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D2.1: Companies/Clusters mapping and VCG.AI enhancing

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Deliverable description

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Abbreviations

ANRI	Alchemia-nova research & innovation gemeinnützige GmbH
ANTEJA	Anteja ECG D.O.O.
BABEG	Kärntner Betriebsansiedlungs- und Beteiligungsgesellschaft m.b.H.
CMU	Cardiff Metropolitan University
FCTA	Fundación Corporación Tecnológica de Andalucía
GA	Grant Agreement
GHG	Greenhouse Gas Emissions
ISTAT	Istituto nazionale di statistica (Italian National Institute of Statistics)
LGCA	Lombardy Green Chemistry Association
NACE	Statistical classification of economic activities in the European Community
PLA	Polylactic Acid
MCDMA	Multi-Criteria Decision-Making Analysis
MFA	Material Flow Analysis
SERN	Startup Europe Regions Network
SYMBIO	Shaping symbiosis in bio-based industrial ecosystems based on circular by-design supply chains
VCG	Value Chain Generator
WP(s)	Work Package(s)

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Executive summary

The SYMBIO project, through Task 2.1 of Work Package (WP) 2, focused on gathering industrial and cluster data to support the prioritisation of circular value chains for implementation in the 12 Pilot Regions. This task, along with inputs from WP1, serves as a foundation for Task 2.2 (Circular Value Chains Modelling). Comprehensive data on companies, including size, revenue, industry classification, and technological capabilities, was gathered to uncover opportunities for circular investment in each region. A framework was established to identify the largest industries and material streams, using the VCG.AI database to define by-product and waste streams for circular models. The methodology focuses on economic and environmental impacts to prioritise BioLinks as well. The data collection exceeded KPI with 549 companies and 74 clusters mapped, providing a robust data set for Task 2.2. The data collection workshops for partners in M5 successfully clarified template completion, tripling the number of companies and quadrupling the number of clusters beyond initial targets. The data and methodologies developed will support the generation and implementation of circular value chains, leveraging over 530 circular value chain models and 150 conversion technologies to drive economic and environmental benefits across the Pilot Regions.

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1. Introduction

The imperative to transition from fossil fuel dependency to a system reliant on renewable and sustainable resources has never been more critical for the health of our planet. Fossil fuels, a primary energy source for over a century, have significantly contributed to environmental degradation, atmospheric pollution, and global climate change. The material footprint of human activity, which encompasses the total amount of raw materials extracted to meet consumption demands, is a major driver of climate change [1]. This footprint includes not only fossil fuels but also metals, minerals, and biomass. The extraction, processing, and disposal of these materials result in substantial greenhouse gas emissions accounting for over 55 percent of greenhouse gas emissions (GHG) along with habitat destruction, and resource depletion [2].

To mitigate these adverse impacts, it is essential to redesign our economic systems towards a circular economy. According to the International Organization for Standardization, the circular economy is defined as an "economic system that uses a systemic approach to maintain a circular flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development."[3] This report aims to align with these standards, demonstrating how circular bioeconomic practices can contribute to sustainability by optimising resource use, minimising waste, and fostering innovation in the bioeconomy sector.

By extending the lifecycle of products, reusing materials, and promoting recycling, a circular economy can significantly lower the material footprint and the associated environmental impacts [4], [5], [6]. This approach not only addresses the pressing issue of resource scarcity but also aligns with sustainable development goals by fostering economic resilience, reducing emissions, and conserving ecosystems.

With a circularity rate of 11.5% in 2022, Europe consumes a higher proportion of recycled materials compared to other world regions [7]. However, progress within the EU has been slow, and the goal of doubling the Union's circularity rate by 2030 remains a distant ambition [7], [8]. To address this gap between action and ambition, the EU-funded project SYMBIO tackles it from the standpoint of developing business models that significantly contribute to decreased dependence on virgin raw materials by valorising wastes and by-products from the bio-based industries.

SYMBIO equips European regional communities with tools and methodologies to develop bio-based business models centred on circular design and industrial symbiosis. By leveraging big data and artificial intelligence, SYMBIO establishes ten symbiotic business models that are both highly profitable and sustainable, with the potential for replication across the EU, thereby increasing the market presence of bio-based products and therefore raising the sluggish increase of circularity rate in Europe in recent years [9]. Big data and artificial intelligence offer an advantage in the first step of establishing new circular models – accelerating the search for circular value chains, providing preliminary environmental and economic impacts and suggesting partner companies that can participate in these new value chains powered by innovative business models. The inclusion of these powerful tools greatly influences the temporal aspect of establishing symbiotic business models by shortening the time for prioritising solutions for the project's regions described in the following paragraph.

The SYMBIO project incorporates a unique methodology that can be described in the following steps:

1. leveraging local biomass through the creation of Regional Data Hubs (WP1)

2. Design of zero-waste value chains (WP2) using big data and artificial intelligence
3. Material Flow Analysis (MFA) and Multi-Criteria Decision-Making Analysis (MCDMA) to identify the most promising symbiotic business models for replication in other EU regions.
4. A reporting system and a decision support tool for all supply chain operators, providing a competitive advantage measurement and monitoring tool (WP3).
5. Bio-based industrial facilities' social, environmental, and economic benefits will be measured (WP4), integrated into the AI digital platform, and disseminated through communication actions and stakeholder engagement (WP5 and WP6).

The approach of design, testing, and validation in twelve EU pilot regions: Lombardy, Piedmont, Veneto, Friuli-Venezia Giulia, Emilia-Romagna, Carinthia, Slovenia, Croatia, Andalusia, Brussels Capital, Wallonia, and Flanders. These regions were selected based on their estimated bio-based resource potential, availability of raw materials, socioeconomic indicators, networks, intangible infrastructures, and potential for developing market-aligned supply chains.

The main objectives of the SYMBIO project include:

1. Identifying and evaluating resources and technical solutions that enable industrial symbiosis and circularity from the design phase in the bio-based ecosystem.
2. Shaping symbiotic value chains using a zero-waste approach through big data and artificial intelligence tools.
3. Developing an integrated reporting system to measure and monitor industrial symbiosis based on regional multi-stakeholder co-creation approaches.
4. Demonstrating the economic, social, and environmental impacts of zero-waste industrial symbiosis models.

The scope of work in this report falls under the first objective – Identifying and evaluating resources and technical solutions that enable industrial symbiosis and circularity from the design phase in the bio-based ecosystem. More precisely, Task 2.1. of the WP2 called “Companies/Clusters mapping and VCG.AI enhancing” is part of the data gathering section of the SYMBIO project where industrial and cluster data was acquired. Data gathered will add to the extensive database of relevant information needed to prioritise circular value chains that can move towards implementation in the Pilot Regions of the project. Together with the inputs collected in WP1, task 2.1. serves as a data basis for the continuation of the WP 2 – Task 2.2. Circular value chains modelling.

The contents of Task 2.1. include developing a methodology to measure the acceleration of value chains from TRL 5 to TRL 9 that can be universally used and replicated in a scalable way. This methodology involves creating two models to describe industry players and regional clusters/enterprise networks across 12 pilot regions. It integrates data collection, data analysis, and value chain generation with the TRL framework to assess and enhance technological progression.

The following chapter details the methodology, followed by the results of data collection.

2. Scope and rational building of the companies and cluster database

The methodology underlying the work detailed in this report and the VCG approach is based on D1.1. SYMBIO Regional Hub handbook for data collection and harmonisation. The handbook is regarded as the project's methodological cornerstone, tasked with establishing selection criteria and data collection strategies for identifying the most promising biomass and technologies to facilitate the transition to a circular bio-based economy. Its main data collection consists of mapping quantities of biomass and technologies/processes needed to valorise these biomass input materials.

The first step involved establishing the criteria based on which the main circular value chains will be chosen. The results include the following aspects:

- Market demand,
- technological maturity,
- biomass availability,
- economic viability,
- environmental sustainability and
- accessibility and scalability.

Based on the criteria listed, twelve biobased products were selected. They represent the most promising solutions to effectively convert biomass. The twelve products are listed as follows:

- Lactic Acid
- Glycerol
- Succinic Acid
- Acetic Acid
- Adipic Acid
- PLA
- PHAs
- Lysine
- Glutamic Acid
- 1,3-Propanediol
- Furfural
- Sorbitol

These twelve products were used as a basis for Task 2.1. which is described in this report. Along with the biomass flows that were defined as possible input materials to produce these products, Anteja defined the industries that can act as potential feedstock providers in the value chains that can produce these products. The industries were defined based on desk research and the data provided on the Value Chain Generator platform.

2.1.Value Chain Generator platform

The Value Chain Generator (VCG.AI®) is a sustainable value chain generation platform that uses artificial intelligence and big data processing to create business BioLinks®. BioLink is a circular business connection

between companies representing the potential for linking material side-streams (material flows, raw materials, by-products, semi-finished products) and waste inputs and outputs between companies in different sectors to build sustainable value chains. It transforms the waste of the company at the outlet into valuable resources of the company at the inlet or vice versa and is an enabler of the circular economy.

The idea of VCG.AI is to automatically detect possible synergistic connections for forming circular value chains based on a wide range of publicly available inputs (i.e., yearly reports, goals, ESG strategy, etc.), as well as public information (public archives, webpages, official reports, etc.), and Anteja's internal company information. The specific problem that VCG.AI is addressing is the complexity of establishing value chains, as companies are unaware of the potential of their residuals, by-products and biowaste.

The VCG.AI platform is based on the latest technology - AI, NLP, big data and cloud technologies - and techniques for adapting the complexity of chains, which will digitalise the value chain establishment process in bioeconomy, enable automatic match-making between stakeholders in the bio-based value chains, improve the process of maintaining and managing value chains through visualisation, and allow its use by a wider range of cross-industry companies.

Currently, the platform boasts more than 500 circular value chain solutions, more than 150 validated transformation technologies, and a database with more than 3.5 million companies.

VCG.AI database capabilities and the methodology for uncovering new circular value chain opportunities will be used in this task to draft the selection of industries, to design two templates for data collection – one for companies and one for clusters. A detailed description of the approach is described in the following chapter.

3. Data Collection

The main activity of Task D2.1. included gathering companies and clusters in Pilot regions. Partners were asked to fill in an Excel sheet of company and cluster information for each of the twelve regions. Two Data Collection Templates in Excel were created: one related to the companies and the other one related to cluster organisations.

Project partners were asked to collect the information from companies and clusters in their regions. The objective was to collect information on at least 200 companies and 20 clusters. The first versions of the Data collection templates were shared with the lead partner to review on the 12th of February with a subsequent meeting executed on the 19th of February to receive feedback and move towards the final version of the templates which was uploaded on the 4th of March to the project Cloud Workspace folder for the partners to fulfil.

For an overview of the templates, please refer to *Annex 1*.

3.1.Data Collection Template for Companies

Objective: Gather comprehensive data on companies within the 12 pilot regions.

- **Approach**: Collect data on company size, revenue, industry classification, production capacities, and existing technological capabilities.

The template sheets for each region consist of 11 main columns that should be completed. Some columns are marked as “mandatory”, some as “desired”, and some as “optional” since not all information could be obtained from all the regions. The VCG methodology can provide satisfactory results with a certain amount of data; however, the more data gathered, the better the results can be.

The collection template for companies requires the following information:

- Official Company name
- Company ID (registration no.)
- Website
- Country
- City
- Street address
- Type (micro, SME, research, large, corporation)
- Description of their activity
- NACE code
- NACE code 2
- NACE code 3

The reason for choosing the stated data points lies in the methodology of the VCG.AI approach. It is set up in a way that does not require company involvement in any step of the approach. Consequently, the initial opportunity mapping can be obtained much faster for a region. As our algorithms are programmed to predict the companies’ material flows, only the NACE codes and company names are needed. For the sake of proximity analysis, we need the addresses of the companies as well to uncover potential clusters of off-takers or clusters of feedstock providers. To assess the size of the material flow, only the type of company is needed. This simple data gathering to uncover significant preliminary insights into which circular value chains have the potential to be implemented in the region gives the VCG.AI approach an edge, as the primary data can be easily obtained through public databases. Company size and revenue point to the mass of material flows that are generated on the location, industry classification gives a glimpse into what kinds of material flows are to be expected in the region and production capacities give an insight into the size of material flows.

3.2.Data Collection Template for Clusters

The approach gathers cluster data, which can serve as a local contact point for the industry. Consequently, this cluster information becomes valuable in the final steps of the VCG.AI approach, when companies are being contacted to present new circular value chains.

The collection template for clusters requires this information:

- Official Cluster name
- Website
- Country

- City
- Street address
- Street number
- Current services provided to its members by the cluster
- Area of specialisation
- Number of cluster members
- Contact person
- Contact e-mail

The reason for choosing the stated data points lies in the VCG methodology. To effectively contact the clusters and gather information from them, the contact person and e-mail is beneficial. It is salient to state at this point that only the contact information from trusted clusters of the organisations from the 12 Pilot Regions participating in the project was collected. Therefore, in case of the need to contact these clusters, the communication would go through trusted sources.

3.3.Selection of the industries

As stated above, desk research and VCG.AI database capabilities offered the pillars for connecting the biomass flows defined in D1.1. with the appropriate industries owning these materials. The full list of material flows and types of industries considered in the data collection is provided in *Annex 3*. The main analysed industries include:

- Dairy industry (cheese production, milk production...)
- Brewery industry
- Soy processing (Soy milk, Soybean oil...)
- Rice farm
- Bakery industry
- Wheat production
- Sugarbeet production
- Sawmills
- Furniture Manufacturing
- Biofuels
- Biogas

These industries were shared with the partners from 12 Pilot regions as a recommending guideline when searching for companies – the process is explained in the following chapter. We have prioritised these industries based on the knowledge and experience of forming successful circular value chains; however, more industries have been revealed as potential feedstock providers as indicated in *Annex 3*. Therefore, it was indicated to the partners from the Pilot Regions that they should include industries outside of the list of recommended ones and adjust their data sheets according to their regional industry specifics.

3.4. Data collection - Methodology

The partner regions employed a multi-faceted approach to gather comprehensive data on companies and clusters, ensuring accuracy and completeness. The following methodologies were utilised:

1. Desk-based research:
    - **Company websites.** Partners conducted thorough searches of company websites to extract information such as official company names, registration numbers, addresses, descriptions of activities, and NACE codes.
    - **Online business directories.** Utilised directories such as LinkedIn, Google Business, and regional business listings to find and verify company details.
2. Support from clusters and industry associations:
    - **Cluster organisations.** Engaged with regional cluster organisations that have direct links to member companies. These clusters provided aggregated data on company sizes, revenues, and technological capabilities.
    - **Industry associations.** Collaborated with industry associations that maintain databases of member companies, offering access to detailed industry-specific data.
3. Government and public databases:
    - **National and regional business registries.** Accessed official business registries and databases maintained by governmental agencies to verify company registration numbers, legal statuses, and addresses.
    - **Statistical offices.** Utilised data from national and regional statistical offices to gather information on industry classifications and economic indicators.
4. Market analysis software:
    - **Business intelligence tools.** Employed market analysis software such as Dun & Bradstreet, Orbis, and similar platforms to retrieve detailed financial information, including company sizes, revenues and addresses.
5. Surveys and direct contact:
    - **Questionnaires.** Distributed structured questionnaires to companies and clusters to collect specific data points directly from the source.
    - **Interviews.** Conducted interviews with key stakeholders within companies and clusters to gain deeper insights into their operations, technological capabilities, and production capacities.
6. Support from competent entities/authorities:
    - **Local economic development agencies.** Partnered with local economic development agencies that have access to regional economic data and company databases.
    - **Chambers of Commerce.** Worked with chambers of commerce that can provide verified information about local businesses and their activities.
7. Cross-verification:
    - **Data cross-checking.** Implemented a cross-verification process to ensure the accuracy of the collected data by comparing information from multiple sources.

- **Data validation**. Validated the data through follow-up communications with companies and clusters to confirm the accuracy and completeness of the collected information.

By employing this comprehensive and multi-source methodology, the partner regions were able to collect detailed and reliable data on companies and clusters, forming a solid foundation for uncovering opportunities for circular investment in the region.

3.5.Limitations of the data collection

While the data collection process aims to gather comprehensive information on companies within each of the 12 pilot regions, several limitations must be acknowledged:

1. **Data accuracy**. The reliability of the collected data is contingent upon the accuracy of the sources. Company-reported data, third-party databases, and public records may contain errors or outdated information, which can affect the overall assessment.
2. **Geographical variability**. The availability and quality of data can vary significantly across different regions and countries. Some regions may have more robust data collection mechanisms in place, while others may lack comprehensive records, leading to inconsistencies in the dataset.
3. **Industry classification**. The use of NACE codes to classify industries may not always accurately reflect the full scope of a company's activities. Companies with diverse operations may be misclassified, affecting the analysis of expected material flows and industry-specific opportunities.
4. **Dynamic business environment**. The business environment is dynamic, with companies frequently undergoing changes such as mergers, acquisitions, or shifts in their operational focus. Such changes can render previously collected data obsolete, necessitating continuous updates to maintain data relevance.
5. **Resource constraints**. Collecting, verifying, and analysing large volumes of data requires significant time and resources. Resource constraints may limit the depth of data collection and the ability to conduct thorough cross-verification, potentially impacting the comprehensiveness of the study.

Mitigation Action - VCG Workshops

Acknowledging these limitations is crucial for interpreting the findings of the data collection process and for developing strategies to mitigate their impact on the overall analysis of circular investment opportunities in the pilot regions. For example, from May 24th to May 28th, three workshops were conducted with partners from all 12 Pilot Regions to resolve final questions about completing the templates. On May 24th, partners from Croatia, Spain, and Italy participated; on May 27th, partners from Austria; and on May 28th, partners from Belgium.

During the workshops, a presentation of VCG was delivered, including a detailed explanation of the specific expectations for the partners from the pilot regions. The workshops were deemed successful, as the rate of template completion increased significantly afterwards.

At the workshop, Anteja ECG emphasised that while the KPI for this task was to gather around 200 companies and 20 clusters (approximately 20 companies and 2 clusters per region across 12 regions), it was encouraged to include more participants. Increasing the number of companies and clusters would significantly enhance the accuracy and quality of the data analysis. This approach proved successful, as

the final count of companies nearly tripled the initial KPI, and the number of clusters increased almost fourfold.

4. Data collection Analysis

Altogether, the project partners collected 579 companies from 12 regions in the SYMBIO project, well above the KPI posed in the General Agreement – around 200 companies. Regarding the cluster data, 102 clusters were collected, exceeding the KPI of around 20 clusters mapped for the regions in the project.

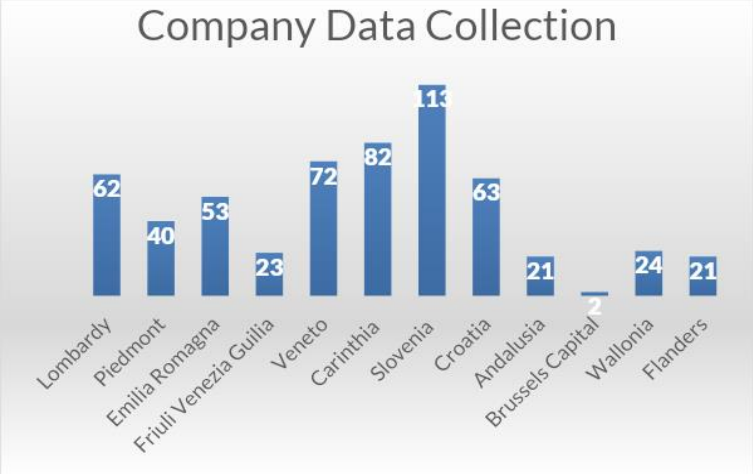

Figure 1: Distribution of collected companies in the 12 Pilot Regions. Source: Anteja ECG

Figure 1 represents the gathered data for companies from the 12 Pilot Regions. The number represents the number of companies gathered. The KPI for this Task was around 200 companies gathered for all 12 regions, which on average meant that each region had to gather around 17 companies. Apart from the Brussels Capital Region, all other regions exceeded this number with notable outliers in Slovenia, Carinthia, Veneto region, Lombardy, and Croatia.

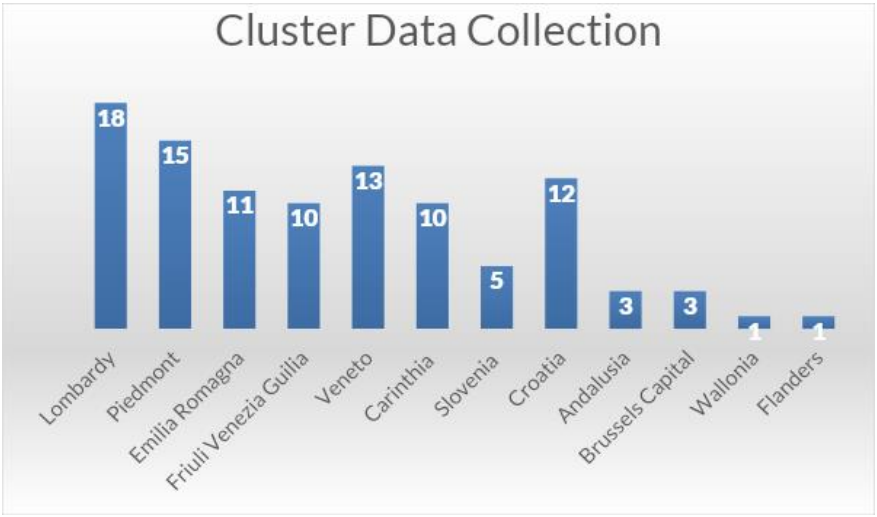

Figure 2: Distribution of collected clusters in 12 Pilot Regions. Source: Anteja ECG

Figure 2 represents the gathered data for clusters from each of the 12 Pilot Regions. The number represents the number of clusters gathered. The KPI for this task was to gather around 20 clusters, which meant, on average, around 2 clusters per region. Apart from Wallonia and Flanders, all other regions exceeded this number with notable outliers in the Lombardy, Piedmont, Veneto and Croatia regions.

4.1.Lombardy Region, Italy

The Lombardy region provided a total of 62 companies, with 44 belonging to the Food industry, 15 to the Wood industry, and 3 to Furniture production. The most represented was the Dairy industry, with 15 large companies and 9 SMEs. From the analysis of the Lombardy region's companies, several promising opportunities for circular value chains can already be identified. The Food products industry, comprising 44 companies, can benefit from initiatives such as repurposing by-products into animal feed or bio-based materials and implementing packaging reuse and recycling systems. The Wood and wood products industry, with 15 companies, can explore wood waste recycling for particleboard or biomass energy, furniture upcycling and repurposing, as well as biomass energy production. The smaller Furniture industry, consisting of 3 companies, can focus on extending product life through repair and refurbishment services, material recovery from discarded furniture, and designing for disassembly to facilitate recycling.

4.2.Piedmont Region, Italy

From examining the companies in the Piedmont region, several promising opportunities for circular value chains have been identified. The industry breakdown is as follows: Dairy products (4 large firms, 5 SMEs), Manufacture of ice cream (1 large firm), Manufacture of malt (2 large firms, 4 SMEs), Manufacture of bread; Manufacture of fresh pastry goods and cakes (3 SMEs), Manufacture of rusks and biscuits; Manufacture of preserved pastry goods and cakes (8 large firms, 5 SMEs), Manufacture of beer (1 SME), Manufacture of veneer sheets and wood-based panels (1 large firm, 1 SME), Manufacture of other builders' carpentry and joinery (1 large firm, 2 SMEs), and Manufacture of wooden containers (3 SMEs). The food products industry can benefit from initiatives such as converting organic waste into compost or biogas and repurposing by-products into animal feed or bio-based materials. The wood and wood products industry can explore wood waste recycling for particleboard or biomass energy, upcycling and repurposing wooden products, and utilising wood residues for biomass energy. Collaborative networks, technological innovation, and supportive policies can further enhance the region's transition towards a sustainable circular economy.

4.3.Emilia Romagna Region, Italy

Based on the analysis of the Emilia Romagna region's companies, the following insights can be drawn from the industry breakdown: The food products industry, particularly in Dairy products (10 large firms, 2 SMEs) and Bakery products (1 large firm, 8 SMEs), dominates the region, indicating a strong potential for initiatives targeting organic waste conversion and byproduct repurposing. The significant presence of the wood and wood products industry, including Manufacture of veneer sheets and wood-based panels (1 large firm, 2 SMEs), Manufacture of wooden containers (2 large firms, 2 SMEs), and other wood-related products, highlights opportunities for wood waste recycling and biomass energy projects. Additionally, the presence of companies in the Manufacture of ice cream, malt, and oils and fats suggests the potential for specialised recycling and reuse programs.

4.4.Friuli Venezia Giulia Region, Italy

Based on the analysis of the Friuli Venezia Giulia region's companies, the following insights can be drawn from the industry breakdown: The food products industry, particularly in Dairy products (1 large firm, 3 SMEs), and Bakery products (2 large firms, 1 SME), dominates the region, indicating a strong potential for initiatives targeting organic waste conversion and byproduct repurposing. The presence of companies in the Manufacture of beer, malt, and prepared feeds for farm animals suggests the potential for specialised recycling and reuse programs. The diverse mix of large firms and SMEs across these industries suggests that both large-scale and small-scale circular initiatives could be effectively implemented, leveraging the strengths of different company sizes to drive a sustainable circular economy in the Friuli Venezia Giulia region.

4.5.Veneto Region, Italy

From the evaluation of companies in the Friuli Venezia Giulia region, the following insights emerge from the industry breakdown: the food products industry, particularly in Dairy products (9 large firms, 6 SMEs) and Bakery products (10 large firms, 5 SMEs), dominates the region, indicating a strong potential for initiatives targeting organic waste conversion and byproduct repurposing. The significant presence of the wood and wood products industry, including Manufacture of veneer sheets and wood-based panels (1 large firm, 2 SMEs), Manufacture of wooden containers (1 large firm, 4 SMEs), and other wood-related products, highlights opportunities for wood waste recycling and biomass energy projects.

4.6.Croatia

From the evaluation of Croatia's companies, the three most represented industries are Dairy products (7 companies), Manufacture of beer (6 companies), and Support activities for agriculture and post-harvest crop activities (5 companies). The food products and beverage industries dominate, indicating significant potential for initiatives targeting organic waste conversion and byproduct repurposing. Additionally, the strong presence of agricultural support activities highlights opportunities to enhance sustainable agricultural practices. Croatia has considerable opportunities to develop circular value chains that enhance sustainability and resource efficiency across these key sectors.

4.7.Andalusia region, Spain

The Andalusia region of Spain, with its diverse range of industries, offers several promising opportunities for circular value chains. Key sectors include the Manufacture of beer (5 companies), Dairy products (1 company), and Prepared feeds (1 company), as well as the Wood industry, logging (1 company), and the Wholesale of construction materials (1 company). These industries can benefit from initiatives such as converting organic waste into compost or biogas, repurposing by-products into animal feed or bio-based materials, and recycling wood waste for biomass energy. Enhancing material recovery and recycling processes in the waste management sector, along with improving production methods and product design in manufacturing, can further boost sustainability and resource efficiency in Andalusia.

4.8.Slovenia

From the evaluation of Slovenia's companies, the most represented industries are Sawmilling and planning of wood (36 companies), Manufacture of other builders' carpentry and joinery (18 companies), and

Manufacture of other food products (6 companies). The wood and paper products industry, including the manufacture of veneer sheets and wood-based panels, has a substantial presence. Additionally, the chemical and pharmaceutical sectors indicate potential for specialised upcycling and reuse projects. Given the substantial presence of these key industries, Slovenia has considerable opportunities to develop and implement circular value chains that can enhance sustainability and resource efficiency across multiple sectors.

4.9.Wallonia Region, Belgium

From the assessment of companies in the Wallonia region of Belgium, several promising opportunities for circular value chains have been identified. The main industry breakdown is as follows: Dairy products (7 large firms), Manufacture of bread and fresh pastry goods (4 large firms), Manufacture of beer (3 large firms) and Manufacture of other food products (2 large firms).

The food products industry, comprising 7 firms in Dairy products and 4 in Bread and pastry manufacturing, can benefit from initiatives such as repurposing by-products into animal feed and most importantly – bio-based materials. The beverage industry, represented by 3 firms in beer manufacturing, also offers potential for similar waste conversion initiatives. Overall, the Wallonia region has substantial potential to enhance sustainability and resource efficiency through well-implemented circular value chains across its key industries.

4.10. Flanders Region, Belgium

An assessment of companies in the Flanders region of Belgium has uncovered several promising opportunities for circular value chains. The industry breakdown is as follows: Dairy products (2 large firms), Manufacture of other food products (1 large firm), Manufacture of beer (10 large firms), Retail sale of fish, crustaceans, and molluscs in specialised stores (1 large firm), Manufacture of bread and fresh pastry goods (5 large firms), and Manufacture of rusks and biscuits; Manufacture of preserved pastry goods and cakes (1 large firm).

The food sector, with its representation in Dairy products and other food products, can leverage initiatives like converting organic waste into compost or biogas and repurposing by-products into animal feed or bio-based materials. The beverage industry, particularly beer manufacturing, offers substantial potential for similar waste conversion projects. The bread and pastry sector can focus on waste reduction and recycling through improved production processes and packaging reuse. The retail sector can enhance sustainability by optimising supply chains and reducing waste.

4.11. Brussels Region, Belgium

This region collected only five companies, mostly categorised as large firms, representing the dairy and bakery industries, a brewery, and a retailer of fruit and vegetables. The sample size is too small to draw further conclusions at this point.

4.12. Carinthia Region, Austria

The industry breakdown for the Carinthia region includes Sawmilling and planning of wood (19 companies), Dairy products (7 companies), Manufacture of beer (8 companies), Waste treatment and

disposal (12 companies), Manufacture of bread; Manufacture of fresh pastry goods and cakes (2 companies), Manufacture of malt (1 company), Manufacture of furniture (5 companies), Manufacture of other chemical products (4 companies), wholesale of chemical products (1 company), and Manufacture of basic pharmaceutical products (1 company).

The waste management sector can improve material recovery and recycling processes. In manufacturing, particularly in beer production and furniture making, there are opportunities for waste minimisation and recycling through better production methods and product design. Overall, the Carinthia region holds considerable promise for boosting sustainability and resource efficiency through the implementation of circular value chains in its key industries.

Conclusion

Altogether 579 companies from the 12 Pilot Regions were collected during M2-M6 of the SYMBIO project. The task can be considered a success as the KPIs were significantly exceeded. The initial reservations regarding the understanding of the task were clarified during the organised workshops in M5. It is important to note that the companies provided by organisations from the 12 Pilot Regions do not fully represent all companies involved in the bioeconomy within these regions. Given the moderate KPI for collecting companies in each region, the scope of work for VCG will be limited. However, Anteja will still be able to extract valuable information for prioritising circular value chains. The data has been uploaded to the VCG.AI database and Anteja ECG now has sufficient data input to start with task 2.2. of the WP2 – Circular value chains modelling.

5. Methodology for the data analysis

Data analysis is part of task 2.2. of the WP2 – Circular value chains modelling which is scheduled for the upcoming period from M6-M14. However, part of Task D.2.1. is as well to define the methodology to measure the acceleration of value chains from TRL 5 to TRL 9 that can be universally used and replicated in a scalable way. Therefore, this chapter focuses on the VCG approach that will be applied in the SYMBIO project and will present the cornerstone for the data analysis.

Data analysis – will follow a framework for uncovering circular value chains that have the potential to be implemented in a certain region: INPUT – TECHNOLOGY – MARKET (BioLinks) (Figure 3).

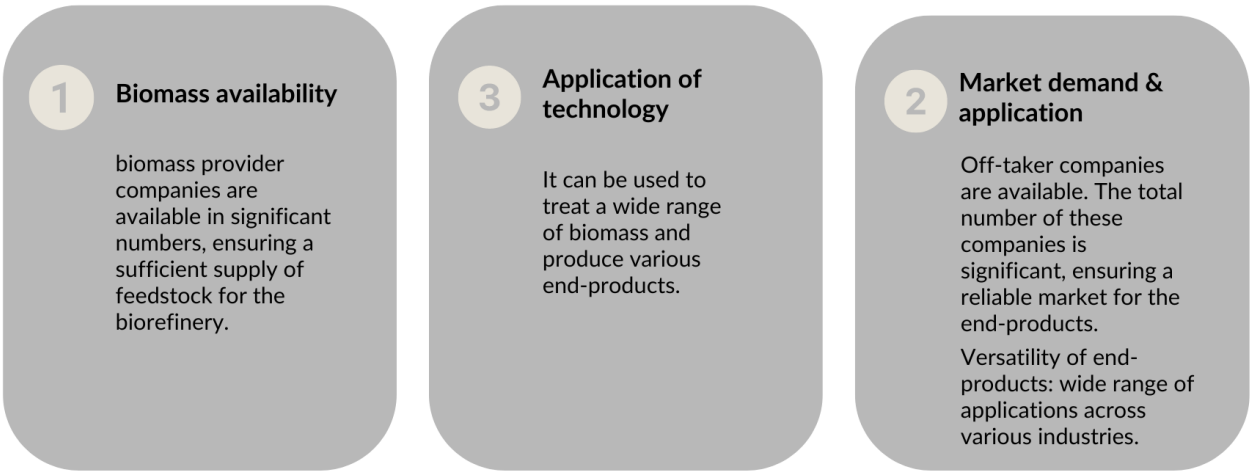

Figure 3: VCG framework methodology. Source: VCG.AI

INPUT - Defining material streams in each industry in the region

The first step of the data analysis is to find the largest companies in the region as these companies own the largest material streams in the region.

STEP 1: Largest industries by cumulative revenue: Identify the top five industries within each region based on cumulative revenue and the number of companies within each industry. in the region.

The reason for implementing this step lies in the fact that to find viable economic opportunities and business models, the following requirements must be met for industries:

- a steady,
- reliable,
- large-scale material flow,
- preferably not scattered around many locations, as the cost and carbon emissions rise in this case, jeopardising the economic and environmental viability of a certain circular value chain.

Therefore, the first step in uncovering circular potential in the region is identifying the largest industries that own the largest material flows by mass (Figure 4).

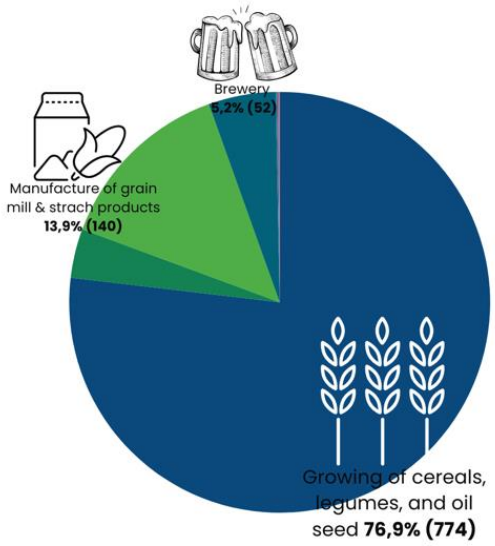

Figure 4: A breakdown of industries by representation in the sample

The next step is to uncover the accumulation of the companies in certain industries and to map these companies in the region to gather hotspots where the most biomass is accumulating.

STEP 2: Total number of companies: Count the number of companies within these industries.

The results are as follows:

- A pie chart with the most prevalent industries in terms of the number of companies.

The third step is prioritising the most sought-after by-products and waste in Europe.

STEP 3: The VCG algorithm derives the most prominent by-product and waste streams (feedstock) in each of the prioritised industries.

We define each industry and company's most prominent by-product and waste streams, as provided in the Data Collection step. The VCG.AI database defines the streams to be used as feedstock in circular models and conversion processes to introduce new products to the market. In the second step, the VCG.AI database and algorithm capabilities are used to define a breakdown of the percentages of each material stream that represents the whole mass balance.

STEP 4: Define the percentage of by-products and waste streams each industry generates (Figure 5).

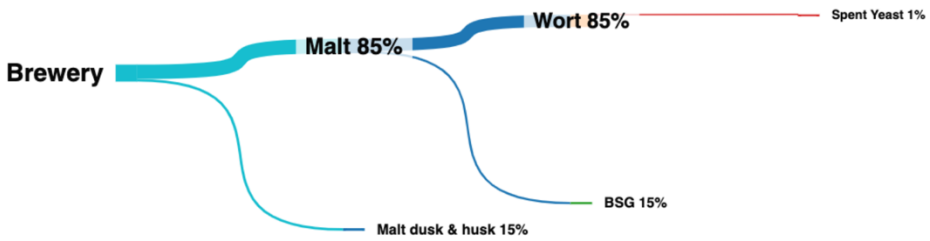

Figure 5: a breakdown of material flows for the brewery industry

The last step of Defining material streams in each priority Industry section is to present a visual map of the companies that can participate as feedstock. This will uncover clusters of companies which may indicate a potential opportunity from a logistic and economic standpoint. It is more beneficial if material streams are closer together.

STEP 5: Locate the industries offering material streams to uncover potential clustering (Figure 6).

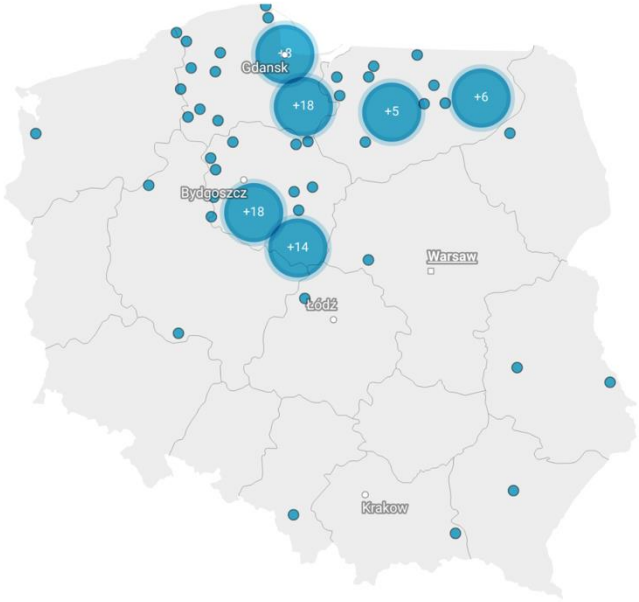

Figure 6: An example of a clustering of potential feedstock providers done for regions in Poland

5.1.Value Chain Generation

Datasets are applied to VCG – and the algorithm provides the value chains.

- **BioLink exploration**: Identify all circular value chain opportunities for specific by-products/residuals identified in priority industries.
- **Implementability (TRL 7-9)**: Evaluate each BioLink's TRL, focusing on those at TRL 7, 8, or 9.
- **Economic impact**: Evaluate each BioLink based on the economic factors

- **Environmental impact**: Evaluate each BioLink based on the environmental factors

In Step 6 a vast VCG.AI database of more than 530 circular value chain models covering a variety of bio-based by-product and waste streams and market applications (chemicals, food and pharma ingredients, packaging materials etc.) will be utilised to identify all the opportunities. These value chains or so-called "BioLinks" revolve around clean technologies that can valorise the material streams mapped in chapter 2.2.2. In VCG, there are more than 150 conversion technologies and processes to enable new circular value chains. Technology providers are offering these cutting-edge solutions that are implementable and scalable in a profitable way along with having a profound environmental impact – either through lowering GHG emissions or upcycling the by-product and waste streams.

In the next steps, these circular value chains are equipped with more data points to give weighting to each and open the possibility to compare and benchmark the BioLinks to make the appropriate prioritisation of them which is the ultimate end goal.

STEP 6: BioLink exploration: Use the VCG.AI database of possible circular value chain solutions.

Steps 7 and 8 give additional weight to each BioLink. The steps consider crucial information needed for evaluating if a certain solution can move further towards implementation.

STEP 7: Economic impact: Uncover the economic impact of each value chain, considering factors such as Return on Investment and investment size.

STEP 8: Environmental impact: Uncover the environmental impact of each value chain compared to business-as-usual (BAU) scenarios, considering factors such as waste reduction and lower CO_2 emissions.

5.2.OUTPUT - Evaluating market potential

The market potential is the crucial aspect in the final part of the three-part process of our approach – Output. It considers two steps, market off-taker availability and market demand for the newly formed circular products that the technologies uncovered in Step 6 produce.

Market off-taker availability provides insight into the strength of the market for new circular products and identifies which companies in the region can participate as off-takers in potential new circular value chains. The VCG.AI approach considers the size of industries that can utilise the new bio-based products as well as statistical market data.

6. Follow-up Workshop

The results of the data analysis will be presented to each region during a designated workshop that will be part of the 2-day meeting from M10-M18. The lead partner in each region is the primary recipient of this information. The next step for the lead partner is to generate interest in the presented circular value chains among regional companies and to schedule a meeting to discuss potential implementation projects.

In the moderated workshops, we aim to demonstrate how the region can progress from TRL 5 solutions to TRL 9 solutions.

7. Implementation

Mentoring, coaching, and training services will be developed based on the action plan prepared during the workshop. These services will include direct work through one-on-one meetings and focus groups. Some sessions will be conducted online, while others will be held in person, complementing project meetings.

The results of the coaching sessions will include validation based on direct engagement with companies. The validated BioLinks will be incorporated into the VCG.AI database.

The plan for the coaching and training sessions will be finalised by the end of January 2025, based on inputs gathered during the workshops.

8. References

[1] E. G. Hertwich, "Increased carbon footprint of materials production driven by rise in investments," *Nat Geosci*, vol. 14, no. 3, pp. 151–155, Mar. 2021, doi: 10.1038/s41561-021-00690-8.

[2] United Nations Environment Programme, "Global Resources Outlook 2024 - Bend the trend: Pathways to a liveable planet as resource use spikes," 2024. Accessed: Jun. 20, 2024. [Online]. Available: https://resourcepanel.org/reports/global-resources-outlook-2024

[3] International Organization for Standardization, "ISO 59004:2024." Accessed: Jun. 20, 2024. [Online]. Available: https://www.iso.org/standard/80648.html?utm_source=hellobar-home&utm_campaign=circular-stds-launch

[4] D. Knäble, E. de Quevedo Puente, C. Pérez-Cornejo, and T. Baumgärtler, "The impact of the circular economy on sustainable development: A European panel data approach," *Sustain Prod Consum*, vol. 34, pp. 233–243, Nov. 2022, doi: 10.1016/j.spc.2022.09.016.

[5] M. Sharmina, D. Pappas, K. Scott, and A. Gallego-Schmid, "Impact of Circular Economy Measures in the European Union Built Environment on a Net-Zero Target," *Circular Economy and Sustainability*, vol. 3, no. 4, pp. 1989–2008, Dec. 2023, doi: 10.1007/s43615-023-00257-2.

[6] C. C. Chen and H. T. Pao, "Circular economy and ecological footprint: A disaggregated analysis for the EU," *Ecol Indic*, vol. 160, Mar. 2024, doi: 10.1016/j.ecolind.2024.111809.

[7] A. Bize, "Accelerating the circular economy in Europe," 2023, doi: 10.2800/055236.

[8] European Commission, *A new Circular Economy Action Plan*. 2020. [Online]. Available: https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

[9] European Environment Agency, "Circular material use rate in Europe." Accessed: Jun. 20, 2024. [Online]. Available: https://www.eea.europa.eu/en/analysis/indicators/circular-material-use-rate-in-europe

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ANNEX 1

A template for collecting company data for the 12 Pilot Regions.

Companies			Mandatory		Desired	Optional				
Official company name	Company id (registration no.)	Website	Country	City	Street address	Type	Description of their activity	NACE Code	NACE Code 2	NACE Code 3

ANNEX 2

A template for collecting cluster data for the 12 Pilot Regions.

Clusters										
Official cluster name	Website	Country	City	Street Address	Street Number	Please provide your current services to your members (max 250 words)	Area of specialisation	Number of Members	Contact Person	Contact email

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ANNEX 3

Defined industries that own the material flows defined in WP1.

The twelve most promising biobased products		Material flow (biomass)	Industry owning the material flow
Lactic Acid		Barley Extract	Brewing Industry
		Whey Protein Hydrolysate	Dairy Industry
		Soybean Meal	Soy processing, Animal feed
		Cottonseed Meal	Oil Extraction, Animal feed
		Alfalfa Fiber and Soya Fiber	Agriculture
Glycerol		Vegetable Oils	Food Processing, Biofuels
		Animal Fats	Food Processing, Biofuels
		Waste Cooking Oil (WCO)	Food Service (Restaurants, Food Manufacturing), Biofuels
Succinic Acid		Corn Stover and Straw	Agriculture (Crop Residues), Biofuels,
		Sugarcane Bagasse (SCB)	Agriculture (Sugar Production), Biofuels, Paper and Pulp
		Wheat Straw	Agriculture (Crop Residues), Biofuels
		Rice Straw	Agriculture (Crop Residues), Biofuels
		Barley Straw	Agriculture (Crop Residues), Biofuels
		Miscanthus	Agriculture (Energy Crops), Biofuels

		Municipal Solid Waste (MSW)	Waste Management (Recycling, Landfills)
		Forestry Residues	Forestry (Logging Residues), Bioenergy, Paper and Pulp
Acetic Acid		Corn Stover	Agriculture (Crop Residues), Biofuels
		Wheat Straw	Agriculture (Crop Residues), Biofuels
		Sugarcane Bagasse (SCB)	Agriculture (Sugar Production), Biofuels, Paper and Pulp
		Poplar Sawdust	Wood Processing (Sawmills), Bioenergy
		Barley Straw	Agriculture (Crop Residues), Biofuels
		Forestry Residues	Forestry (Logging Residues), Bioenergy, Paper and Pulp
Adipic acid		Oil crops: Rapeseed	Agriculture (Oilseed Crops), Biofuels
		Oil crops: Canola	Agriculture (Oilseed Crops), Biofuels
		Oil crops: Palm	Agriculture (Plantation Crops), Food Processing (Palm Oil), Biofuels
		Oil crops: Coconut	Agriculture (Plantation Crops), Food Processing (Coconut Oil), Cosmetics
		Forestry Residues	Forestry (Logging Residues), Bioenergy, Paper and Pulp
		Corn Stover	Agriculture (Crop Residues), Biofuels

		Rice Straw	Agriculture (Crop Residues), Biofuels
		Sugarcane Bagasse (SCB)	Agriculture (Sugar Production), Biofuels, Paper and Pulp
PLA		Corn	Agriculture (Grain Production, Feed, Biofuels), Food Processing
		Sugarcane	Agriculture (Sugar Production), Biofuels
		Sugar beet	Agriculture (Sugar Production), Biofuels
		Wheat	Agriculture (Grain Production, Food Processing), Biofuels
		Cassava	Agriculture (Root Crops), Food Processing, Biofuels
		Soybean	Agriculture (Grain Production, Oil Extraction, Animal Feed)
PHAs		Sugarcane waste	Agriculture (Sugar Production), Biofuels
		Sugarcane Bagasse (SCB)	Agriculture (Sugar Production), Biofuels, Paper and Pulp
		Corn Stover	Agriculture (Crop Residues), Biofuels
		Wheat Straw	Agriculture (Crop Residues), Biofuels
		Forestry Residues	Forestry (Logging Residues), Bioenergy, Paper and Pulp
		Municipal Solid Waste (MSW)	Waste Management (Recycling, Landfills), Bioenergy

		Waste Cooking oil (WCO)	Food Service (Restaurants, Food Manufacturing), Biofuels
		Oil crops: Canola	Agriculture (Oilseed Crops), Biofuels
		Oil crops: Palm	Agriculture (Plantation Crops), Food Processing (Palm Oil), Biofuels
		Oil crops: Soybean	Agriculture (Oilseed Crops), Food Processing, Biofuels
Lysine		Corn Stover	Agriculture (Crop Residues), Biofuels
		Wheat Straw	Agriculture (Crop Residues), Biofuels
		Molasses	Agriculture (By-product of Sugar Production), Food Processing, Biofuels
Glutammic Acid		Corn Stover and Syrup	Agriculture (Crop Residues, Sweeteners), Food Processing, Biofuels
		Wheat Straw	Agriculture (Crop Residues), Biofuels
		Rice Straw	Agriculture (Crop Residues), Biofuels
		Sugarcane Bagasse	Agriculture (Sugar Production), Biofuels, Paper and Pulp
		Soybean meal	Agriculture (Animal Feed), Food Processing
		Molasses	Agriculture (By-product of Sugar Production), Food Processing, Biofuels
1,3-Propanediol		Corn Steep Liquor	Agriculture (Animal Feed, Fermentation Processes)

		Crude Glycerol	Biofuels (Biodiesel Production By-product), Chemical Manufacturing
		Corn Stover	Agriculture (Crop Residues), Biofuels
		Wheat Straw	Agriculture (Crop Residues), Biofuels
		Rice Straw	Agriculture (Crop Residues), Biofuels
		Sugarcane Bagasse	Agriculture (Sugar Production), Biofuels, Paper and Pulp
Furfural		Forestry Residues	Forestry (Logging Residues), Bioenergy, Paper and Pulp
		Municipal Solid Waste (MSW)	Waste Management (Recycling, Landfills), Bioenergy
		Maize Cobs	Agriculture (Crop Residues), Biofuels
		Corn Stalks and Cobs	Agriculture (Crop Residues), Biofuels
		Sugarcane Bagasse	Agriculture (Sugar Production), Biofuels, Paper and Pulp
		Wheat Straw	Agriculture (Crop Residues), Biofuels
		Rice Husks	Agriculture (Crop Residues), Biofuels
		Barley Straw	Agriculture (Crop Residues), Biofuels
Sorbitol		Switchgrass	Agriculture (Energy Crops), Biofuels
		Corn Cobs	Agriculture (Crop Residues), Biofuels

		Rice Straw	Agriculture (Crop Residues), Biofuels
		Eucalyptus	Forestry (Tree Plantations), Paper and Pulp, Bioenergy
		Empty Fruit Bunch (EFB)	Agriculture (Palm Oil Production By-product), Biofuels
		Sugarcane Bagasse and Oat	Agriculture (Sugar Production, Cereal Processing), Biofuels, Paper and Pulp
		Cotton Wool and Textile	Textile Industry (Fiber Production, Fabric Manufacturing)
		Tissue and Printing Paper	Paper and Pulp Industry (Tissue Paper, Printing Paper Production)
		Sorbitol Derivatives	Chemical Industry (Food Additives, Pharmaceuticals, Personal Care Products)