs. It is possible to operate poplar forests as biomass production ecosystems with low energy input, resulting in significant improvements to habitat quality for flora and fauna, erosion control, and reduced fertilizing and spraying requirements (Meyer et al. 2021).

Innovative bio-based product: RE-CORD

Biochar is the solid product from lignocellulosic biomass thermochemical conversion such as slow pyrolysis together with gas and a liquid phase (Bio-oil). Solid biomass is introduced into a carbonization demo plant where it is pyrolized. The biochar is collected by gravity in a sealed vessel. Biochar is a highly porous material with a wide range of possible uses, including sustainable agriculture, as it improves the water holding capacity and the organic matter content in soil, in particular in marginal lands and regions where rain is scarce, and irrigation is difficult for a number of environmental or economic reasons.

Table 53 Information regarding innovative bio-based products – Biochar

Feedstock lo-gistics	Processing scale	Amount of prod-uct out-put per year	By-products	Process-TRL	Product composi-tion	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known com-petitors	Market out-look 2030	Societal trends that influence mainstreaming

Road	100kg/h (inlet) - rotary kiln, continuous	5 to 10 tons /year - demonstrative purposes	wood vinegar	7	88,5% Carbon	100 years	Agricultural amendments and fertilizers (organic or conventional) - Biodegradable mulch films	Farms - Biodegradable mulch film producers - Organic amendment producers	Many	expected CAGR 2020-2023 + 68%	Production capacity

Market potential

According to the European Biochar Industry Consortium, approximately 21,000 tons of biochar were manufactured in Europe in 2020. The **biochar** market size, already generating 1.8 bn€ revenue in 2021, is expected to advance at a CAGR of over 10% during 2021–2030. Biochar's importance is expected to grow as a Carbon Capture Use and Storage (CCUS) market is expected to have a turnover of 500 M€ in 2026.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using Biochar as a bio-based substitute of Carbon Black masterbatch in the production of biodegradable in soil mulch films.

Also using the wood vinegar which is a by-product in the Biochar production could improve circularity. Wood vinegar is an aqueous fraction of condensates which contains approximately 30% of acetic acid and can be used as a Biostimulate.

Southern Germany, Eningen unter Achalm: Biodegradable Biolubrificants from Oilcrops (Crambe)

For the production of Biodegradable Biolubrificants, Oilcrops (Crambe) are cultivated and converted trough different process steps (Fig. 21). Crambe was identified as highly suitable crop for the region which indicates a regional implementation potential. Additionally, the importance of biodegrabdable lubrificants is growing due to its superior product characterstic, i.a. constant viscosity, making this value chain an attractive option for further study in MIDAS.

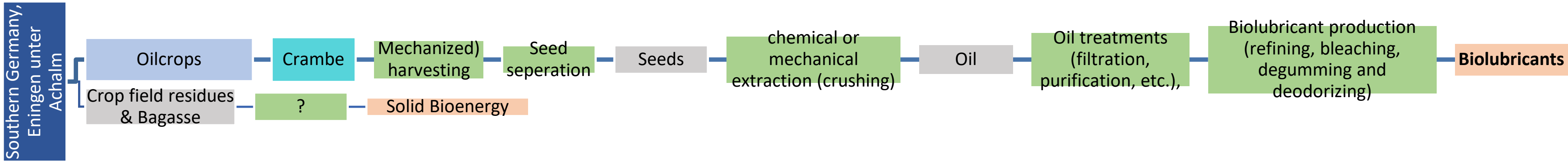

Figure 21 Value chain and web - Southern Germany, Eningen unter Achalm

Regional information

Table 54 Regional information case study Southern Germany, Eningen unter Achalm

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Eningen unter Achalm (Upper Lindenhof)	Southern Germany (Swabian Alb)	mild, and generally warm and temperate (cfb)	8,6 °C; 816 mm	Soil depth: 15-35 cm Organic content: >2.5% Nmin April 2023: app. 50 kg/ha K2O: 9.1 mg/100 g (class B, medium) P2O5: 23.9 mg/100 g (class C, high) MgO: 4.2 mg/100 g (class A, low)	Limitations in rooting	Permanent grassland: Meadows (intensive to extensive), pastures (mainly sheep). Arable farming:Wheat and spelt (winter-annual), malting barley (summer-annual), corn, canola	Agricultural area of Swabian Alb: 3061.42 km² with 50/50 permanent grassland/arable landSmall-scale farm systems i.e. farm size is 30 ha, over 70% of farms are part-time farms. The entire region is not considered particularly productive due to the high stone content and the rapid infiltration	Small-scale farming systems i.e. farm size is around 30 ha, over 70% of farms are part-time farms

				pH: 7.3 ("ok" for clayey soil) Stone content of topsoil: 15-25 vol% Texture composition in topsoil (excluding stones): Clay: 42.6 wt% Silt: 44.8 wt% Sand: 12.6 wt%		Specialty crops (lower area relevance): potatoes, lentils, camelina, buckwheat, caraway seeds Fruit growing: Scattered fruit (e.g., old apple and pear varieties) and viticulture (of lesser importance).	of rainwater. This means that the water supply to the soils is therefore often limiting, despite generally adequate rainfall. There is no precise indication of the marginal agricultural land area. Large portions of the region are to be classified as marginal. However, in a broader sense, normal agriculture is mostly practiced on these lands. If an estimated 3% of the agricultural land were to be classified as marginal according to the conditions of the region, this would correspond to an area of about 9000 ha.	

Agricultural production:

UHOH is producing perennial and annual crops in an intercropping field trial. From the initial assessment. Crambe has been identified as a promising crop for the region.

Table 55 Information regarding crop cultivation UHOH - Southern Germany

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Crambe	Annual	Seed	Rotary harrow (2 times)	13	100-200	30-75 kg N/ha (or adapted to soil reserves); 40-80 kg P/ha; 60-90 kg K/ha, depending on soil conditions	-	spring to summer	Combine threshing	3 Mg DM/ha straw, 1.5 Mg/ha grain (fresh matter)	big bags	Oil	1.3- 3 Mg/ha (seeds), ~800kg/ha (oil

Crambe is an annual herbaceous species, with an average height of 1.00-1.20m (Zhu 2016). The height might vary due to growth conditions like soil fertility, season, and plant density (Samarappuli et al. 2020). Crambe's taproot, which reaches down up to 1m into the soil, allows the plant to withstand dry, saline conditions. The overall growth is erect with numerous branches (Zhu 2016). The cotyledons are heart-shaped, while after maturing the leaves are oval, smooth-surfaced, and light green (Samarappuli et al., 2020). The plant produces small white to light, yellow-colored flowers distributed racemically, which are self-pollinated. Crambe oil has a unique fatty acid composition, containing up to 65% erucic acid (Righini et al. 2016). Having a high content of erucic acid makes crambe oil toxic for food or animal feed but useful for many other purposes. Crambe oil can be used for cosmetics, lubricants, and biofuels. Crambe oil is thermostable; its chemical structure makes it suitable for use as an industrial lubricant.

Innovative bio-based product:

Novamont (ELPE) will convert vegetable oils into new biodegradable biolubricants, to be used for lubrication of agricultural machinery as UTTO with improved performance. Particular attention will be paid to the selection of the additives, which must guarantee biodegradability and non-toxicity.

Table 56 Information regarding innovative bio-based products – Biolubrificants, phenol-formaldehydetype adhesives

	Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming
Biolubfricants	Truck/Lorry Big Bags	5ton/batch	TBI	NA	4	Protected by IP right	1/2 year (TBI depending on the processes)	hydraulic oils, UTTO	B2B	Traditional UTTO	TBI	-
phenol-formaldehyde type adhesives	Truck	Lab sacle	N/A	none	6	phenol, formaldehyde, water, NaOH, protein	1 month	construction, furniture	wood-based panels industry	other institutes/companies developing know-how for thermosetting polymers	21.17 billion USD	increased request of wood-based panels and all other applications of phenolic resins

Market potential

The global **biolubricants** market exceeded 1.7 bn€ in 2015 (630 ktons) and is expected to witness growth at 5.4% CAGR over the period 2016-2024 due to the superior product characteristics such as constant viscosity, high flash points, biodegradability and lower emission levels.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using the seedcake for the production of phenol-formaldehyde type adhesives. The other parts of crambe, such as stems, leaves, and roots, are not valorized in the current bioeconomy. As with other crops, this green, lignocellulose biomass can be used for fiber, for biogas, or left on the field as green mulch.

Northern Italy, Bologna: Particleboards from Woody Biomass (Hemp)

For the production of Particleboards woody biomass (Hemp) is cultivated and converted trough different process steps (Fig. 22). Particleboards from Hemp has been identified as highly suitable processing pathway indicating a regional implementation potential. Additionally, hemp has been identified as highly suitable crop for the region making this value chain an attractive option for further study in MIDAS.

Figure 22 Value chain and web - Northern Italy - Bologna

Regional information

Table 57 Regional information case study Northern Italy, Bologna

City	Region	Climate		Soil characteristics	Marginality	Regional information		
		Köppen-Geiger climate classification	Annual temperature & precipitation, altitude			Land use in the region	Land availability (marginal land)	Regional farming systems
Ozzano dell' Emilia (Bologna)	Northern - central Italy	warm and temperate (cfa)	14,3°C; 700 mm	Soil depth: 15-35 cm Organic content: >2.5% Nmin April 2023: app. 50 kg/ha K2O: 9.1 mg/100 g (class B, medium) P2O5: 23.9 mg/100 g (class C, high) MgO: 4.2 mg/100 g (class A, low) pH: 7.3 ("ok" for clayey soil) Stone content of topsoil: 15-25 vol% Texture composition in topsoil	Adverse terrain, Limitations in rooting (a. Unfavourable soil texture	depending on the slope the soil depth can be 50-100 cm, SOM is usually about 1-1.2%, pH is sub-basic (>7)	winter wheat, alfalfa,	TBD

				(excluding stones): Clay: 42.6 wt% Silt: 44.8 wt% Sand: 12.6 wt%				

Agricultural production:

UNIBO is producing perennial and annual crops in an intercropping field trial. From the initial assessment Hemp has been identified as a promising crop for the region.

Table 58 Information regarding crop cultivation UNIBO - Northern Italy

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Hemp	Annual	Seed	ploughing + harrowing)	45 kg/ha	30-75 (seed); 150-250 (fiber)	500 kg/ha of Guanito, an organic fertilizer containing 6% N and 15% P2O5. we might add extra 30 kg/ha of N later on in the season, but for now we have not applied any (whole plot)	no	Summer to Fall	cutting and baling	8-10 t/ha DM (expected)	bale + truck	Fiber	1.0-1.5 Mg/ha (seeds), 8-15 Mg/ha (dry stems

Innovative bio-based product:

CHIMAR will manufacture particleboards for various purposes (furniture, objects, wall finish-es etc). MIDAS biomass will use to replace wood in the production of particleboards. The replacement will start from low levels (e.g. 20-30%) and it will be gradually increased. The target is a 100% replacement of wood.

Table 59 Information regarding innovative bio-based products – Particleboards

Feedstock logistics	Processing scale	Amount of product	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming

		output per year									
Truck	lab scale (pilot plant)	Not applicable	-	TRL 6	Composite of lignocellulosic biomass and an adhesive	TBI	Furniture, constructions	Wood-bsed panels industry	Other companies that develop know-how in the field	34 USD million	Growing demand for eco-friendly building materials, increasing investment in construction industry, rising popularity of do-it-yourself (DIY) projects

Market potential

The wood-based panel industry is strong in Europe as **Particleboards** and **MDF-Boards** have high volume shares, at 30.7 and 12.0 million m^3 in 2020 respectively. The technology and services used in MIDAS account for over 10% of the annual global production.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using adhesives and coatings from CHIMAR as well as covering material from Latex (CHIMAR/GuaTecs) for the production of particleboards.

Southern Italy (2), Catania (Sicily): Biodegradable in Soil Mulch films and Biostimulants from Oilcrops (Cardoon)

For the production of Biodegradable in soil mulch films and Biostimulants, Oilcrops (Cardoon) are cultivated and converted trough different process steps (Fig. 23). Cardoon has been identified as highly suitable crops for the region which indicates a regional implementation potential. Additionally, the importance of biodegrabdable soil mulch film is growing due to i.a. an increasing growth in sustainable agriculture making this value chain an attractive option for further study in MIDAS.

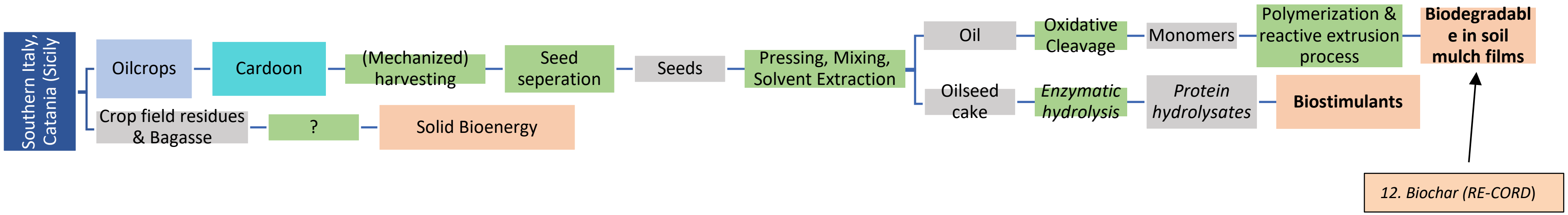

Figure 23 Value chain and web - Southern Italy (2) - Catania

Regional information

Table 60 Regional information case study Southern Italy (2), Catania

City	*Region*	*Climate*		*Soil characteristics*	*Marginality*	*Regional information*		
		Köppen-Geiger climate classification	*Annual temperature & precipitation, altitude*			*Land use in the region*	*Land availability (marginal land)*	*Regional farming systems*
Agira (Catania)	Sicily	Mediterranean hot summer (csa)	18,6°C; 586mm	Analysis not available yet	Adverse chemical composition of soil; adverse climate, steep slope	Wheat, olive, almond	161896	Rainfed herbaceus grains, rainfed tree crops

Agricultural production:

UNICT is producing perennial and annual crops in an intercropping field trial. From the initial assessment Cardoon has been identified as a promising crop for the region.

Table 61 Information regarding crop cultivation UNICT- Southern Italy (2)

Crop Name	*Cycle*	Propagation	Soil preparation	Sowing density	Plant density	Fertilization	Water (if irrigated)	Harvest period	Harvesting method	total Yield)	Storage and durability	Main product	Potential production
Cardoon	Perennial	Seed or suckers	Harrowing before planting	3,3	33333	50 N/y; 50 P/y; 100K/y	Rainfed	Summer	Baled straw (forage harvester mounted with a robust header or a biomass harvester-baler	0.6 seed, 12 biomass (DM) (expected)	-	Lignocellulose, Oil	3.7-13.8 Mg DM/ha/y (lignocellulose biomass), 0.5-1.5 Mg DM/ha/y (seeds)

Innovative bio-based product:

Novamont will convert vegetable oils through proprietary chemical and biotechnological processes, into purified monomers that will be used in polymerization and reactive extrusion processes in order to obtain biodegradable and compostable biomaterials suitable to be transformed trough film-blowing into biodegradable in soil mulch films. Mulch film will be characterized through rheological, mechanical, hydrolytic stability and in soil biodegradability EN17033 and will be tested on fields carried out in WP2 & 3.

An innovative protocol will be defined for the obtainment of protein hydrolysates from the seed cake left after by oil extraction performed by NOVAMONT towards use in new formulations of low impact biostimulants for application at various crops.

Table 62 Information regarding innovative bio-based products – Biodegradable in soil mulch films, Biostimulants, Biochar

	Feedstock logistics	Processing scale	Amount of product output per year	By-products	Process-TRL	Product composition	Product lifetime	Targeted market	Customer group (B2B/B2C)	Known competitors	Market outlook 2030	Societal trends that influence mainstreaming

Biodegradable in Soil Mulch films	Truck/Lorry in Big Bags	Different Sizes from Lab to Industrial scale	TBI	Pelargonic Acid	From 4 to 9	Protected by IP right	~1year	Agriculture; Europe	B2B	Novamont is producer of Biomaterials, mulch film are produced by converters. Biomaterials competitors are BASF, FKUR,		
Biostimulants	Truck/Lorry Big Bags	50l/batch reactor	TBI	Waste water	7	Covered by IP protection	TBI	Farmers	B2B	TBI	-	-

Market potential

Global **mulch film** market is expected to reach 4.4 bn€ in 2024, growing at a CAGR of 6.8% between 2018 and 2024. In Europe (86 kton/year), only 3 % of the total amount of plastic mulches is currently biodegradable. Thanks to its ability to address drawbacks of conventional products such as high film disposal cost (between 50 to 250 €/kg), chemical effects of plastic pollution in soil, and the increasing growth in sustainable agriculture, the importance of **biodegrabdable soil mulch film** is growing.

Value web perspective:

A potential cascading use and linking of value chains could be achieved by using the seedcake for the production of Agricultural Biostimulants (Novamont).

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7. Outlook

A large variety of promising and innovative industrial crops, cropping systems and bio-based products are considered in the MIDAS project. Bringing together different regions, biophysical marginalities, stakeholders' expertise and available technical knowledge led to the identification of 129 biomass-to-product pathways which were presented in a biomass use superstructure approach (Deliverable 5.1). This allowed to confirm the **technological potential** for every industrial crop grown on marginal land in MIDAS.

To further steer the process towards the design and development of bio-based value chains and webs we assessed wether there is **a regional implementation potential** of all technologically possible biomass-to-products pathways. This is a key and strategic step to guide the decision-making process of actors involved in the development of those value chains. Accordingly, we therefore adapted and applied a **superstructure-based multi-criteria evaluation approach** for this deliverable, with the aim of providing a baseline of implementable value chains and web concepts. This meant identifying suitable **site-specific pathways** for every case study region from a broad perspective while including relevant stakeholders and contextualized information.

For this we used a multi-criteria set, which included proxy indicators and incorporated context-dependent factors at regional level, to assess the technologically possible biomass-to-product pathways. Promising pathways with a regional implementation potential were selected based on the assessment results, stakeholder expertise and contextualized information. We hereby identified **19 promising biomass-to-product pathways** which we further described with the collected regionalized information.

The application of this participatory screening approach indicates its usefulness and applicability in research and development projects related to the identification of potential bio-based value chains. This process can be enriched through the incorporation of additional relevant aspects to assess the implementation potential such as policy framework, product competitiveness and value added. However, the availability of information for the specific context is a constraint for the further extension of the criteria set.

This study provides a portfolio of options for the further analysis and development of bio-based value chain and web concepts. The information gathered at early stage can be seen as a baseline and will help to guide the implementation of regional value web concepts in an iterative process and to elicit relevant conditions, characteristics and potentialities for research and development roadmaps towards their up-scaling, commercial implementation and continuous upgrading. Therefore, the results of this task are valuable input to reduce uncertainty at early stages of value chain and webs' design and development.

However, as some of the crops have not been tested in certain regions before (e.g, Melilot in Northern Spain) and some conversion technologies are still under development (low TRL), some uncertainties are apparent. Different knowledge gaps about the agricultural production of industrial crops on marginal land (e.g, management of speciality crops) and the processing of these crops into different products are evident.

With the aim of ensuring a multi-dimensional analysis of the value chains and web concepts and a simultaneous consideration of both technical and non-technical challenges, further investigation as part of the WP5 in MIDAS is considered. This include the sustainability assessment by applying a life-cycle approach (T5.3) and modelling for biodiversity restoration potential (LARCH) (T5.4). Other aspects like the inclusion of regional advisory groups, the refinement of the multi-criteria tool and incorporation of information from marginality maps (WP1) and business models (WP6) are also to be covered.

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