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D1.2 – Regional Data-Hub inventory and data map

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AUTHOR(S): Maria Elena Saija, Federica Binello, Luca Mattiocco, Ilaria Re, Lombardy Green Chemistry Association (LGCA) Piotr Swiatek, Katie Beverley, CMU
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Abbreviations

AMOCEAB	Adrion Master's on Circular Economy and Bioeconomy
B2BE	Business to Bioeconomy Facilitator
BELSPO	Belgian Federal Science Policy Office
BIT	Italian Bioeconomy Strategy
CER	Central Europe Representation
CLAN	National Agrifood Cluster
CNR	National Research Council
CREA	Council for Agricultural Research and Analysis of Agricultural Economics
ERDF	European Regional Development Fund
EIT	European Institute of Innovation and Technology
ENEA	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
EU	European Union
IIT	Italian Technology institute
IRMO	Institute for Development and International Relations
ISPRA	Superior Institute for Environmental Protection and Research
ISTAT	National Institute of Statistics
JTF	Just Transition Fund
LGCA	Lombardy Green Chemistry Association
MCDMA	Multi-Criteria Decision-Making Analysis
MFA	Material Flow Analysis
MSW	Municipal Solid Waste
O(s)	Objective(s)
PHA	Polyhydroxyalkanoates
PLA	Polylactic Acid
S.p.A.	Società per Azioni (Italian Public Company)
SME	Small and Medium-sized Enterprise
SPRING	Italian Circular Bioeconomy Cluster

SRIP	Strategic Research and Innovation Partnership
Srl	Società a responsabilità limitata (Italian Limited Liability Company)
SYMBIO	Shaping symbiosis in bio-based industrial ecosystems based on circular by-design supply chains
TBMCE	Technologies and Business Models for the Circular Economy
TRL	Technology Readiness Level
UN	United Nations
VIB	Vlaams Instituut voor Biotechnologie
VLAIO	Flanders Innovation & Entrepreneurship
WCO	Waste Cooking Oil
WP(s)	Work Package(s)
WPH	Whey Protein Hydrolysate

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Executive summary

The SYMBIO Regional Data-Hub inventory and data map (**D1.2**), an integral part of the **WP1** (**Task 1.2**) of the Work Plan, aims to provide a comparative assessment of regional biomass availability, business models, technologies, and knowledge in **12 European pilot regions** (Lombardy, Piedmont, Veneto, Friuli-Venezia Giulia, Emilia-Romagna, Carinthia, Slovenia, Croatia, Andalusia, Brussels Capital, Wallonia, Flanders) to enable the understanding of symbiosis industrial enablers and their prioritization.

Achieving a sustainable circular economy requires a comprehensive transformation of current production and consumption systems, moving from the linear "take-make-waste" model towards a circular approach where materials and products are continuously circulated through maintenance, reuse, refurbishment, remanufacturing, and recycling. This shift necessitates rethinking traditional concepts of growth and consumption, prioritizing dematerialization, collaborative consumption models, and innovative business strategies aligned with circular principles. A coordinated, interdisciplinary approach is essential to overcoming the challenges of this transition and achieving a more resilient and equitable future. In this context, industrial symbiosis is a powerful strategy that fosters collaboration between industries to optimize resource use, minimize waste, and enhance sustainability. This approach is especially relevant in bio-based and circular business models, which aim to establish closed-loop systems that reduce reliance on non-renewable resources. The integration of industrial symbiosis with bio-based models is vital for advancing the circular economy and promoting sustainable practices that support both economic and environmental goals.

In this framework, D1.2 – builds on the Regional Hub Handbook (D1.1) – evaluates the state-of-the-art and future prospects of biological resources, technologies, and facilities in each pilot region from an industrial symbiosis perspective. The report provides a comparative assessment of regional biomass availability, business models, and technologies, and informs the development of strategies and interventions crucial for successfully implementing industrial symbiosis, ultimately contributing to the project's goal of establishing sustainable, circular economies in Europe.

The following section presents in detail the main contents of D1.2, including:

1. assessment of the regional availability of bio-based raw materials
2. assessment of technologies and business models
3. data harmonization and matching
4. strengths and weaknesses of regional ecosystems for industrial symbiosis.

With this document, SYMBIO employs a comprehensive methodology to identify biobased products, biomass, and promising technologies in each pilot region. This in-depth analysis makes it possible to improve the efficiency of resource utilization and infrastructure through industrial symbiosis, incentivizing the collaboration of diverse entities and the creation of new value chains. This analysis is a strategically critical aspect of improving economic security and sustainability in Europe.

1. Introduction

1.1. Industrial symbiosis to build bio-based and circular business models

Achieving a sustainable circular economy requires a fundamental and comprehensive transformation of our current production and consumption systems. The linear "take-make-waste" model, which dominates the global industry, is increasingly becoming unsustainable, leading to resource depletion, environmental degradation, and waste accumulation. To address these challenges, a paradigm shift towards a circular economy is imperative—one in which materials and products are continuously circulated through processes such as maintenance, reuse, refurbishment, remanufacturing, and recycling.

This transformation involves a rethinking of traditional concepts of growth and consumption, prioritizing the dematerialization of products, the promotion of collaborative consumption models, and the innovation of business strategies that align with circular principles. However, overcoming the inherent challenges and limitations of this transition demands a coordinated, holistic, and interdisciplinary approach. By working together towards a shared vision of a sustainable circular economy, we can create a more resilient and equitable future.

In this context, **industrial symbiosis** emerges as a powerful strategy, where different industries collaborate to optimize resource use, minimize waste, and enhance overall sustainability. This approach is particularly relevant within bio-based and circular business models, which aim to establish closed-loop systems that reduce dependence on non-renewable resources.

Industrial symbiosis involves the exchange of materials, energy, water, and by-products among industries, fostering an environment where waste from one entity becomes a resource for another. This not only increases efficiency but also contributes significantly to reducing environmental impacts, such as carbon emissions and resource depletion[1]. The integration of industrial symbiosis with bio-based business models is therefore vital for advancing the circular economy, as it underscores the continual use of resources and the reduction of waste through innovative and sustainable processes. By leveraging local resources and creating synergies, businesses can develop sustainable practices that contribute to both economic and environmental goals[2].

The benefits of industrial symbiosis extend beyond individual businesses, contributing to broader economic resilience and environmental sustainability goals, particularly within the European Union. Indeed, industrial symbiosis plays a crucial role in helping Europe achieve its sustainability objectives by promoting resource efficiency, reducing waste, and fostering circular economic practices.

The benefits of industrial symbiosis include:

- **Resource Efficiency**: Industrial symbiosis facilitates the exchange of materials, energy, and by-products among different industries. This approach allows companies to utilize waste from one process as a resource for another, significantly reducing the demand for virgin materials and minimizing waste generation. The European Commission estimates that widespread implementation of industrial symbiosis could result in annual savings of up to €1.4 billion and generate additional revenues of €1.6 billion[3].
- **Economic benefits**: Collaborative resource sharing can lead to lower operational costs for participating businesses, reducing dependence on imports. With Europe ranking among the highest in per capita net imports of raw materials globally, improving resource efficiency through industrial symbiosis is strategically critical for enhancing economic security and sustainability[4].

- **Environmental Impact**: Industrial symbiosis contributes to the decarbonization of industries by optimizing resource use and reducing waste. By consuming less energy and producing fewer emissions, businesses can move closer to achieving long-term climate neutrality, a central goal of the EU's climate policies. The European Union's Circular Economy Action Plan emphasizes the integration of industrial symbiosis as a key component of transforming production and consumption patterns, which is essential for achieving greater circularity, reducing environmental impacts, and enhancing sustainability across industries[5].

However, despite its clear benefits, the widespread adoption of industrial symbiosis faces several challenges. These include the need to establish robust partnerships, build trust among stakeholders, and develop effective communication channels to facilitate collaboration. Overcoming these obstacles is crucial to fully realizing the potential of industrial symbiosis and, by extension, advancing the circular economy across Europe and beyond.

1.2.Scope of the Regional Data-Hub inventory and data map

The SYMBIO project aims to meet the need for a comprehensive transformation of the current production and consumption systems, providing European regional communities with tools and methodological frameworks to develop **bio-based business models** based on **circularity by design** and **industrial symbiosis**. Supported by big data and artificial intelligence, SYMBIO shapes **10 highly profitable and sustainable symbiotic business models**, designed for replication across the EU, to boost the presence of bio-based products in the market. The project also introduces a system for modelling, measuring, and monitoring symbiosis, along with its social, economic, and environmental impacts. The SYMBIO methodology will be tested and validated in **12 EU pilot regions** (Lombardy, Piedmont, Veneto, Friuli-Venezia Giulia, Emilia-Romagna, Carinthia, Slovenia, Croatia, Andalusia, Brussels Capital, Wallonia, and Flanders). These regions were chosen based on their bio-based resource potential, raw material availability, socio-economic indicators, intangible networks and infrastructure, and their capacity to develop close-to-market CBE supply chains. Engaging all supply chain stakeholders through a **quadruple-helix approach**, SYMBIO aims to unlock and stimulate local development potential by promoting sustainable, innovative, tangible, and participatory pathways toward a green transition through an inclusive, bottom-up CBE nexus.

In this context, the SYMBIO project aims to achieve the following main **objectives** (Os):

O1. Identify and evaluate resources and technical solutions that allow industrial symbiosis and circularity right from design in the bio-based ecosystem.
O2. Shaping symbiotic value chains using a zero-waste approach through big data and artificial intelligence tools.
O3. Develop an integrated reporting system to measure and monitor industrial symbiosis based on regional multi-stakeholder co-creation approaches.
O4. Demonstrate zero-waste industrial symbiosis models' economic, social, and environmental impacts.

The project focuses on the synergistic use of local biomass by establishing Regional Data Hubs (WP1) that will support in designing zero-waste value chains (WP2) using big data and artificial intelligence. Material Flow Analysis (MFA) and Multi-Criteria Decision-Making Analysis (MCDMA) will identify the most promising symbiotic business models that can be replicated in other EU regions. A reporting system and decision support solution will help operators measure the competitive advantage of the symbiotic industrial model and monitor sustainability performance (WP3). Finally, the social, environmental, and

economic benefits of bio-based industrial facilities will be assessed (WP4), integrated into an AI digital platform, and shared through communication and stakeholder engagement efforts (WP5 and WP6).

This report is part of ***WP1 – Mapping and assessing resources and technical solutions enabling industrial symbiosis***, which aims to evaluate the current state and future prospects of the most significant biological resources, technologies, and facilities in each pilot region from an industrial symbiosis perspective. The involvement of users and stakeholders at every stage ensures that the key factors enabling industrial symbiosis are effectively prioritized.

Based on the *D1.1 – Regional Hub handbook for data collection and harmonisation*, the project's methodological pillar responsible for setting the selection criteria and data collection strategies for the most promising biomass and technologies developed under *Task 1.1 – Discover: explore regional ecosystems, measuring challenges and opportunities*, this report presents a comparative assessment of regional biomass availability, business models, technologies, and a bio-based industries innovation ecosystem actors analysis in an integrated matrix and dataset.

This report, part of ***Task 1.2 – Data analysis, harmonization, and prioritization***, is a crucial step in evaluating the state-of-the-art and future potential of key biological resources, technologies, and facilities in each pilot region concerning industrial symbiosis. The data collection process was enhanced by leveraging the partners' experience from other EU projects and initiatives, as well as their connections with clusters and companies in the sector, and additional resources (e.g., scientific publications, JRC data, etc.). LGCA and CMU coordinated these activities in collaboration with sub-activity managers, providing support to regional partners in identifying and addressing data gaps. Regular online meetings and one-on-one discussions ensured the continuous updating of the work based on newly gathered data and information, maximizing the effectiveness of the activity.

The understanding of the factors enabling industrial symbiosis and their prioritization is based on the following activities:

1. **Evaluation of the regional availability of biobased raw materials:** This involves a quantitative analysis of biomass availability across the various pilot regions, focusing on both primary and secondary biomass resources. These data are essential for guiding the development and sustainability of the bioeconomy and circular value chains, thereby shaping regional economic growth and industrial symbiosis potential.
2. **Evaluation of business models:** This involves a quantitative analysis of biomass utilisation and technological development of companies and research entities that are at the forefront of producing high-value molecules derived from bio-based raw materials. Identifying the regional distribution of technological advances and business models is critical to enabling industrial symbiosis and establishing new value chains.
3. **Data harmonization and matching:** This involves integrating and standardizing the diverse datasets from the pilot regions to identify potential synergies between different industries. By harmonizing data related to biomass availability, technological capabilities, and business models, the project can effectively match complementary resources and needs across regions, facilitating the identification of viable industrial symbiosis opportunities and ensuring the efficient use of resources, thereby optimizing value chains for circularity and sustainability.
4. **Trigger dynamics for industrial symbiosis:** This involves an initial analysis by stakeholders in the different regions of the socio-economic, environmental, and regulatory factors that can accelerate

the adoption of symbiotic business models. By pinpointing these dynamics, the project can design targeted interventions to encourage cross-sectoral cooperation, drive innovation, and create resilient regional economies based on sustainable and circular principles. The initial analysis conducted in WP1 forms the basis for co-development of the bioeconomy ecosystem in workshops as part of WP3.

The D1.2 report plays a pivotal role in the SYMBIO project, as it lays the foundation for understanding and prioritizing the factors that enable industrial symbiosis across regions. By providing a comprehensive analysis of regional resources, business models, and technological advancements, this report informs the development of strategies and interventions that will drive the successful implementation of industrial symbiosis, ultimately contributing to the project's goal of creating sustainable, circular economies in Europe.

2. Regional availability of biobased raw materials

In the Regional Hub Handbook (D1.1) 12 promising products of biobased interest that represent significant or growing demand from bioeconomy stakeholders, according to specific characteristics such as price, characteristic, and accessibility were selected. The most promising biomasses were identified for each product, representing the organic raw material used for producing the 12 promising products identified. In the Regional Hub Handbook, a division between primary and secondary biomass was made, whereby primary biomass refers to the initial plant materials directly harvested from nature and secondary biomass consists of the by-products or residues left over after the primary biomass has been processed or harvested.

This section of the report aims to provide a comprehensive overview of the availability of biomasses across the various pilot regions, with a particular emphasis on both primary and secondary biomass resources. Primary biomass—such as crops and forest products—serves as the foundational raw material for the bioeconomy, and its availability is closely linked to regional agricultural productivity and land use patterns. However, secondary biomass is also critically important, including agricultural residues, forestry by-products, and waste from industrial processes. By incorporating both types of biomasses, this section highlights their collective role in maximizing resource efficiency and minimizing waste.

The regional availability of biobased raw materials is a crucial factor influencing the development and sustainability of the bioeconomy and circular value chains. Different regions possess varying capacities to produce and supply these materials influenced by a range of factors including diverse climatic conditions, agricultural practices, and the natural endowment of resources. This variability not only shapes the potential for regional economic development but also impacts the efficiency and sustainability of biobased supply chains.

Understanding the geographic distribution and accessibility of biobased raw materials is essential for identifying potential areas for investment, optimizing supply chain logistics, and promoting regional economic development.

The insights provided in this section are intended to guide stakeholders in making informed decisions about resource allocation, supply chain management, and regional development strategies within the context of the SYMBIO project.

2.1 Italy

2.1.1 Italian Biomass Availability

Italian[1] primary biomass availability reflects its rich agricultural tradition and diverse climatic zones, which contribute to a wide range of biobased raw materials. The country's favourable conditions for cultivating various crops, coupled with its extensive forestry resources, position Italy as a significant player in the bioeconomy sector. This section delves into the specific types of biomasses available across 5 different regions of Italy involved in the SYMBIO project (*Lombardy*, *Piedmont*, *Veneto*, *Emilia Romagna* and *Friuli Venezia Giulia*), examining the production capacities and regional disparities. By understanding the Italian context, stakeholders can better leverage the nation's biomass potential for sustainable development and economic growth.

[1] 'Italian' refers to the 5 Italian project regions (*Lombardy*, *Piedmont*, *Veneto*, *Emilia Romagna* and *Friuli Venezia Giulia*)

The data used in this analysis was sourced from ISTAT, the Italian National Institute of Statistics[6]. ISTAT is a public research organization that provides comprehensive and up-to-date official statistical data across various sectors to support citizens, companies, organizations and public decision-makers. All data included in this report refer to the year 2022. This choice was made to maintain consistency and comparability across all datasets.

Analysing the Italian primary biomass data is clear how the main biomasses available can contribute to the production of a wide range of biobased materials. **Table 1** shows the overall Italian cultivated area (1.961.109 hectares) with a total of the main primary biomass production volume of 22.496.763 tonnes.

Table 1 *Italian primary biomass availability (ISTAT, 2022).*

Type of biomass	Cultivated Area (Hectare)	Production Volume (Tonnes)
Barley	96.851,00	589.202,30
Soya	341.231,00	914.269,20
Rice	213.765,00	1.208.349,00
Maize	501.857,00	4.261.643,50
Wheat	379.924,00	2.233.405,60
Alfalfa	361.790,00	10.917.007,90
Rapeseed	13.886,00	42.987,20
Sugar beet	49.944,00	2.323.346,90
Oat	1.861,00	6.551,30
TOTALS	1.961.109,00	22.496.762,90

The Italian Cultivated Area and Production Volume calculated as a percentage are shown in **Figure 1**. Maize dominates the ***Cultivated Area***, occupying 26% of the total agricultural land. This is followed by wheat (19%), alfalfa (18%), soya (17%), rice (11%), barley (5%), sugar beet (3%), rapeseed (1%), and finally, oats at just 0.1% (rounded to 0% in the figure). The distribution of these crops reflects the agricultural priorities and environmental conditions of Italy, where maize, wheat, and alfalfa are particularly well-suited to the country's diverse climate and soil types. Maize, being a staple crop, is extensively cultivated for both human consumption and livestock feed, thriving in the warm, temperate regions of Italy. Wheat, a cornerstone of Italian cuisine, benefits from the Mediterranean climate, which provides ideal growing conditions. Alfalfa, a perennial legume, is valued for its high nutritional content and its role in crop rotation due to its nitrogen-fixing abilities, which enrich the soil.

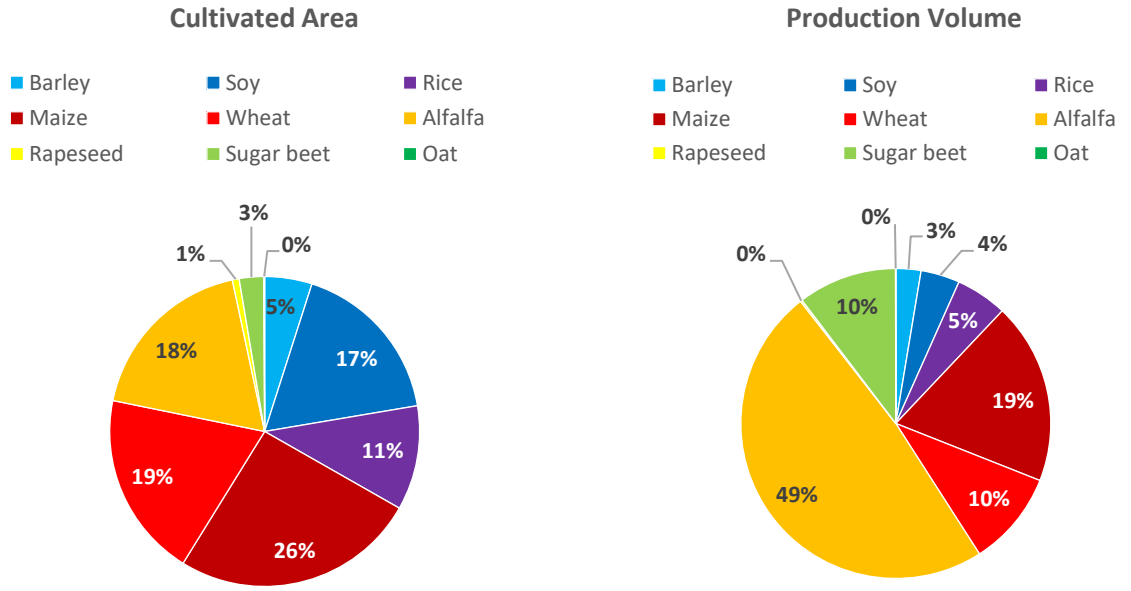

Figure 1 *Italian Cultivated Area and Production Volume percentages (ISTAT, 2022).*

Examining the ***Production Volume***, *alfalfa* emerges as the most significant contributor, accounting for 49% of the total biomass production. This dominance underscores its importance in the Italian agricultural landscape, where it is primarily grown for animal feed, but also plays a crucial role in soil health and crop rotation practices. Alfalfa's extensive root system enhances soil structure and fertility, making it an indispensable crop in sustainable farming systems. *Maize* follows with 19% of the total production volume, reflecting its dual role in both food and feed industries. *Wheat* and *sugar beet* each contribute 10% to the total production, with wheat being a vital food source and sugar beet serving as a key crop for sugar production in the country. The remaining biomass sources, including barley, soya, rice, oat, and rapeseed, collectively account for less than 10% of the total regional biomass. The limited presence of these crops is indicative of their specialized uses or niche market demands. For instance, barley is primarily grown for brewing and feed, while soya is increasingly important for both animal feed and as a protein source in human diets. Rice, although significant in specific regions like the Po Valley, is constrained by water availability and therefore occupies a smaller overall share.

This distribution of biomass availability is a direct reflection of Italy's agricultural priorities, climatic conditions, and market demands. The focus on crops like maize, wheat, and alfalfa highlights the balance

between food security, animal feed production, and sustainable agricultural practices. Additionally, the prominence of alfalfa and other leguminous crops illustrates the importance of soil health and crop diversity in maintaining the productivity and sustainability of Italy's agricultural sector.

2.1.2 Italian Biomass Distribution

Italy's diverse agricultural landscape, characterized by its varied climate zones and fertile soils, plays a significant role in the country's economy and cultural heritage. Through a comprehensive analysis of the quantitative presence of both primary and secondary biomass across various regions, it becomes evident how crucial biomass is not only to the agricultural sector but also to local industries that depend on these resources. The distribution and production volumes of different types of biomasses, ranging from staple crops like maize and wheat to specialized crops such as alfalfa and soya, directly impact food security, animal husbandry, bioenergy production, and the biobased industry in Italy and beyond.

The following analysis examines the specific types of primary and secondary biomasses prevalent in Italy, highlighting their spatial distribution, production volumes, and the underlying factors that drive these patterns. By understanding these dynamics, we gain insight into the strategic importance of biomass in supporting both traditional agricultural practices and the evolving demands of modern industry.

BARLEY

Primary Biomass

The total barley **Production Volume** (tonnes) across the five project regions in Italy amounts to 589.202 tonnes[6], with most of this biomass concentrated in the Lombardy, Veneto, and Emilia-Romagna regions (**Figure 2**). This distribution closely aligns with the **Cultivated Area** (hectare) dedicated to barley in these regions, where Veneto stands out with the highest yield. Interestingly, despite Piedmont having a cultivated area of only 4.000 hectares smaller than Veneto, its barley production is significantly lower. This notable disparity underscores the profound impact of environmental conditions, soil quality, and regional farming practices on crop yields. Factors such as climate, rainfall, soil composition, and agricultural techniques contribute to Veneto's superior productivity compared to Piedmont.

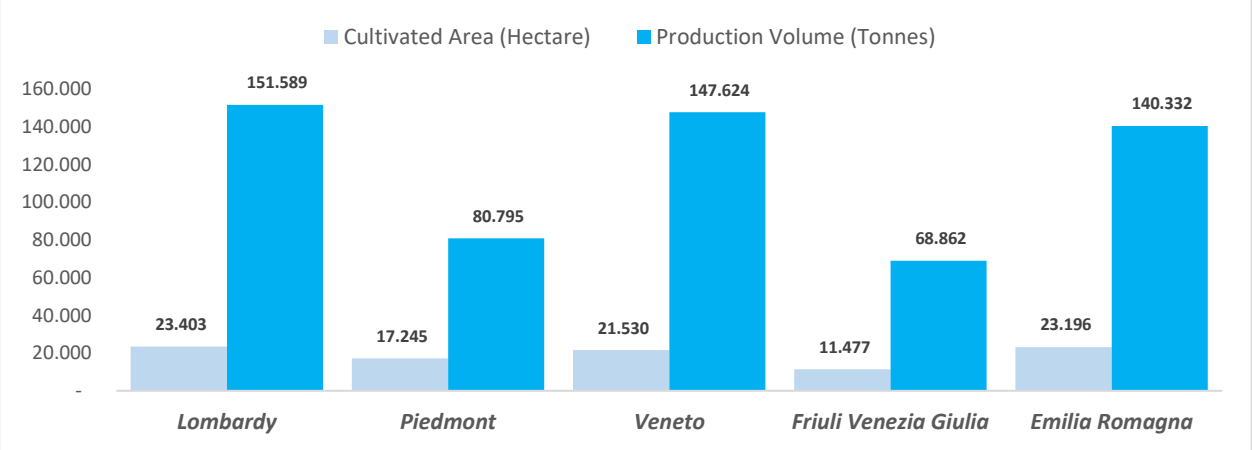

***Figure 2** Barley Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

Barley's prominence in Italy can be attributed to its versatility and resilience. It is a crop that can adapt to a wide range of environmental conditions, from fertile plains to more marginal lands, making it a preferred choice for Italian farmers. Its ability to withstand drought and thrive in different soil types has made barley

a staple in Italian agriculture for over 12.000 years. Historically, barley was one of the first domesticated grains, and its cultivation spread rapidly across Europe due to its adaptability, cementing its role in Italy's agricultural heritage.

In particular, the concentration of barley production in Lombardy, Veneto, and Emilia-Romagna can be attributed to several interrelated factors, including environmental conditions, soil quality, and agricultural practices. The climate in these regions is generally favourable for barley cultivation, with a temperate climate and adequate rainfall, especially in the Lombardy and Emilia-Romagna regions. For example, the Po Valley, which spans parts of Lombardy and Emilia-Romagna, has rich alluvial soils that provide essential nutrients for crops. In contrast, Piedmont, despite having a similar cultivated area, has less favourable soil conditions, which can significantly impact barley yields.

Additionally, barley is a highly valuable crop in Italy also from an economic point of view. Beyond its nutritional benefits as a rich source of vitamins and minerals, barley serves as a key ingredient in a variety of products. It is integral to the production of malt, which is essential for brewing beer, an industry of growing importance in regions like Veneto and Lombardy. Additionally, barley is used in producing coffee substitutes, animal feed, and certain traditional foods, further underscoring its economic significance.

The concentration of barley production in Veneto, Lombardy, and Emilia-Romagna reflects a combination of historical agricultural practices, favourable environmental conditions, and the adaptability of the crop for different applications. These factors have enabled these regions to not only maintain but also enhance their barley yields, ensuring that the crop remains a vital part of Italy's agricultural output and economic landscape.

Secondary biomass

The two main barley by-products considered in the following analysis are **barley extract** and **barley straw**. Barley extract is produced through a series of steps involving milling, mashing, filtration, and concentration of the liquid wort, while barley straw is a by-product of the harvesting process, collected and dried for various uses[7]. The barley extract Production Volume has been calculated using the specific conversion rate[8], whereas the production of barley straw for Italy is 5,8 tonnes per hectare[9].

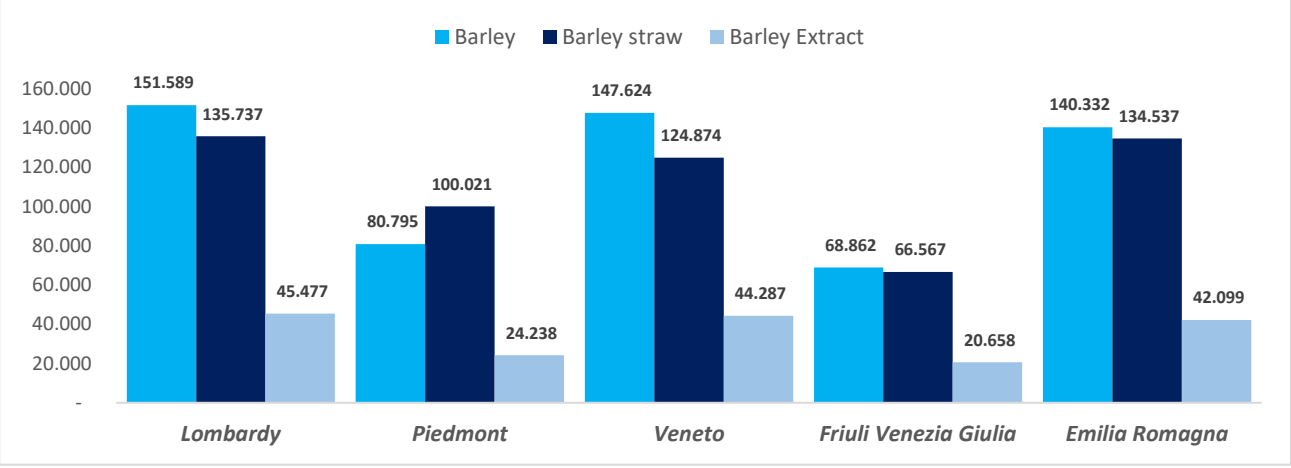

Figure 3 *Comparison of Production Volumes (tonnes) of primary biomass (barley) and secondary biomass (barley extract, barley straw) (ISTAT, 2022).*

As shown in **Figure 3**, Lombardy emerges as the leading producer in both categories, with 45.477 tonnes of barley extract and 135.737 tonnes of barley straw (for each, 24% of the respective national total), highlighting the region's pivotal role in Italy's barley production landscape. Veneto and Emilia-Romagna also make substantial contributions, each producing over 40.000 tonnes of barley extract and between 124.000 and 134.000 tonnes of barley straw, further emphasizing their importance within the Italian biomass sector. Secondary biomass responds to the trend of lower production volumes in Piedmont than in other Italian regions, as shown in the primary biomass section.

These data are critical for understanding the role of barley by-products in the broader context of biomass resources, particularly when compared to other agricultural residues such as wheat straw, maize stover, and rice husks. For instance, while wheat straw typically boasts a higher overall production volume across Italy, its distribution is often less concentrated in specific regions, which makes barley straw a more regionally significant biomass, especially in Northern Italy. Similarly, maize stover, another major agricultural residue, is predominantly produced in areas with extensive maize cultivation, such as the Po Valley. However, unlike barley straw, its production is less evenly distributed across the regions, lacking the regional balance observed in barley production.

These comparisons underscore the importance of region-specific biomass resources in Italy, particularly in the context of energy production, sustainable agriculture, and resource management.

SOYA

Primary Biomass

The overall production of soybeans across the five Italian project regions amounts to 914.269 tonnes, with Veneto, Friuli Venezia Giulia, and Lombardy emerging as the leading contributors[6].

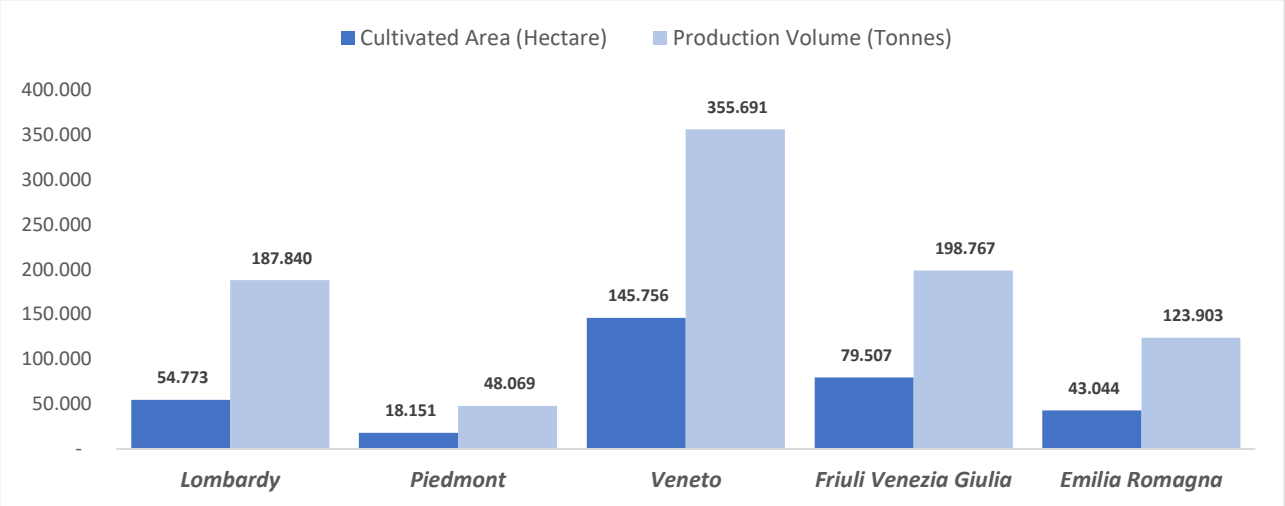

Figure 4 *Soya Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

The climate and soil conditions in these northeastern regions are well-suited for growing soybeans on a large scale. As shown in **Figure 4**, Veneto has over 145.000 hectares dedicated to soybean cultivation, the most of any Italian region, followed by Friuli Venezia Giulia with around 79.000 hectares.

The main reason for the widespread use of soybeans in Italy is the low production and high sales costs, as well as the impact of growing soybeans on cereal succession and land enrichment. Soya is already used in animal feed production, but also consumer habits have changed profoundly in recent years, with an increased preference for plant-based products[10].

This significant output can be traced back to the 1980s when Italy embarked on a strategic initiative to reduce its dependence on imported protein sources. The government and agricultural sector recognized the potential of soybeans as a key crop to meet this goal. To support this shift, processing facilities were established, and agricultural cooperatives played a vital role in helping farmers transition to soybean cultivation. These cooperatives provided the necessary resources, expertise, and market access, which were essential for the successful integration of soybean into Italian agriculture.

In Veneto, this historical push for soybean production led to a remarkable expansion of soybean acreage, transforming the region into a central hub for soybean farming in Italy[11]. The success of this initiative is evident in the current yield levels, with an average of 3 tonnes per hectare across the key regions. This yield not only reflects the effectiveness of the strategies implemented during the 1980s but also highlights the ongoing advancements in cultivation techniques and resource management that continue to drive productivity.

The robust growth observed in Veneto is further reinforced by the region's well-developed infrastructure and strong cooperative networks, which continue to support farmers and enhance the efficiency of the soybean supply chain. This supportive environment has cemented Veneto’s pivotal role in Italy’s soybean industry, ensuring that the region remains at the forefront of national production.

Looking forward, the contributions from Veneto, Friuli Venezia Giulia, and Lombardy are expected to remain central to Italy’s agricultural landscape[12]. These regions are likely to continue driving innovations in soybean cultivation, further improving yields and sustainability. As the demand for plant-based protein sources grows globally, Italy's soybean production, anchored by these key regions, will play an increasingly important role in meeting both domestic and international needs. The historical foundations laid in the 1980s, combined with the current advancements, position Italy to be a competitive player in the global soybean market, while also enhancing the sustainability and resilience of its agricultural sector.

Secondary Biomass

Soya is a crucial global crop, valued for its nutritional value and versatility. While soybeans themselves are widely recognized and consumed, the byproducts of their processing, particularly soybean meal (or cake) are less familiar to the general public, despite their significant benefits. When soybeans are processed, the primary objective is to extract oil, leaving behind a protein-rich byproduct known as soybean meal. This meal is predominantly used in animal feed, with approximately 70% of the world's soya production dedicated to this purpose, and 98% of that feed comprises soybean meal. The production of soybean meal is closely linked to soybean oil production, as 85% of global soybeans are processed for both oil, which is used for human consumption, and meal, which sustains the livestock industry[13].

Whole soybeans contain about 40% protein (meal) and 20% fat (oil) on a dry matter basis[14]. The amount of secondary biomass produced from soybeans in Italy has been calculated using the specific conversion rate[15].

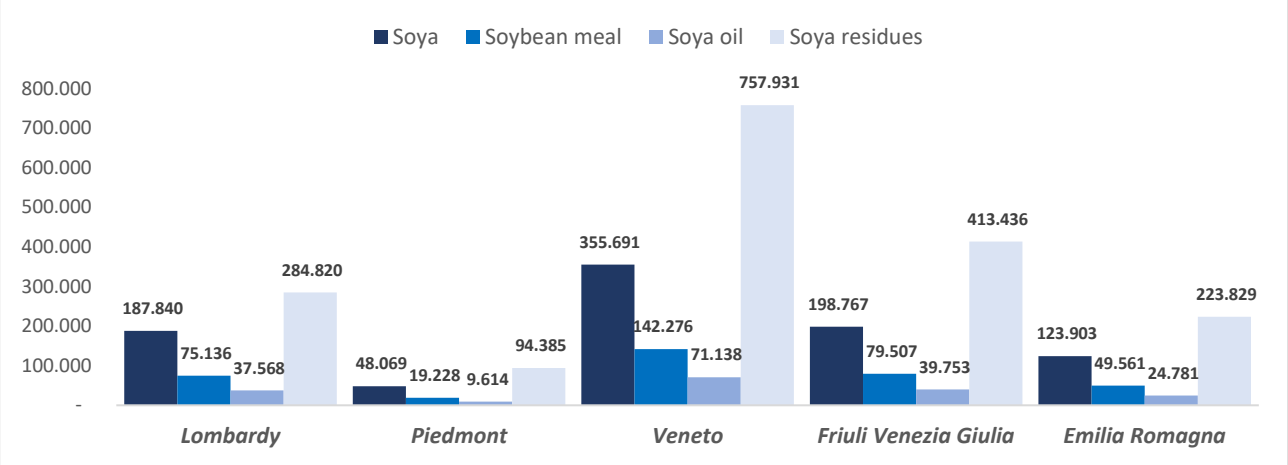

Figure 5 *Comparison of Production Volumes (tonnes) of primary biomass (soya) and secondary biomass (soybean meal, soya oil, soya straw) (ISTAT, 2022).*

In Italy, the production volumes of secondary biomasses derived from soya, which are related specifically to soybean meal, soya straw, and soya oil, exhibit notable regional disparities, with soybean meal consistently emerging as the most produced byproduct. As shown in **Figure 5**, the Veneto region stands out as the leader, producing an impressive 142.276 tonnes (39% of the national total) of **soybean meal**, followed by Friuli Venezia Giulia and Lombardy, with 79.507 tonnes (22%) and 75.136 tonnes (21%), respectively.

In contrast, the production of **soya oil**, though still significant, is markedly lower. Veneto once again leads with 71.138 tonnes (39% of the national total), while Friuli Venezia Giulia and Lombardy follow with 39.753 tonnes (22%) and 37.568 tonnes (21%), respectively. **Soya residues**, however, have the highest production volumes among the three byproducts, with Veneto producing 757.931 tonnes, Friuli Venezia Giulia 413.436 tonnes, and Lombardy 284.820 tonnes.

This analysis underscores Veneto's dominance in the production of all three categories of soya-derived biomasses, particularly soybean meal and soya oil. Several factors contribute to this trend in Italy. Veneto's leadership can be attributed to the region's favourable agricultural conditions, well-developed infrastructure, and robust agro-industrial sector, which collectively support higher production efficiency and output. Additionally, the region's strategic focus on livestock farming drives the demand for soybean meal, further boosting its production. While still contributing significantly, Friuli Venezia Giulia and Lombardy fall behind Veneto due to regional differences in agricultural priorities, land use, and industrial capacity. The relatively lower production of soya straw across all regions highlights its lesser economic significance compared to the more valuable soybean meal and oil, which are essential for both the animal feed industry and human consumption.

RICE

Primary Biomass

The total rice production across the five project regions amounts to 1.208.349 tonnes[6], with the majority concentrated in the Piedmont and Lombardy regions. These regions, located in the fertile Po Valley of northern Italy, have long been the country's leaders in rice production due to their favourable natural and historical conditions. Piedmont alone dedicates a substantial 113.456 hectares of land to rice cultivation, significantly impacting the agricultural landscape by limiting the available land for alternative crops like soya and barley. In contrast, other regions such as Emilia Romagna, Veneto, and Friuli Venezia Giulia contribute significantly less, with 4.377, 3.014, and 17 hectares dedicated to rice cultivation, respectively (**Figure 6**).

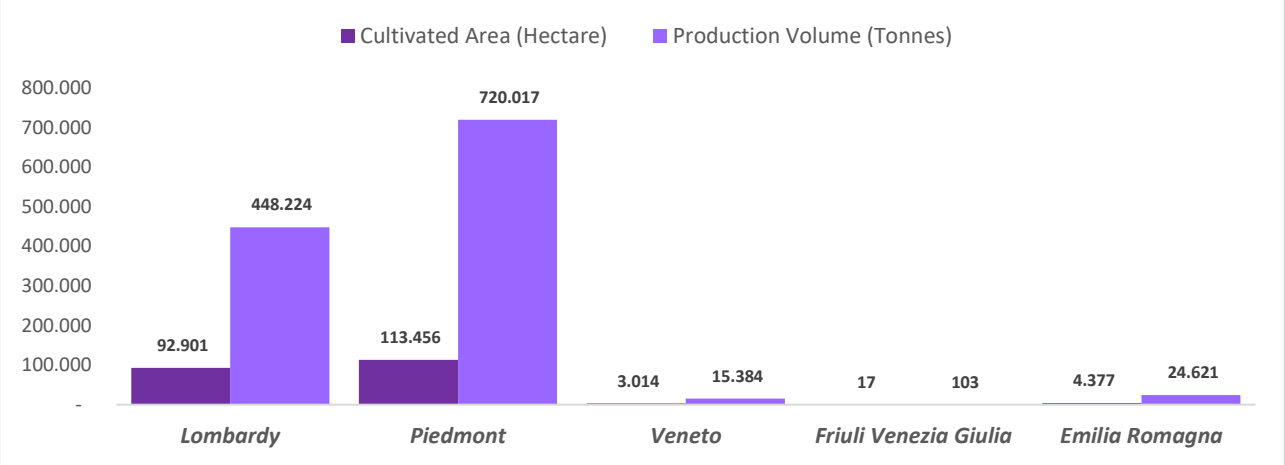

Figure 6 *Rice Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

Rice production in Friuli Venezia Giulia is notably limited compared to other Italian regions. This can be attributed to the region's small amount of arable land, as 40% of it is mountainous and suitable only for grazing. Additionally, the soil along the Tagliamento River is not ideal for rice cultivation, with the right bank being more suitable for grains and the left bank prone to waterlogging. Furthermore, rice farming requires flooded fields, but Friuli Venezia Giulia lacks the extensive irrigation systems found in Italy's major rice-producing areas. The region is also more focused on cultivating other crops, such as barley, maize, root vegetables, fruit, and other vegetables[16].

The overall rice yield[2] in these regions averages 5 to 6 tonnes per hectare, a productivity supported by the abundant water resources provided by the Po River and its tributaries. The climate, characterized by warm, humid summers, along with nutrient-rich alluvial soils, further enhances the suitability of the area for rice farming. Rice cultivation in Lombardy and Piedmont has deep historical roots, dating back to the 15th century. This long-standing tradition has been sustained by advanced irrigation systems and a robust local agricultural culture, making these regions synonymous with high-quality rice production (i.e., Arborio and Carnaroli rice)[17].

[2] The yield is calculated in tonnes per hectare across all regions.

The prominence of rice cultivation in Piedmont and Lombardy also explains the relatively lower production of soya and barley in these areas. The high value and demand for rice, both locally and internationally, make it a priority crop, reducing the emphasis on other agricultural products. Moreover, government support, coupled with ongoing research and innovation, continues to reinforce Lombardy and Piedmont's status as Italy's top rice producers, enabling them to maintain their competitive edge in the global market.

Secondary Biomass

The study focuses on two primary rice byproducts: **rice husk** and **rice straw**. The rice husk is the tough outer layer that encases the rice grain, protecting its growth. It accounts for approximately 20% of paddy rice and is produced in substantial quantities, with notable potential for use in energy production[18]. Rice straw, on the other hand, comprises the stem and leaf material left behind after rice grains are harvested. Its diverse applications include animal feed, papermaking, ethanol production, and more.

According to the specific conversion rate[19], the total production of rice husk in the studied regions is considerable, with Piedmont and Lombardy leading the way, producing 226.912 (53% of the national total) and 185.802 tonnes (43%), respectively (**Figure 7**). This distribution mirrors the overall rice production, which is heavily concentrated in these two regions due to their extensive rice-cultivated lands and favourable agricultural conditions. Similarly, the production of rice straw is dominated by Piedmont and Lombardy, yielding 567.280 (53% of the national total) and 464.505 tonnes (43%), respectively. In contrast, Veneto, Friuli Venezia Giulia, and Emilia Romagna produce significantly smaller quantities of these byproducts, reflecting their more limited rice cultivation areas.

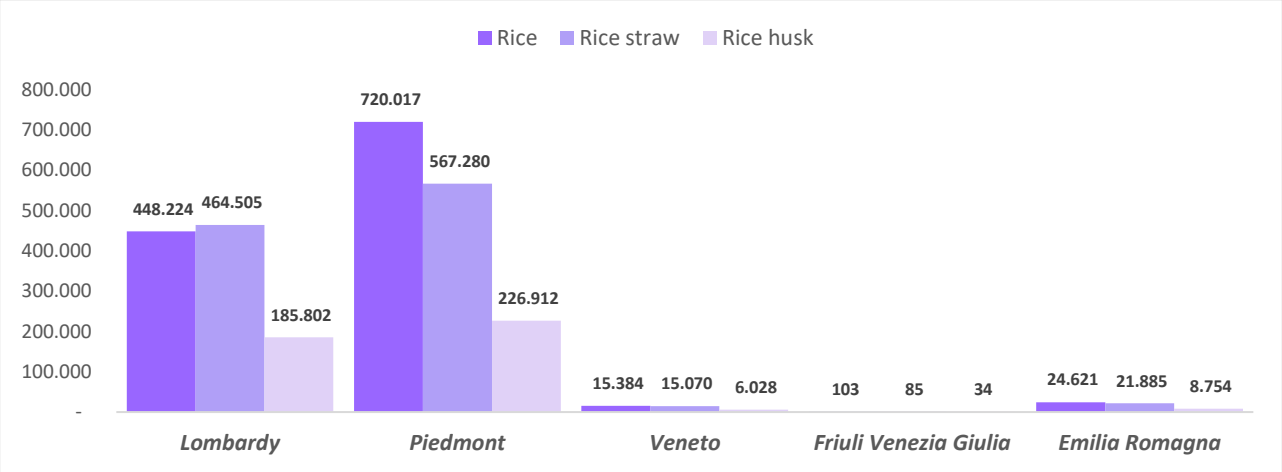

Figure 7 *Comparison of Production Volumes (tonnes) of primary biomass (rice) and secondary biomass (rice straw, rice husk) (ISTA, 2022).*

This analysis highlights the pivotal role of Lombardy and Piedmont in Italy's rice industry, not only as top producers of high-quality rice varieties but also as key contributors to the generation of substantial amounts of secondary biomass. This biomass holds significant potential for various agricultural and industrial applications, presenting opportunities for further exploration and innovation.

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Grant Agreement No 101135166

MAIZE

Primary Biomass

The total maize production across the five project regions reaches an impressive 4.261.644 tonnes[6], with the majority concentrated in the Piedmont, Lombardy, and Veneto regions, as shown in **Figure 8**. This concentration is far from coincidental; it is the result of a confluence of factors that make these areas particularly ideal for maize cultivation.

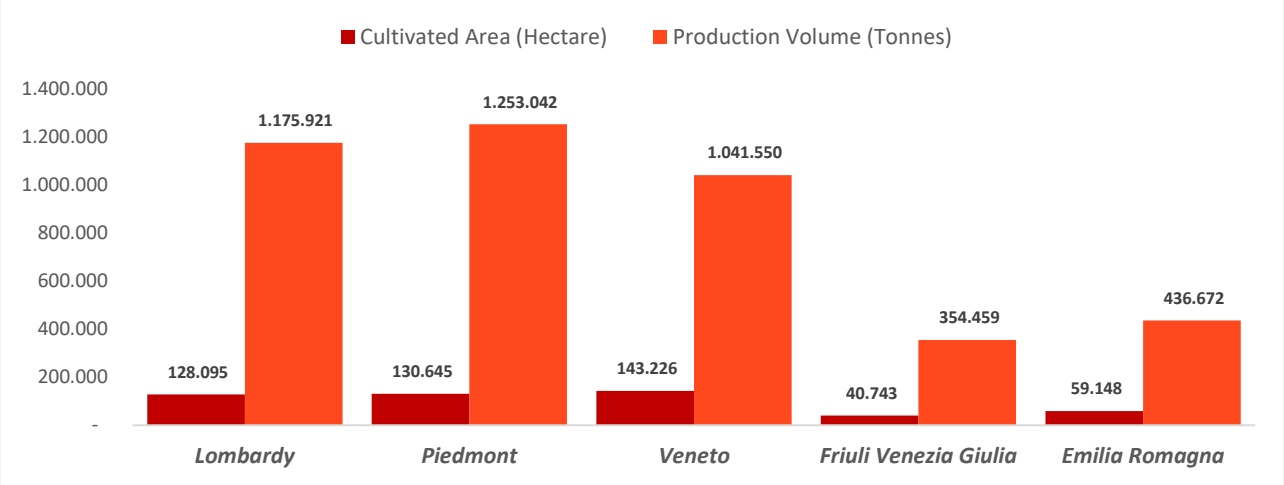

Figure 8 *Maize Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

Piedmont, Lombardy, and Veneto have extensive areas dedicated to agriculture, with large tracts of land specifically allocated to maize. The vast agricultural land, combined with favourable environmental conditions such as fertile soils, ample water resources, and a climate conducive to maize growth, provides a solid foundation for high yields. The regions benefit from advanced agricultural practices, including precision farming, efficient irrigation systems, and the use of high-quality seeds, all of which contribute to maximizing productivity. Moreover, the strong economic infrastructure in these regions supports maize production on a large scale. Well-established supply chains, access to markets, and a robust agro-industrial sector ensure that maize farming is not only viable but highly profitable[20,21]. Additionally, the presence of research institutions and government support further bolsters the efficiency and sustainability of maize cultivation in these regions.

Together, these factors create an environment where maize farming not only thrives but does so at a level that positions Piedmont, Lombardy, and Veneto as the dominant forces in maize production within the project area. The synergy between natural resources, technological advancement, and economic strength makes these regions the powerhouses of maize production in Italy, driving both the quantity and quality of the output. This trend is a clear reflection of the strategic advantages these regions possess, enabling them to lead in one of the most important agricultural sectors in the country.

Secondary Biomass

The study examines a combination of secondary maize residues: stover and straw. These byproducts are significant in terms of biomass production, with potential applications in energy generation, animal feed, and biofuel production. The production of these residues is notably high in regions like Veneto, Piedmont, and Lombardy which leads with 1.274.711, 1.162.741 and 1.140.046 tonnes respectively. Friuli Venezia Giulia and Emilia Romagna also contribute significantly, producing 362.613 and 526.417 tonnes,

respectively. This could be due to regional differences in agricultural practices or maize varieties that produce more biomass. Lombardy, Veneto and Piedmont also show a strong correlation between maize production and residue generation, reflecting their efficient harvesting and processing techniques. In Friuli Venezia Giulia and Emilia Romagna, the production of maize and residues is significantly lower, likely due to smaller cultivated areas or less favourable growing conditions. However, the relatively high residue output in these regions suggests a focus on maximizing biomass for secondary uses such as bioenergy or livestock feed, even if maize grain production is not as high. Overall, these numbers highlight the regional variations in maize cultivation practices and their impact on both grain and residue production.

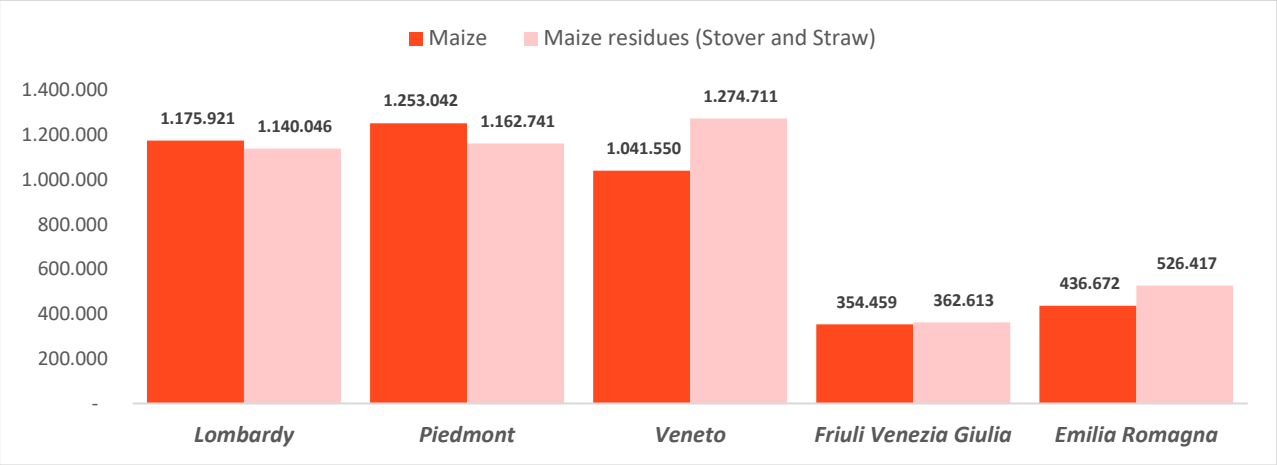

Figure 9 *Comparison of Production Volumes (tonnes) of primary biomass (maize) and secondary biomass (maize residues) (ISTAT, 2022).*

WHEAT

Primary Biomass

The total wheat production across the five project regions amounts to 2.233.406 tonnes[6]. As illustrated in **Figure 10**, most of this production is concentrated in the Emilia-Romagna and Veneto regions. This distribution aligns closely with the amount of land dedicated to wheat cultivation in each region, with Veneto achieving the highest yield at 7 tonnes per hectare.

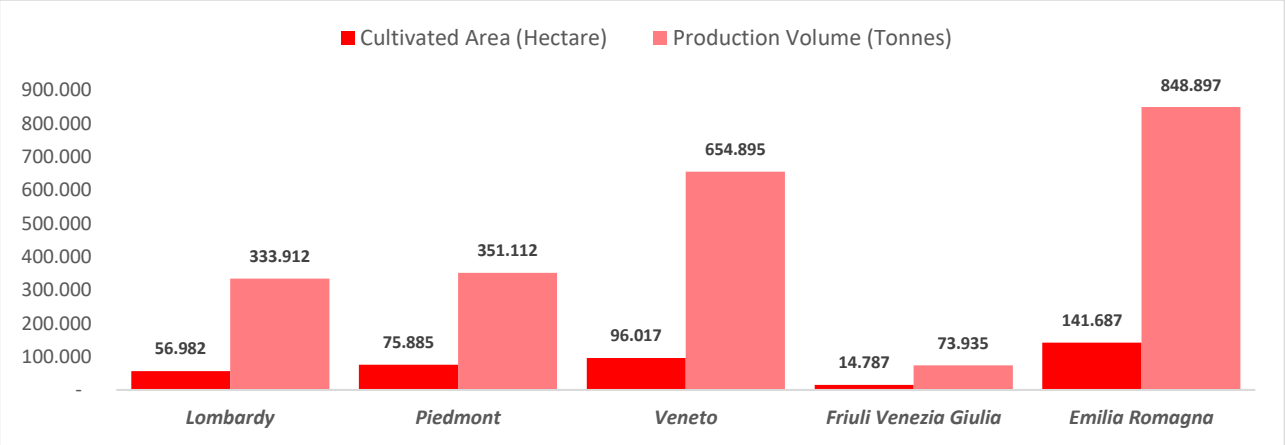

Figure 10 *Wheat Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

Emilia-Romagna's exceptional suitability for wheat production is largely due to its rich alluvial soils, which are primarily composed of fine, dense silt deposits originating from the Alps and Apennines. These deposits have formed a deep, fertile layer with high organic matter content, creating an ideal environment for wheat cultivation. The region's diverse soil types, including clay and loam, offer excellent drainage and nutrient retention, both critical factors for successful wheat growth. Moreover, the soil in Emilia-Romagna maintains a balanced pH and is abundant in essential nutrients like nitrogen and phosphorus, which contribute to high yields and quality grain[22].

The region also benefits from a favourable climate, with adequate rainfall and around one-third of its farmland being irrigated. This ensures a consistent water supply during dry periods, further supporting wheat production. Additionally, the widespread adoption of sustainable farming practices, such as crop rotation and integrated pest management, helps maintain soil health and agricultural productivity over time[23].

This combination of fertile soils, favourable climate, and advanced agricultural practices underpins Emilia-Romagna and Veneto's leading roles in Italy's wheat production, ensuring both high yields and superior grain quality.

Secondary Biomass

Wheat straw, the secondary biomass considered in this study, is the stem and leaf material that remains after wheat grains have been harvested. It is a byproduct of wheat cultivation and is produced in large quantities globally.

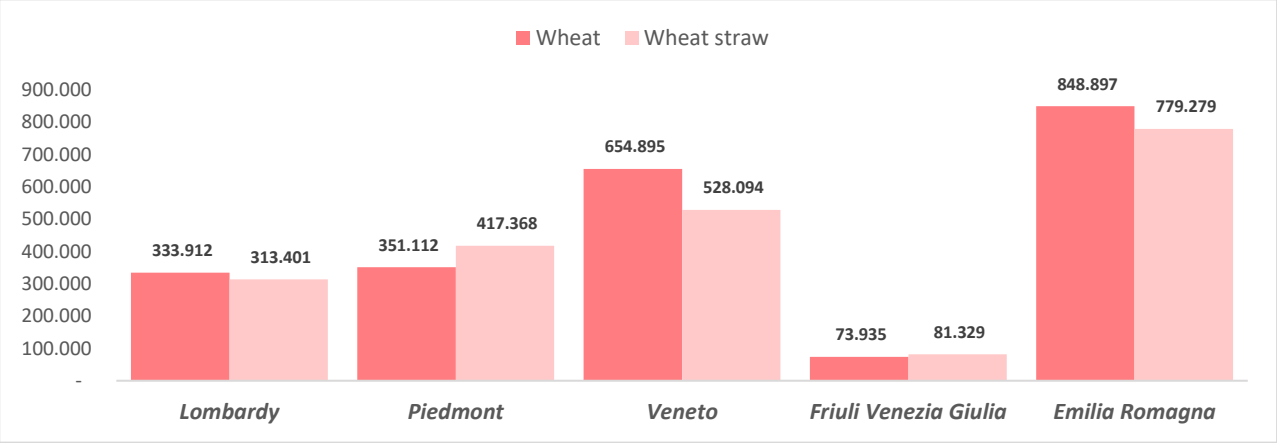

Figure 11 *Comparison of Production Volumes (Tonnes) of primary biomass (wheat) and secondary biomass (wheat straw) (ISTAT, 2022).*

From 1 hectare of Wheatfield, 5,5 tonnes of wheat straw is obtained[24]. The total production of wheat straw in Italy is equal to 2.119.469 tonnes. In line with what was highlighted in the previous paragraph, Veneto and Emilia Romagna lead with significant production of wheat straw, equivalent to 528.094 tonnes (25% of the national total) and 779.279 tonnes (37%), respectively (**Figure 11**). Piedmont also contributes notably with 417.368 tonnes (20%), while Lombardy and Friuli Venezia show lower volumes at 313.401 tonnes (15%) and 81.329 tonnes (4%), respectively. These differences are likely due to the varying extents of agricultural land dedicated to wheat cultivation in these regions and their different climatic conditions favouring wheat growth.

ALFALFA

Primary Biomass

The total alfalfa production across the five project regions amounts to 10.917.008 tonnes[6]. As indicated in **Figure 12**, most of this production (69%) takes place in Emilia-Romagna. While this distribution aligns with the amount of land dedicated to alfalfa cultivation in each region, it's worth noting that the highest yield per hectare is found in Lombardy, with an impressive 42.14 tonnes/hectare, followed by Emilia-Romagna at 30 tonnes/hectare.

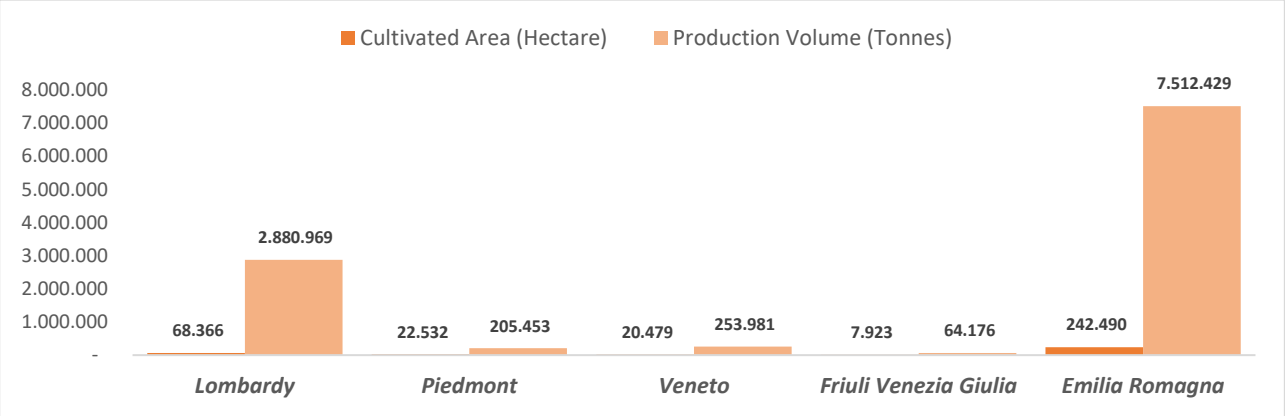

***Figure 12** Alfalfa Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

Emilia-Romagna stands out as a major hub for alfalfa production due to its unique combination of optimal environmental conditions, advanced agricultural practices, and deep regional expertise. The region's climate, characterized by abundant sunshine and adequate rainfall, creates an ideal environment for alfalfa growth. The soil, ranging from clay loams to limestone, provides the deep, permeable, and moisture-retentive qualities essential for the crop's development. These natural advantages are further enhanced by Emilia-Romagna's strong dairy industry, which depends heavily on alfalfa as a high-protein forage crop to improve forage intake and boost milk protein output in dairy cows.

The significance of alfalfa in Emilia-Romagna is reinforced by the region's long history of cultivation, which has fostered a wealth of knowledge and expertise, making it one of the leading producers in both Italy and Europe. With 141.687 hectares dedicated to alfalfa, the region benefits from large-scale production that allows for efficiencies and specialization, further strengthening its position in the market. Additionally, the availability of disease-resistant alfalfa varieties and the use of advanced farming equipment have streamlined production, making cultivation more accessible and profitable.

This combination of a favourable climate, strategic importance to the dairy industry, and established agricultural expertise has positioned Emilia-Romagna as a leader in alfalfa production. Its success in this sector is a testament to the region's ability to leverage its natural and economic advantages, driving widespread adoption and sustained growth in alfalfa cultivation.

Secondary Biomass

Alfalfa fibre, a nutrient-rich feed widely used for horses, poultry, and other livestock, is highly valued for its superior nutritional profile. Packed with high protein content, digestible fibre, and essential minerals like calcium, alfalfa fibre plays a critical role in promoting muscle development, providing sustained energy, and supporting bone health in animals. Because of its low sugar and starch levels, it is particularly beneficial for

animals with metabolic issues, making it a great feed for maintaining overall nutrition and improving the health and performance of various livestock.

Considering the specific conversion rate[25], **Figure 13** illustrates the significant production volumes of alfalfa fibre across different Italian regions, with Emilia-Romagna emerging as the clear leader, producing 3.004.972 tonnes (69% of the total production). Lombardy follows with 1.152.388 tonnes (26%), while regions such as Piedmont, Veneto, and Friuli Venezia Giulia contribute substantially less, with production generally hovering around or below 100.000 tonnes (5%). The total production of alfalfa fibre is equal to 4.366.803 tonnes.

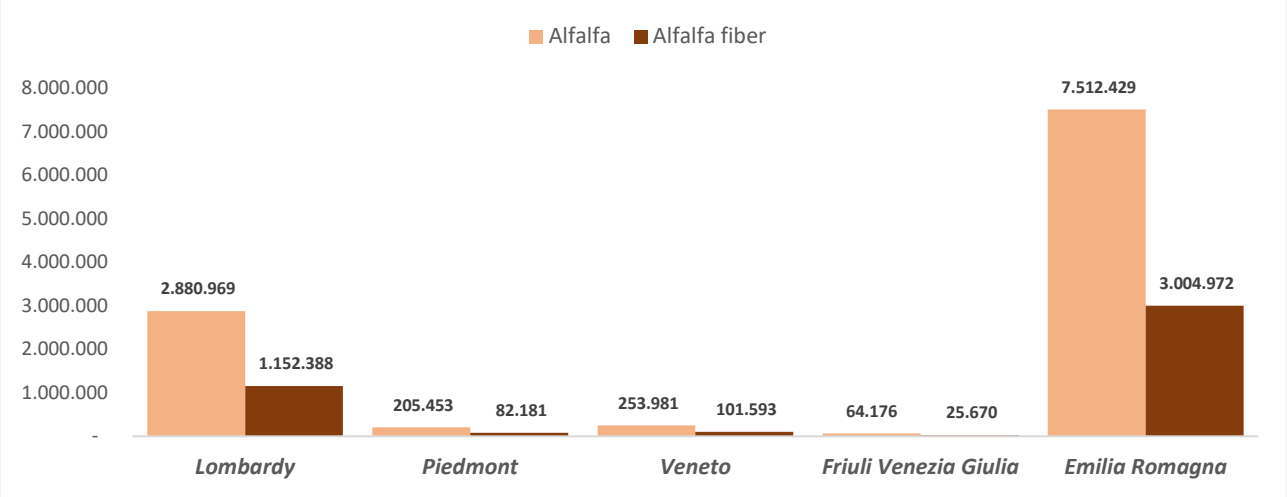

Figure 13 *Comparison of Production Volumes (tonnes) of primary biomass (alfalfa) and secondary biomass (alfalfa fibre) (ISTAT, 2022).*

This regional variation in alfalfa fibre production is closely linked to the agricultural priorities and demands within these areas. In Emilia-Romagna and Lombardy, alfalfa cultivation is particularly prevalent due to the high local demand for livestock feed, driven by the regions' extensive dairy and livestock industries. These regions prioritize alfalfa as a key crop because of its critical role in sustaining their livestock sectors, which require consistent, high-quality feed to maintain productivity and health.

The prominence of alfalfa fibre production in Emilia-Romagna and Lombardy also reflects their favourable growing conditions, advanced agricultural practices, and well-established supply chains, all of which support large-scale alfalfa farming[26]. Additionally, the strong tradition of livestock farming in these regions further reinforces the focus on alfalfa cultivation, as it directly meets the needs of their thriving dairy and meat industries.

Finally, Alfalfa cultivation is crucial for dairy cattle feeding in the Parmigiano-Reggiano cheese production area, located precisely in Emilia Romagna[27].

This trend underscores how regional agricultural strategies are shaped by local economic demands, environmental conditions, and historical practices, leading to the concentrated production of alfalfa fibre in these leading regions.

RAPESEED

Primary Biomass

Rapeseed production in Italy is driven by a combination of economic, environmental, and agricultural factors, making it a valuable crop within the country's agricultural landscape. Economically, the increasing demand for biofuels, particularly biodiesel, has positioned rapeseed as a crucial crop due to its high oil content[28]. The Italian government's strong support for biofuel production, in line with national renewable energy targets, ensures a stable and profitable market for rapeseed. This stability provides Italian farmers with a reliable income source, as they can benefit not only from oil production but also from rapeseed meal, a byproduct that is in high demand for animal feed[29]. The ability to generate revenue from multiple streams enhances the crop's economic appeal.

From an environmental perspective, rapeseed cultivation plays a significant role in promoting sustainable agriculture[30]. The crop's natural ability to fix nitrogen in the soil reduces the need for chemical fertilizers, thereby improving soil health and contributing to long-term agricultural sustainability. Additionally, rapeseed-based biofuels have a lower carbon footprint compared to traditional fossil fuels[31], aligning with Italy's broader goals of reducing greenhouse gas emissions and combating climate change.

Agriculturally, rapeseed is a beneficial component in crop rotation systems[32]. Its inclusion helps break pest and disease cycles, enhances soil structure, and boosts overall farm productivity. The crop's adaptability to the potassium-rich soils found in many parts of Italy further underscores its suitability for cultivation across the country[30].

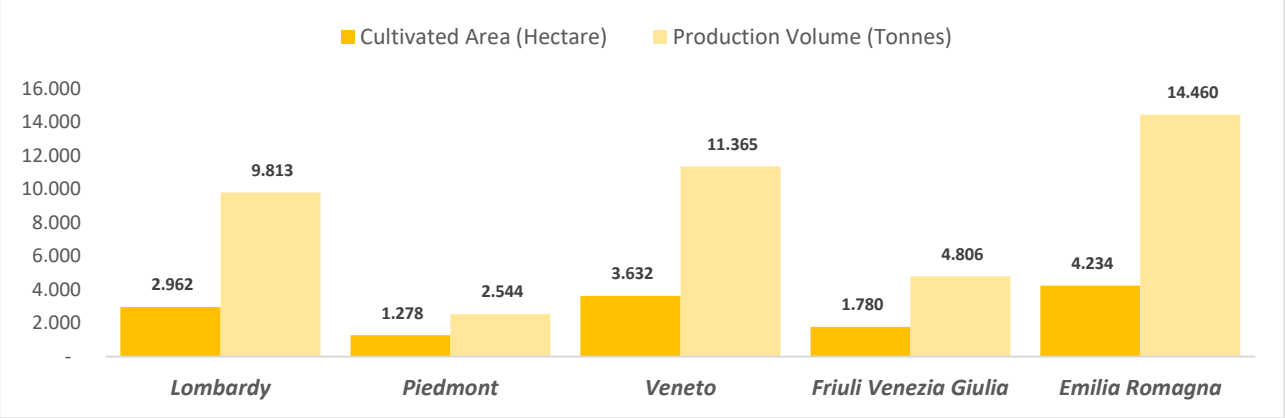

Figure 14 *Rapeseed Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

Despite these numerous advantages, total rapeseed production across the five key project regions remains relatively modest, amounting to only 42.987 tonnes[6]. Most of this production (69%) is concentrated in Emilia-Romagna, Veneto, and Lombardy (for an amount of 14.460, 11.365, and 9.813 tonnes, respectively) (**Figure 14**). This distribution reflects the regions' dedicated rapeseed cultivation areas, which achieve an overall yield of approximately 3 tonnes per hectare.

The pattern of rapeseed production in Italy highlights the crop's strategic importance in regions where economic, environmental, and agricultural conditions are most favourable. Emilia-Romagna, Veneto, and Lombardy, with their supportive climates, advanced farming techniques, and strong market demand, lead the way in rapeseed cultivation, underscoring the crop's potential as both a renewable energy source and a cornerstone of sustainable farming practices in Italy.

Secondary Biomass

Figure 15 highlights the production volumes of **rapeseed oil** across various regions in Italy, with Emilia-Romagna emerging as the leading producer at 2.892 tonnes. Veneto follows with 2.273 tonnes, and Lombardy with 1.963 tonnes. In contrast, Piedmont and Friuli Venezia Giulia contribute significantly smaller amounts, producing just 509 and 961 tonnes, respectively.

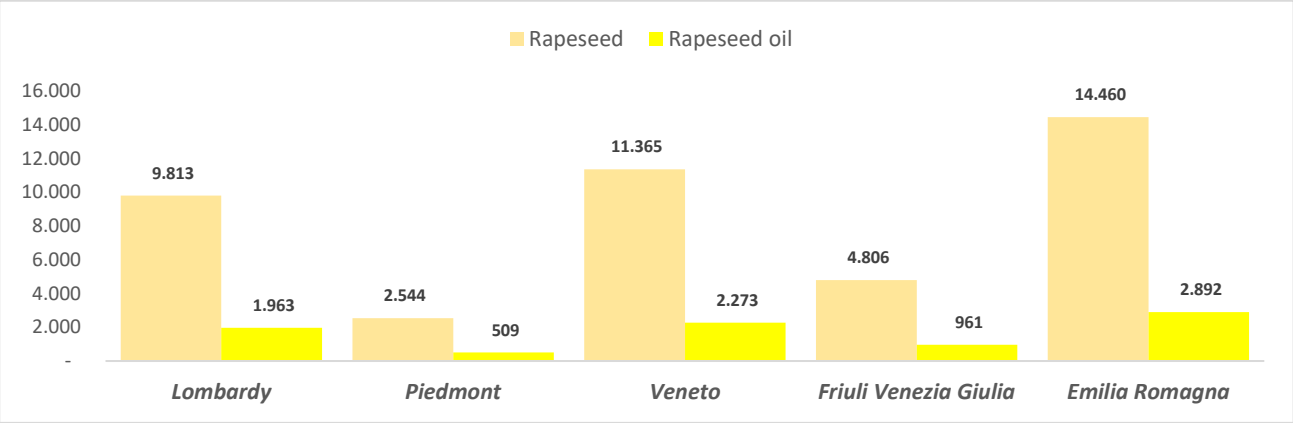

***Figure 15** Comparison of Production Volumes (tonnes) of primary biomass (rapeseed) and secondary biomass (rapeseed oil) (ISTAT, 2022).*

The lower production volumes of rapeseed oil may reflect the crop's lesser prominence in these regions compared to wheat and alfalfa, influenced by regional demand, soil suitability, and agricultural practices.

SUGAR BEET

Primary Biomass

The total sugar beet production across the five project regions amounts to 2.323.347 tonnes[6], with the bulk of this output concentrated in Friuli Venezia Giulia, Emilia-Romagna, and Veneto. Notably, Friuli Venezia Giulia alone contributes a remarkable 53% of the overall production (**Figure 16**), highlighting its pivotal role in the sugar beet industry.

This dominance is the result of several critical factors that have established Friuli Venezia Giulia as a leader in sugar beet cultivation. Historically, Friuli Venezia Giulia has been engaged in sugar beet farming for generations, fostering a rich agricultural heritage and deep-seated expertise. This longstanding tradition has led to the development of a robust agricultural infrastructure and a reservoir of specialized knowledge that ensures consistently high yields, currently averaging 50 tonnes per hectare. Additionally, Friuli Venezia Giulia benefits from the continued operation of sugar processing facilities, a significant advantage at a time when many other Italian regions have seen a decline in such factories. These facilities not only create a reliable local market for sugar beet but also minimize transportation costs, making beet farming more economically viable and attractive for local producers.

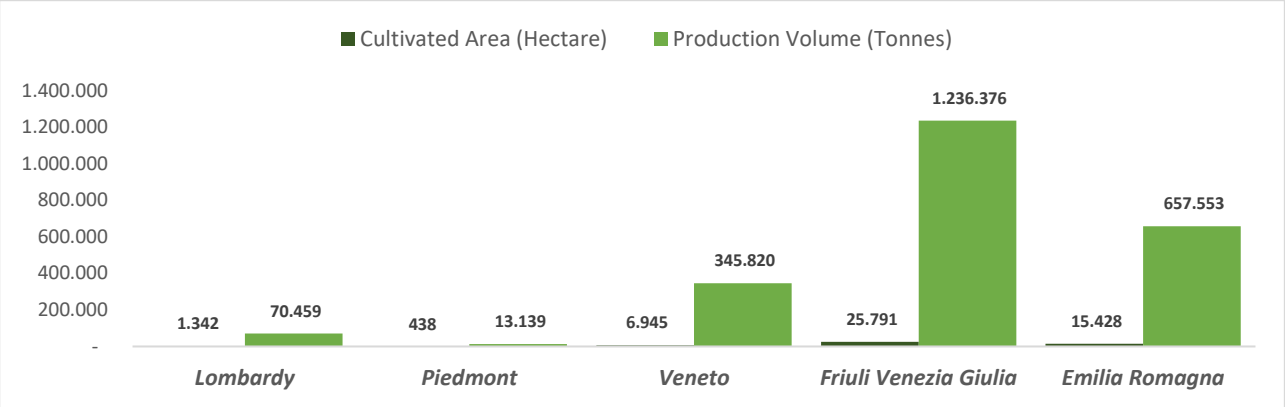

Figure 16 *Sugar beet Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

The region's success is further enhanced by the increasing market demand for sugar beet, driven by the growing interest in bioethanol and other bioproducts. This demand aligns with the broader shift towards sustainable agricultural practices and the circular economy, positioning sugar beet as a profitable and environmentally friendly crop. Agricultural cooperatives, such as COPROB, also play a crucial role in supporting local farmers through collective marketing, resource sharing, and technical assistance, enhancing both production efficiency and profitability[33].

Collectively, these factors—historical expertise, strategic infrastructure, market demand, and cooperative support—have solidified Friuli Venezia Giulia's leadership in sugar beet production within the project regions, making it a cornerstone of the local agricultural economy.

Secondary Biomass

Secondary biomasses were not considered for sugar beet.

OAT

Primary Biomass

The total oat production across the five project regions is relatively modest, totalling just 6.551 tonnes[6]. Most of this production is concentrated in Piedmont and Lombardy, where more extensive cultivated areas are dedicated to this crop (**Figure 17**). This geographic distribution underscores the regional focus on oat cultivation, with yields[3] averaging around 3-4 tonnes per hectare.

Oat production in Italy is driven primarily by favourable climatic conditions and agricultural practices that support the crop's growth. In particular, the temperate climates of Northern Italy, combined with the regions' well-drained soils, create an optimal environment for cultivating oats. While the total output remains small compared to other crops, the successful yield in these regions reflects the efficiency and expertise of local farming practices. Interestingly, oats also thrive in other regions of Central and Southern Italy, where the climate and soil conditions are similarly well-suited to this crop.

In the context of the five project regions, the relatively modest production levels highlight a focus on other, more dominant crops, such as wheat, maize, or alfalfa, which occupy a larger share of the agricultural landscape.

[3] The yield is calculated in tonnes per hectare across all regions.

Despite the limited production volume, the efficiency and focus on oat farming in Piedmont and Lombardy illustrate the significance of localized agricultural practices and the critical role that regional climate plays in determining crop viability and success. This suggests that, although oats may not be a primary crop in these regions, they remain an important component of the agricultural diversity and sustainability of the local farming systems.

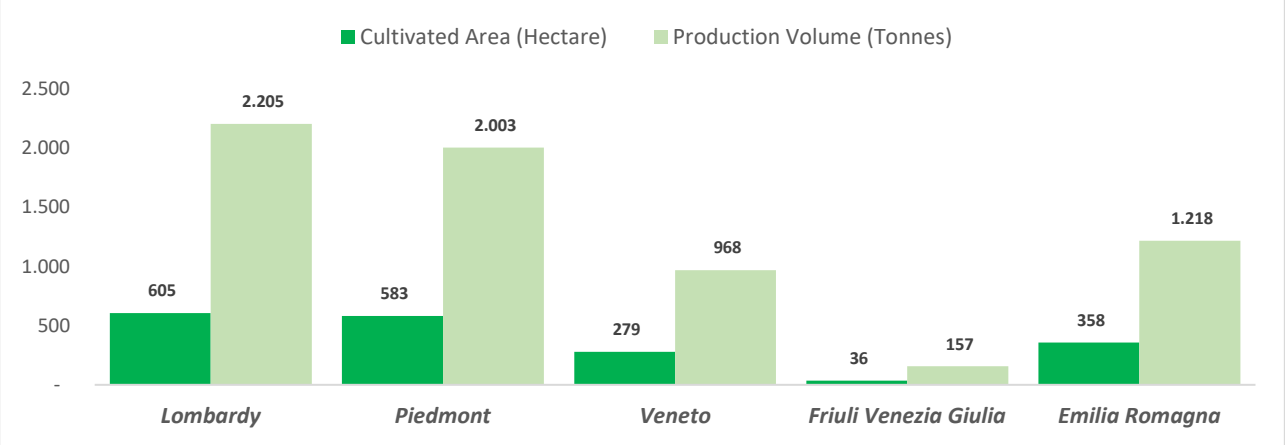

Figure 17 *Oat Cultivated Area (hectare) and Production Volume (tonnes) in each Italian region (ISTAT, 2022).*

Secondary Biomass

Secondary biomasses were not considered for oat.

INDUSTRIAL WOOD

Primary Biomass

The industrial wood biomass production across the five regions—Lombardy, Piedmont, Veneto, Friuli Venezia Giulia, and Emilia-Romagna—shows considerable variation in volume, reflecting regional differences in forest resources, industry infrastructure, and demand for wood-based products.

Based on the latest wood biomass data from ISTAT[6], the total production of industrial roundwood and wood fuel—including wood for charcoal—amounts to approximately 2.326.916 tonnes. While the most recent wood biomass overall data for Italy are from 2015, the figures specific to Friuli Venezia Giulia are from 2013, as these are more complete and allow for better comparison with the other regions.

Figure 18 shows that Lombardy has extensive forested areas and a robust wood industry, emerging as the leading producer with 1.646.133 tonnes. Emilia Romagna follows with 300.463 tonnes, benefiting from its active timber sector. Piedmont produces 200.337 tonnes, driven by a combination of forest resources and regional demand for biomass. Veneto, although contributing a smaller amount of 174.825 tonnes, still plays a significant role in the region's wood biomass supply.

Despite its smaller geographic size, Friuli Venezia Giulia manages to produce 29.405 tonnes, reflecting its efficient use of forest resources.

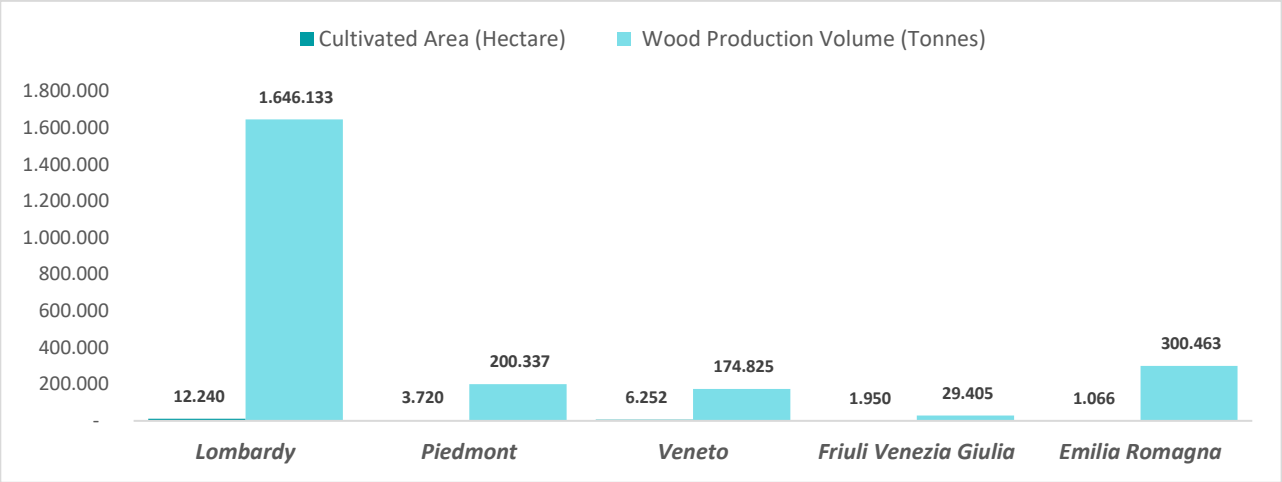

Figure 18 *Wood Cultivated Area (Hectare) and Production Volume (Tonnes) in each Italian region (ISTAT, 2022).*

The differences in production levels across these regions are influenced by several factors, including the extent and management of forested areas, the local demand for industrial wood and wood fuel, and the strength of the regional wood processing industries. Effective forest management practices, particularly in regions like Lombardy and Emilia-Romagna, have helped maintain sustainable wood production while meeting industrial needs. Additionally, the arbitrary conversion factor used to estimate these volumes assumes that a cubic meter of firewood weighs 1,38 tonnes, the value was chosen for consistency in reporting[34].

Overall, this data highlights the variability in wood biomass production across the five regions, shaped by a combination of natural resources, economic factors, and regional industrial practices. The significant output from Lombardy underscores the region's role as a key player in Italy's wood biomass industry.

Secondary Biomass

Secondary biomass, primarily consisting of **wood residues** generated from industrial roundwood processing and forest management activities, exhibits notable variability across the five Italian regions.

As shown in **Figure 19**, Lombardy—with its significant primary biomass output—unsurprisingly leads in secondary biomass generation, producing approximately 50.650 tonnes of wood residues. Piedmont follows closely with 41.332 tonnes, supported by its well-established forestry sector. Veneto and Emilia-Romagna contribute 14.556 tonnes and 14.841 tonnes, respectively, reflecting their active, albeit less extensive, wood industries. Friuli Venezia Giulia, with the smallest primary biomass output, generates the least secondary biomass at 444 tonnes. Despite its modest contribution, these wood residues play a crucial role in the biomass supply chain, offering the potential for energy production, waste reduction, and advancing the circular economy.

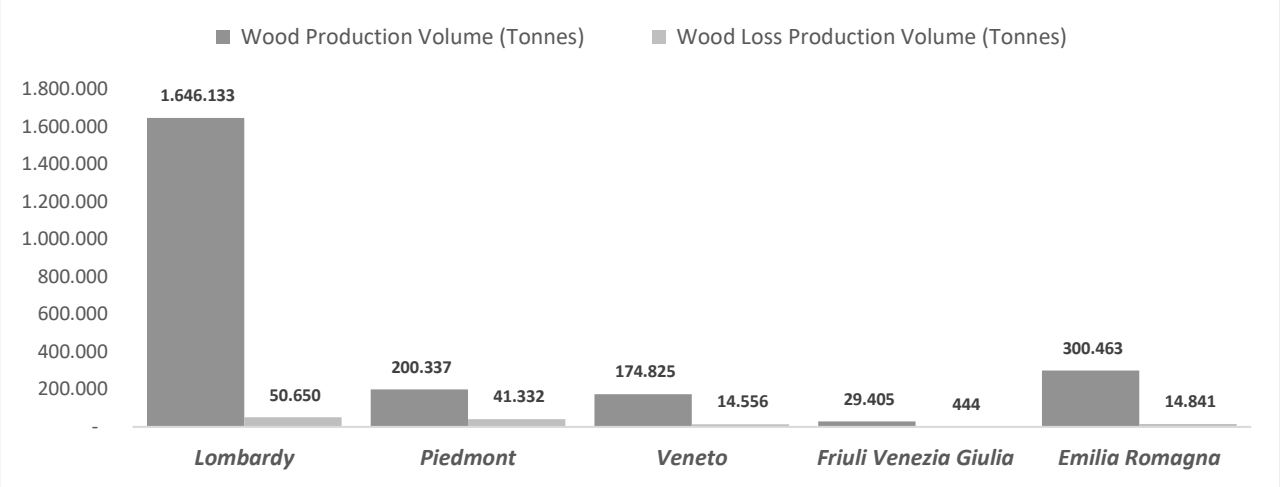

Figure 19 *Comparison of Production Volumes (tonnes) of primary biomass (wood) and secondary biomass (wood residues) (ISTAT, 2022).*

The regional disparities in secondary biomass volumes underscore the significance of efficient forest management and processing practices in maximizing resource utilization and minimizing environmental impact. In Lombardy and Piedmont, where the industrial base is strong, particularly in manufacturing and furniture production, the demand for industrial roundwood is higher. However, the fragmented nature of the supply chain in these regions—often reliant on non-domestic timber—leads to inefficiencies and increased processing losses. This situation is further exacerbated by historical events like the Vaia storm in 2018, which caused extensive forest damage, particularly in Lombardy and Piedmont, significantly contributing to wood losses.

In contrast, Veneto and Friuli Venezia Giulia have embraced more sustainable forest management practices, characterized by better planning, selective harvesting techniques, and a stronger emphasis on ecological health. This focus on sustainability, coupled with a market orientation toward certified practices, has resulted in lower processing losses and healthier forest ecosystems. Additionally, the more stable forest composition in these regions has allowed for a more reliable wood supply, minimizing the impact of external factors and historical challenges.

In conclusion, the differences in industrial roundwood processing and forest wood losses between regions like Lombardy and Piedmont, compared to Veneto and Friuli Venezia Giulia, highlight the complex interplay between economic structures, historical contexts, and forest management practices. While Lombardy and Piedmont face challenges related to supply chain inefficiencies and historical disruptions, Veneto and Friuli Venezia Giulia benefit from their commitment to sustainable practices, resulting in lower wood losses and a more balanced approach to biomass production[35,36].

OTHER INDUSTRIAL BYPRODUCTS

Obtaining precise production values for specific types of biomasses in each Italian region was challenging. However, we have compiled general data on the production volumes of various biomasses across Italy, including **Whey Protein Hydrolysate**, **Municipal Solid Waste (MSW)**, **Animal Fats**, **Waste Cooking Oil (WCO)**, and **Poplar Sawdust**. Among these, Municipal Solid Waste (MSW) stands out as the most significant, as illustrated in **Figure 20**.

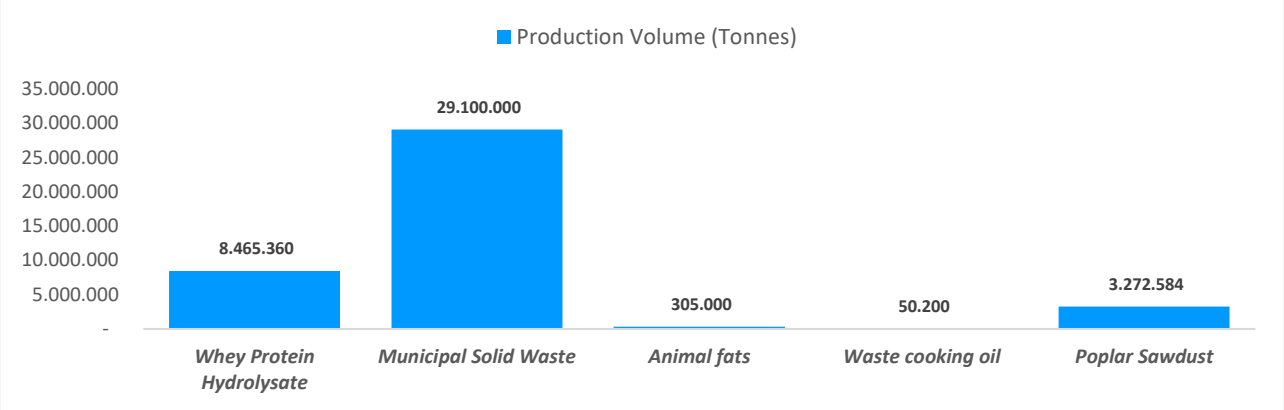

Figure 20 *Comparison of Production Volumes (tonnes) of Whey Protein Hydrolysate, Municipal Solid Waste, Animal fats, Waste cooking oil and Poplar sawdust (ISTAT, 2020).*

MSW is a substantial waste stream generated by households and offers considerable potential as a source of lignocellulosic biomass. According to ISPRA Ambiente, Italy produced over 29 million tonnes of MSW in 2022[37]. Whey Protein Hydrolysate is another widely available biomass. According to ISTAT, Italy produced around 8.465.360 tonnes of this by-product in 2022[6], underscoring its significance within the dairy industry. Poplar sawdust, a by-product of the wood manufacturing sector, reached a production volume of around 3.272.584 tonnes in 2022[6], further highlighting its availability as a biomass source. Although produced in smaller quantities, Waste Cooking Oil and Animal Fats also represent viable biomass resources, with a production volume of 50.200 tonnes and 305.000 tonnes, respectively, in 2022[6]. Despite their relatively lower volumes, these materials play a crucial role in various industrial applications, particularly in the production of biofuels and other sustainable products.

The diverse range of biomass types and their respective production volumes underscore the potential for these resources to contribute to Italy's renewable energy goals and circular economy.

2.1.3 Italian Biomass Final Overview

The comprehensive analysis conducted underscores the crucial role that primary biomass plays in Italy's agriculture and industry. Primarily cultivated for food and feed, these biomasses are the backbone of the agricultural sector. However, not all the produced biomass is utilized as originally intended. A substantial portion remains unused or is converted into secondary biomasses. These secondary biomasses, often perceived as lower in value due to their diminished utility in their original form, possess significant untapped potential.

Through advanced technological processes, these secondary biomasses can be transformed into high-value by-products such as polylactic acid (PLA), lactic acid, succinic acid, acetic acid, adipic acid, polyhydroxyalkanoates (PHAs), lysine, glutamic acid, 1,3-propanediol, furfural, and sorbitol. These by-products are essential for various industries, including pharmaceuticals, bioplastics, and food additives,

demonstrating the importance of revalorizing secondary biomasses. This revalorization process not only mitigates waste but also opens new avenues for economic growth by creating new value chains and supporting sustainable industrial practices.

To maximize the benefits of this approach, it is vital to start by assessing the regional availability of primary biomasses and the secondary biomasses they generate. By identifying and optimizing these resources, we can ensure the efficient use of agricultural outputs while fostering the development of innovative products that contribute to a circular economy. Unlocking the hidden potential of these abundant biomasses and their derivatives is key to driving sustainable development.

Revalorizing secondary biomasses offers a pathway to enhancing the economic viability of agricultural practices and reducing waste, ultimately leading to a more resilient and sustainable production system. This process is not only critical for achieving environmental sustainability but also for driving economic growth. As such, it should be a focal point for future research and innovation, positioning Italy at the forefront of sustainable agricultural and industrial practices.

2.2 Austria (Carinthia Region)

2.2.1 Carinthia Biomass Availability

Carinthia biomass potential is deeply anchored in its robust forestry sector and diverse agricultural activities, which together form the foundation of the country's bioeconomy[38]. The nation's vast forested regions ensure a continuous supply of wood and wood by-products, while its fertile agricultural landscapes produce a variety of crop residues and energy crops[39]. This section explores the specific types of biomass resources available across Carinthia, highlighting their potential for sustainable energy generation and economic development.

An analysis of primary biomass data from Austrian sources, mainly Austrian national statistics office[40] and AgrarMarkt Austria[38] clearly shows how the country's eight key biomass types can significantly contribute to the production of a wide array of biobased materials. **Table 2** illustrates that the total cultivated area, in Carinthia, for these major biomass types amounts to 28.817 hectares, yielding a combined primary biomass production of 324.462 tonnes.

Table 2 Carinthian primary biomass availability (Sommererhebung 2023 Agrar Markt Austria, Statistik.at, 2022 and 2023).

Type of biomass	Cultivated Area (Hectare)	Production Volume (Tonnes)
Barley	3.892	26.674
Soya	4.806	130.577
Maize	15.736	141.200
Wheat	3.334	20.255
Alfalfa	200	1.509
Rapeseed	99	436
Sugar beet	15	929
Oat	735	2.882
TOTALS	**28.817**	**324.462**

The Carinthian Cultivated Area and Production Volume calculated as a percentage are shown in **Figure 21**. Maize dominates the ***Cultivated Area***, occupying 55% of the total agricultural land. This is followed by Soya

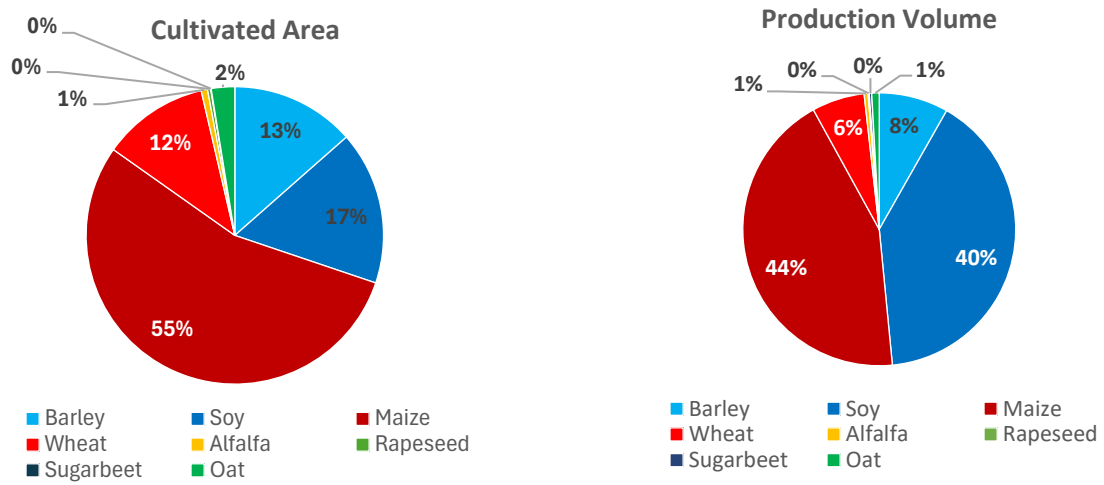

Figure 21 *Austrian Cultivated Area and Production Volume percentages (Sommererhebung 2023 Agrar Markt Austria, Statistik.at, 2022 and 2023).*

(17%), Barley (13%), Wheat (12%), Oat (3%), Alfalfa (1%) and finally, Rapeseed and Sugar beet at under 0,5% (rounded to 0% in the figure). The distribution of these crops reflects Austria's agricultural priorities and environmental conditions, where maize, soya, and wheat are particularly well-suited to the country's diverse climate and soil types. Maize, a staple crop, is widely cultivated for both human consumption and livestock feed, flourishing in Carinthia.

Examining the ***Production Volume***, *Maize* emerges as the most significant contributor, representing 44% of the total biomass production. This dominance underscores its critical role in Carinthian agriculture, where it is primarily used for animal feed, but also plays a vital part in soil health and crop rotation practices. Soya, which accounts for 40% of biomass production. The remaining biomass sources, including barley, wheat, sugar beet, oats, alfalfa, and rapeseed, each contribute less than 10%. Their smaller presence reflects their specialised uses or niche market demands. For example, barley is mainly cultivated for brewing and animal feed, while wheat is increasingly significant for both livestock feed and as a protein source in human diets.

This distribution of biomass resources mirrors Carinthia's agricultural priorities, climate, and market needs.

2.2.2 Carinthia Biomass Distribution

SOYA & MAIZE

Soya and maize are the most abundant biomass resources in Carinthia, with annual yields of 130.577 and 141.200 tonnes, respectively[40]. The region's climate, especially in the eastern areas, is well-suited to their cultivation due to warm temperatures, adequate rainfall, and a long growing season[41]. Rising temperatures and favourable precipitation patterns have further enhanced crop yields by allowing earlier planting and later harvesting[42]. In areas with lower rainfall, irrigation systems ensure a reliable water supply, supporting healthy crop growth. Secondary biomasses, valuable byproducts of soya and maize production, play a crucial role in various industries. ***Maize stover***, a key secondary biomass, amounts to 76.248 tonnes and consists of leaves, stalks, and cobs left after grain harvest. It is frequently used as animal

fodder, particularly in the form of silage, and as a raw material for bioenergy production. These secondary biomasses add significant value to Austria's agricultural sector, supporting industries from animal farming to renewable energy, and underscoring the sector's efficiency and sustainability.

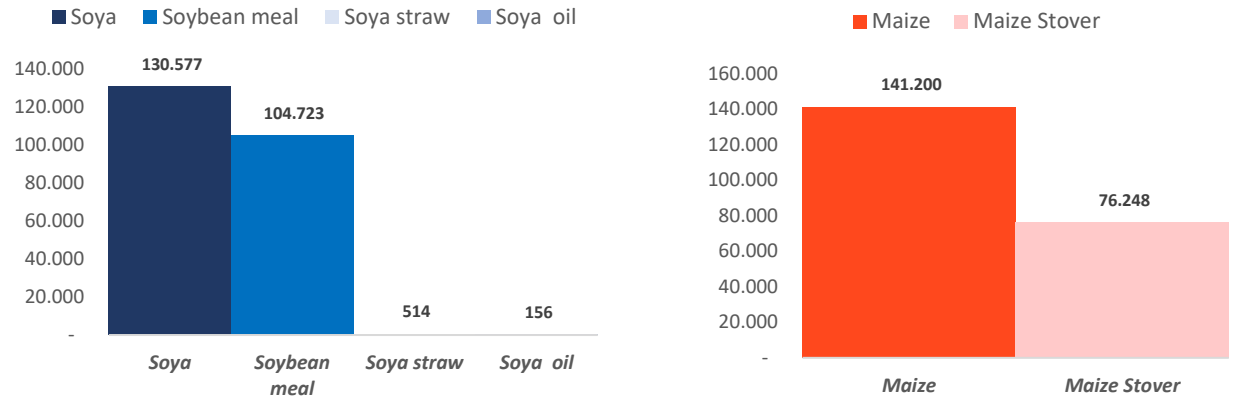

Figure 22 *Comparison of Production Volumes (tonnes) of primary biomass (soya; maize) and secondary biomass (soybean meal, soya straw, soia oil; maize stover) (Statistik.at, 2023).*

Soybean meal, the most significant secondary biomass from soya, has a potential production volume of 25.423 tonnes[4] [43] and is widely used as a high-protein animal feed, driving its large-scale production (**Figure 22**). Other potential byproducts include an estimated 514 tonnes of soya straw and 156 tonnes of soya oil. ***Soya straw*** is commonly used for animal bedding, soil conditioning, and bioenergy production, while soya oil finds applications in cooking, food processing, and as a base for biodiesel.

BARLEY & WHEAT

As illustrated in **Figure 23**, wheat is the most extensively cultivated grain in Carinthia, covering around 3.300 hectares[38]. It is primarily grown for food production, with an average yield of 6 tonnes per hectare, resulting in an annual output of approximately 20.255 tonnes.

[4] Value calculated using the specific conversion rate. The information regarding the applied conversion rate is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

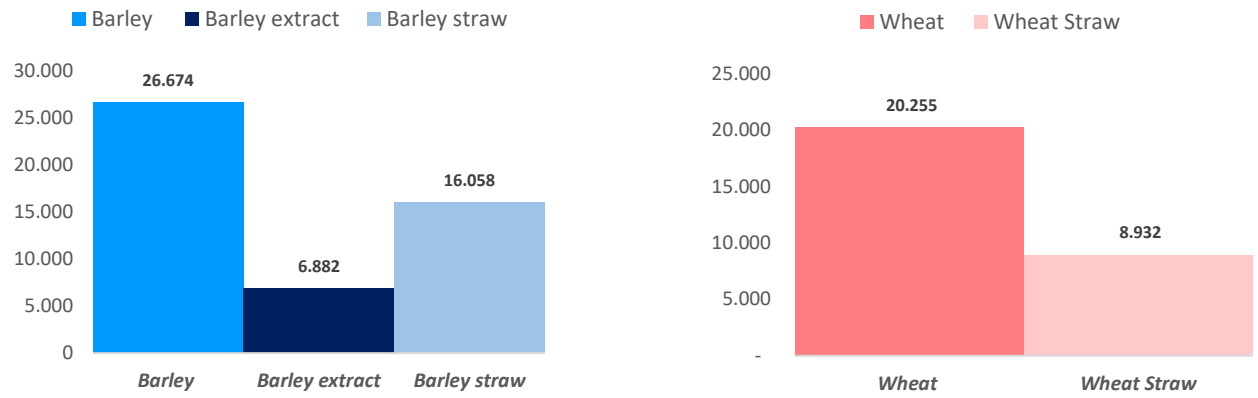

Figure 23 *Comparison of Production Volumes (tonnes) of primary biomass (barley; wheat) and secondary biomass (barley extract, barley straw; wheat straw) (Statistik.at, 2023).*

Barley is Carinthia's third most important cereal crop, mainly used for animal feed and malting. Winter barley is predominantly grown for feed, while summer barley is cultivated for malting purposes. Barley cultivation spans about 3.892 hectares, emphasizing its importance in both local consumption and export markets.

INDUSTRIAL WOOD

Figure 24 *Comparison of Production Volumes (tonnes) of primary biomass (wood) and secondary biomass (wood residues) (Statistik.at, 2023).*

Carinthia is characterized by nearly 60% forest cover[44], providing a substantial natural resource for its thriving timber industry. The region produces around 2.89 million tonnes[40] of industrial roundwood and wood fuel annually, including wood for charcoal (**Figure 24**). This abundant timber supply feeds into Carinthia's well-established wood processing sector, which includes around 160 timber industry companies, 180 carpentry firms, 750 joinery firms, and a paper factory. These enterprises are equipped with the necessary infrastructure and expertise to efficiently process the region's abundant timber resources[44]. Additionally, the region generates around 1.13 million tonnes of secondary biomass[5] [45], mainly in the form of wood residues from industrial roundwood processing and forest management

[5] Value calculated using the specific conversion rate. The information regarding the applied conversion rate is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

activities. These wood residues are vital to the biomass supply chain, contributing to energy production, waste reduction, and the advancement of the circular economy. Forestry and wood processing are crucial economic drivers in Carinthia, employing around 10.000 people, with forestry income often exceeding agriculture income for many farms[46]. The region is also committed to sustainable forest management, with 75% of its forests classified as moderately altered or close to their natural state. This approach ensures a continuous supply of timber while preserving ecological balance[46]. Carinthia's wood products, particularly those exported to Italy, are vital to Austria's foreign trade, making the region a key player in the country's wood production industry[47].

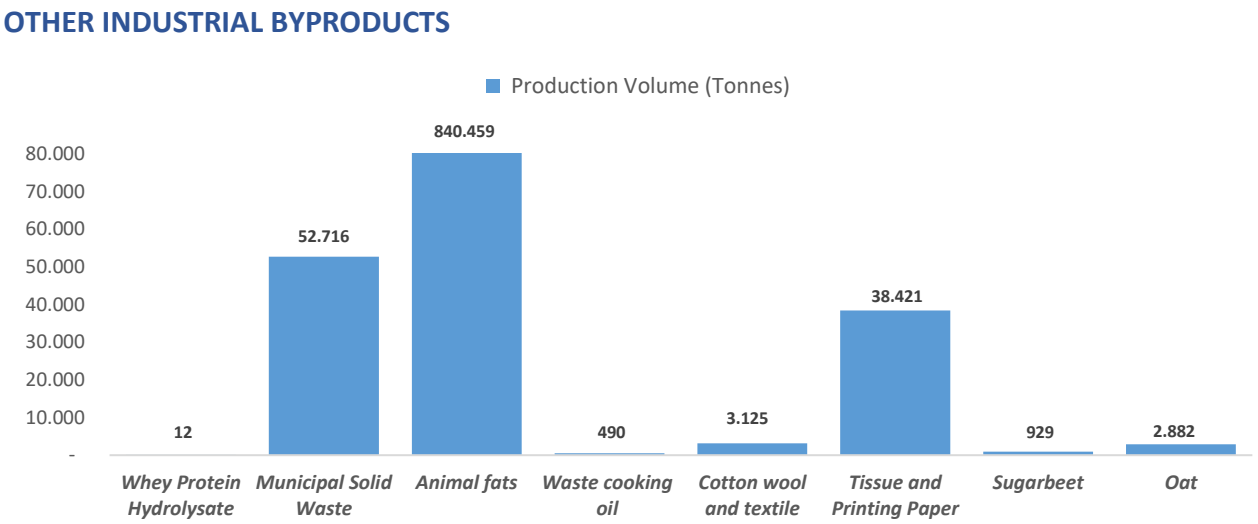

Figure 25 *Comparison of Production Volumes (tonnes) of Whey Protein Hydrolysate, Municipal Solid Waste, Animal fats, Waste cooking oil, Cotton wool and textile, Tissue and printing paper, Sugar beet and Oat (Statistik.at, 2023).*

Due to difficulties in obtaining precise production values for specific biomass types in the Carinthia region, we have compiled general data on the production volumes of various biomass categories. These include Whey Protein Hydrolysate, Municipal Solid Waste, Animal Fats, Waste Cooking Oil, Cotton Wool and Textile, Tissue and Printing Paper, Sugar beet and Oat. Among these, Animal Fats are the most prominent, with a production volume of 840.459 tonnes, as highlighted in **Figure 25**.

2.3 Belgium (Brussels Capital, Wallonia, and Flanders)

2.3.1 Belgian[6] Biomass Availability

Belgium's three regions—Brussels Capital, Wallonia, and Flanders—possess diverse biomass resources with significant potential for sustainable energy generation and economic development. By leveraging these abundant biomass resources, Belgium is well-positioned to expand its renewable energy capacity and progress towards a greener future.

An analysis of primary biomass data from Belgian sources reveals that the country's six major biomass types can play a key role in producing a wide range of biobased materials. As shown in **Table 3**, the total

[6] "Belgium" was used to describe data of the three Belgian regions in the SYMBIO project

cultivated area for these biomass types covers 487.530 hectares, resulting in a combined primary biomass production of 7.510.264 tonnes[48].

Table 3 *Belgian primary biomass availability (EUROSTAT, 2022).*

Type of biomass	Cultivated Area (Hectare)	Production Volume (Tonnes)
Barley	60.870	272.764
Maize	156.920	598.520
Wheat	204.470	1.841.170
Rapeseed	8.600	36.470
Sugar beet	53.270	4.743.700
Oat	3.400	17.640
TOTALS	**487.530**	**7.510.264**

The Belgium Cultivated Area and Production Volume calculated as a percentage are shown in **Figure 26**. Wheat dominates the ***Cultivated Area***, occupying 42% of the total agricultural land. This is followed by Maize (32%), Barley (12%), Wheat (12%), Sugar Beet (11%), and finally, Rapeseed and Oat at respectively 2% and 1% of the national production. The distribution of these crops reflects Belgium environmental conditions, where Sugar beet and Wheat are particularly well-suited to the country's diverse climate and soil types. Maize, a staple crop, is also widely cultivated for both human consumption and livestock feed.

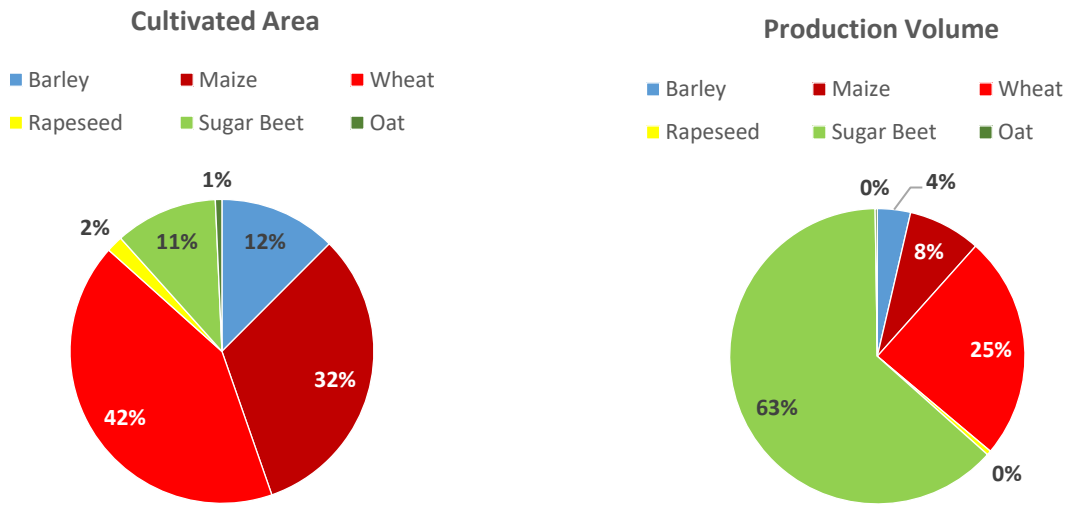

Figure 26 *Belgian Cultivated Area and Production Volume percentages (EUROSTAT, 2022).*

Examining the ***Production Volume***, *Sugar Beet* emerges as the most significant contributor, representing a great quantity of 63% of the total biomass production. This dominance underscores its critical role in Belgian agriculture, where it is primarily used for sugar production, but also plays a vital part in soil health

and crop rotation practices. Wheat, which accounts for 25% of biomass production, thrives in Belgium's temperate climate where ample rainfalls create ideal growing conditions.

The remaining biomass sources, including Barley, Maize, Sugar Beet, Oats, And Rapeseed, each contribute less than 10%. Their smaller presence reflects their specialized uses or niche market demands, for example, Barley is mainly cultivated for Belgian breweries and animal feed.

2.3.2 Belgian Biomass Distribution

BARLEY

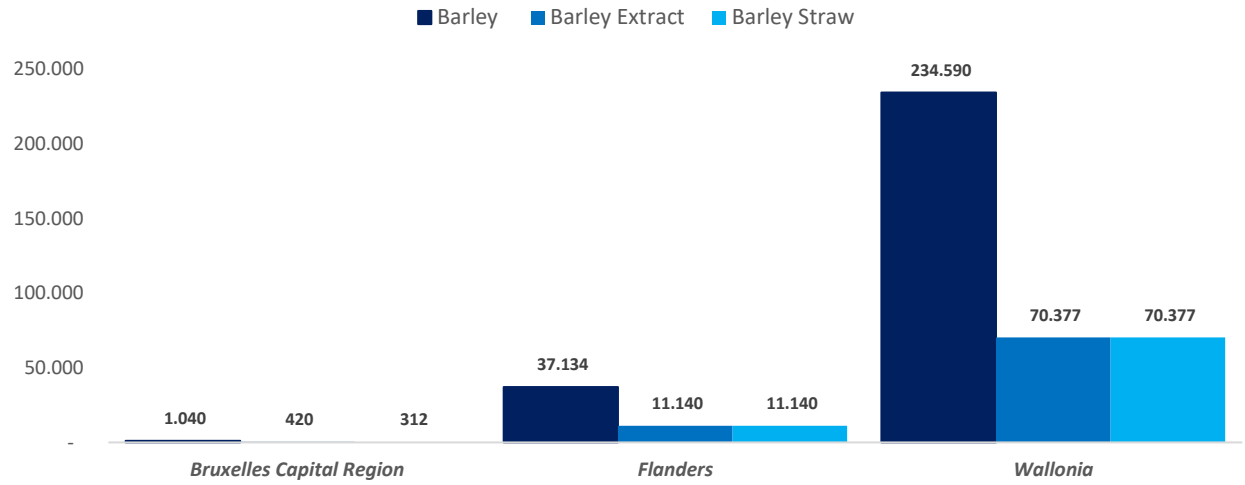

Figure 27 *Barley Production Volume (tonnes) in each Belgian region (EUROSTAT, 2022).*

The total barley production volume across the three project regions in Belgium reaches 272.764 tonnes[49]. However, there is a significant disparity in production levels between the Brussels Capital Region and the more agriculturally dominant regions of Wallonia and Flanders (**Figure 27**). This discrepancy highlights the considerable influence of environmental conditions and regional farming practices, which are far more favourable in rural areas. In Wallonia and Flanders, where expansive farmlands, fertile soils, and more suitable climatic conditions prevail, barley cultivation thrives. Meanwhile, the urbanized landscape and limited agricultural space in the Brussels Capital Region constrain its production capacity. The difference in farming techniques, available land, and regional environmental conditions underscores the importance of rural regions in driving Belgium's barley production.

MAIZE

The total maize production across the three project regions reaches an impressive 598.520 tonnes[49], with the majority concentrated in the Flander region (495.240 tonnes), as shown in **Figure 28**. Maize cultivation is crucial in Belgium's agriculture due to its economic, environmental, and food security implications. Economically, the area dedicated to maize cultivation has expanded, driven by higher grain prices from global disruptions like the Ukraine conflict. The introduction of high-yield, disease-resistant maize varieties has further increased profitability, making harvests more reliable and reducing costs.

Environmentally, maize is well-suited to Belgium's changing climate, with projections suggesting that warmer temperatures could boost yields. The crop is also compatible with sustainable farming practices,

including eco-schemes aimed at enhancing biodiversity and soil health. The study also examines a combination of secondary maize residues: stover and straw. These byproducts are significant in terms of biomass production, with potential applications in energy generation, animal feed, and biofuel production. The production of these residues is proportional, in Belgium, to the production volume in a conversion rate of 1:1[50].

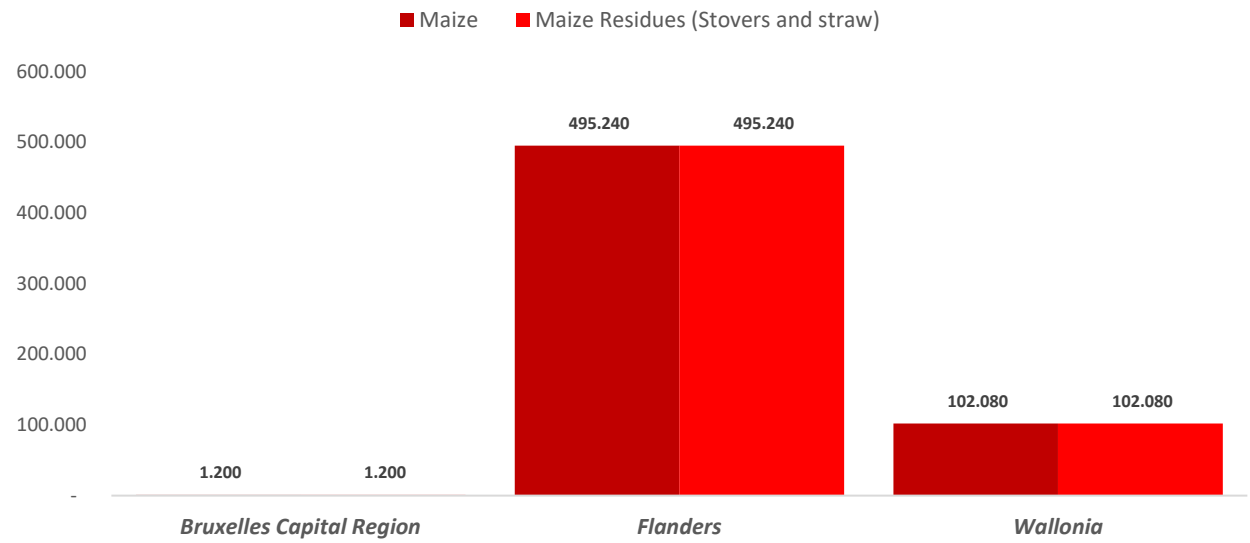

Figure 28 *Maize Production Volume (tonnes) in each Belgian region (EUROSTAT, 2022).*

SUGARBEET

Sugar beet cultivation in Belgium is highly developed, driven by a combination of favourable environmental conditions, historical significance, modern agricultural practices, economic viability, supportive policies, and sustainable farming techniques. The country's temperate climate, with humid conditions and dry, sunny periods leading up to harvest, provides an ideal environment for sugar beet growth. Additionally, Belgium's rich, well-drained soils support high-yield crops, enhancing the sector's profitability.

Historically, sugar beet farming has deep roots in Belgium, particularly in Tienen, known as the "Sugar City," which is home to one of Europe's largest sugar processing facilities. This historical foundation has fostered a strong tradition of sugar beet cultivation. Modern agricultural practices in Belgium are highly advanced, with companies like *SESVanderHave* leading innovations in sugar beet seed production. The use of satellite technology for crop monitoring has transformed farming, increased yields and reduced costs.

Economically, the sugar beet industry is vital, with demand driven by the food and beverage sectors. Competitive pricing within the EU's sugar market further incentivizes farmers. Belgium also benefits from EU agricultural policies that provide subsidies and research funding, encouraging sustainable practices and technological advancements.

Additionally, sugar beet plays a key role in crop rotation systems, improving soil health and sustainability, which leads to consistently higher yields.

Wallonia generates the highest volume, with 3,195,680 tonnes of primary biomass and 798,920 tonnes of sugar beet by-products. The Flanders also contribute significantly, with 1,536,470 tonnes of primary product and 384,118 tonnes of residues (**Figure 29**). These production volumes underscore Belgium's position as a leader in sugar beet cultivation in Europe, ensuring the continued growth and success of this important agricultural industry.

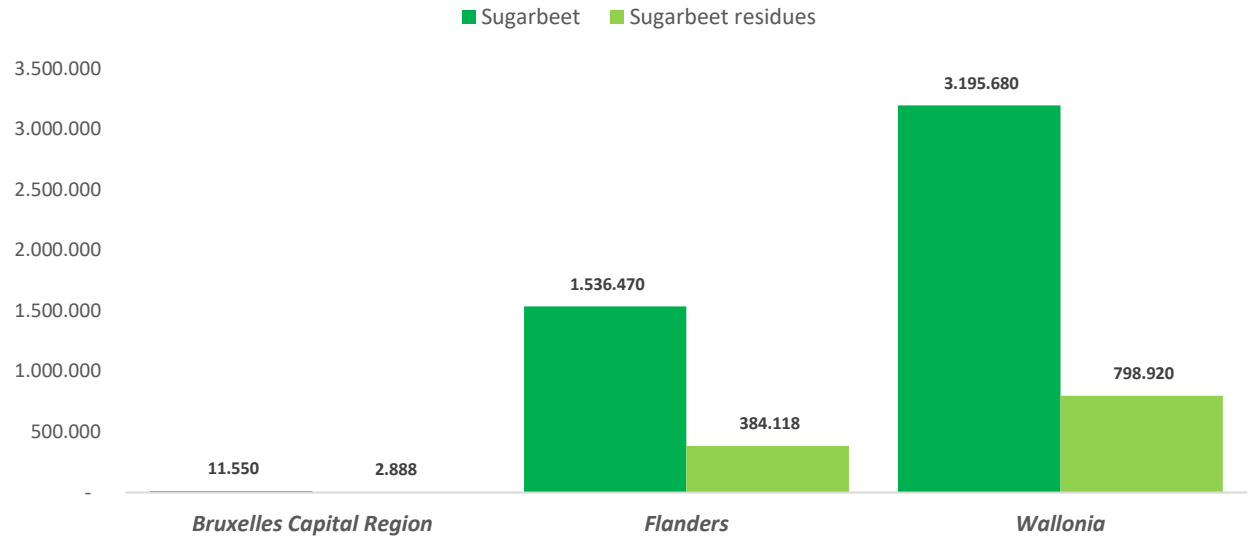

***Figure 29** Sugar beet Production Volume (tonnes) in each Belgian region (EUROSTAT, 2022).*

WHEAT

Belgium's wheat production is shaped by a complex interplay of economic factors, agricultural practices, and trade dynamics. Economically, Belgium is a significant player in the global wheat market, ranking as the 19th largest importer and 35th largest exporter of wheat. In 2022, Belgium imported around $1.16

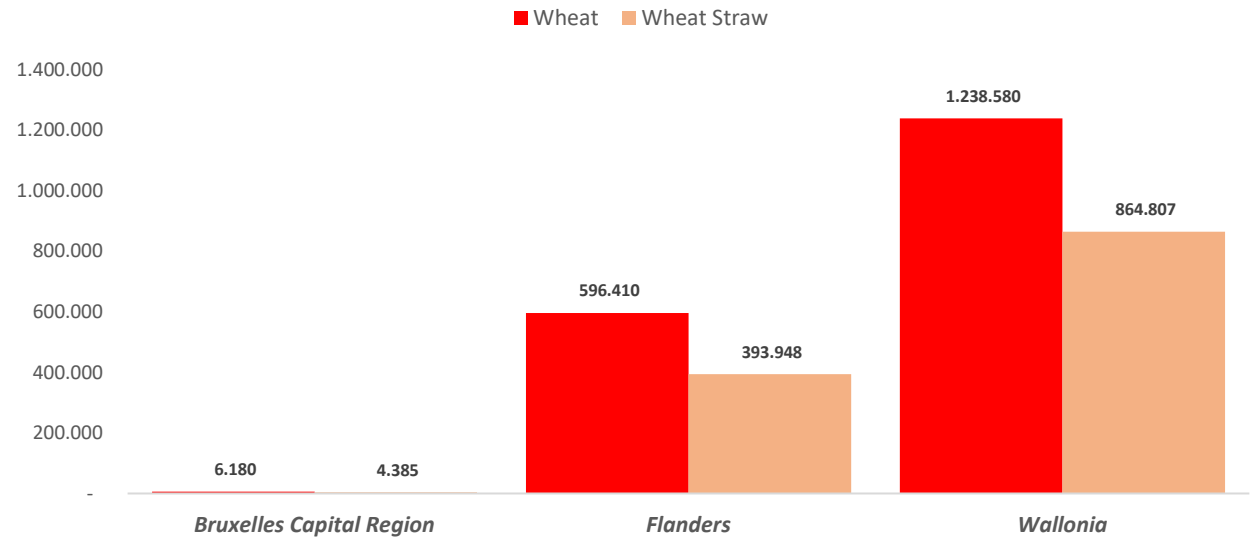

***Figure 30** Wheat Production Volume (tonnes) in each Belgian region (EUROSTAT, 2022).*

billion worth of wheat, while its exports amounted to just $140 million, reflecting a strong dependence on imports to meet domestic demand[51]. The primary sources of these imports include France, Germany, and the Netherlands, underscoring Belgium's strategic role within the European wheat supply chain. Domestically, the demand for wheat is driven by its use in food production and animal feed, although Belgian wheat is often unsuitable for high-quality milling due to lower protein content[52]. To maintain sustainability and optimise yields, Belgian farmers incorporate wheat into crop rotation systems and employ advanced agricultural techniques, including the use of improved seed varieties and modern farming technologies. Despite the heavy reliance on imports, Belgium also pursues export opportunities, particularly with neighbouring countries, while remaining responsive to global market trends[51].

Belgium's wheat production amounts to 1.841.170 tonnes, concentrated in the Wallonia and Flanders regions. Wallonia contributes 596.410 tonnes of primary biomass and 393.948 tonnes of secondary biomass, while Flanders accounts for 1.238.580 tonnes of primary biomass and 864.807 tonnes of secondary biomass (**Figure 30**). These data reflect the regional disparities in wheat production within the country and further emphasise the importance of strategic agricultural practices and international trade in shaping Belgium's wheat industry.

RAPESEED & OAT

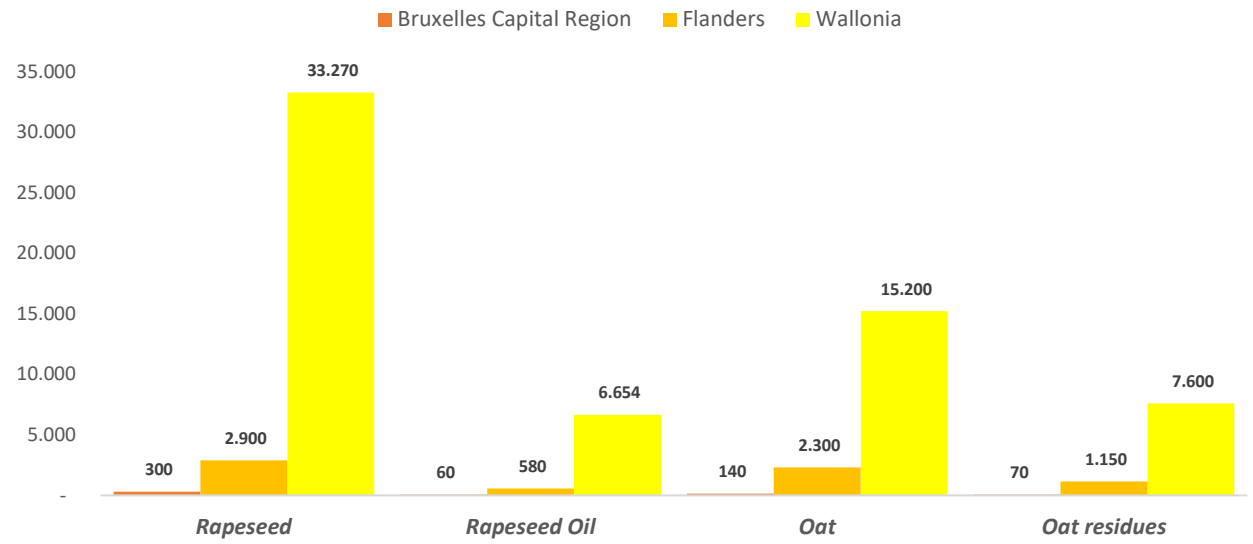

Figure 31 *Comparison of Production Volumes (tonnes) of primary biomass (Rapeseed; Oat) and secondary biomass (rapeseed oil; oat residues) (EUROSTAT, 2022).*

Belgium's agricultural landscape prominently features the cultivation of rapeseed and oats due to their agronomic benefits, economic viability, and adaptability to local farming practices. Rapeseed is primarily grown for its oil-rich seeds, which are used in various food products like margarine and mayonnaise. The oil extracted is prized for its health benefits, being low in saturated fats and high in omega-3 fatty acids[53]. Additionally, rapeseed plays a crucial role in crop rotation systems, acting as a "break crop" that helps suppress weeds and improve soil quality, thereby enhancing the productivity of subsequent cereal crops[53]. The economic appeal of rapeseed has grown in recent decades, with the European Union reporting significant increases in its production[49].

Oats, another key crop in Belgium, are valued for their versatility and nutritional benefits, serving both as livestock feed and as a food source for humans[54]. Oats thrive in Belgium's temperate climate and contribute to soil health, often used in crop rotations to improve soil structure and promote nitrogen fixation. Together, the cultivation of rapeseed and oats supports Belgium's sustainable farming practices, ensuring both economic gains and long-term soil fertility[55].

The **Figure 31** illustrates the production figures for rapeseed and oats across three regions in Belgium: Brussels Capital Region, Flanders, and Wallonia. The data is segmented into four categories: Rapeseed, Rapeseed Oil, Oat, and Oat residues. Wallonia dominates production across all categories, particularly in rapeseed, where it produces a substantial 33.270 tonnes, compared to 2.900 tonnes in Flanders and only 300 tonnes in the Brussels Capital Region. Similarly, Wallonia leads in oat production with 15.200 tonnes and oat residues with 7.600 tonnes, while the other regions contribute significantly less. Flanders, however, surpasses Wallonia in the production of rapeseed oil with 580 tonnes, though Wallonia is close behind with 6,654 tonnes. This data underscores Wallonia's leading role in the cultivation of these crops, reflecting its prominent position in Belgium's agricultural sector.

OTHERS INDUSTRIAL BYPRODUCTS

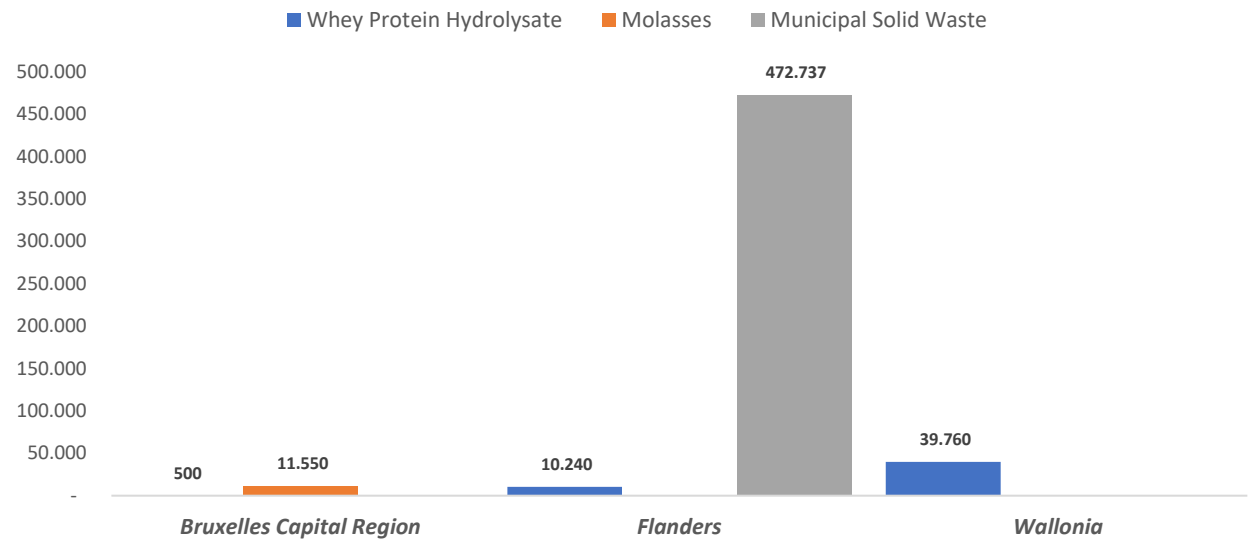

***Figure 32** Comparison of Production Volumes (tonnes) other industrial byproducts (Whey Protein Hydrolysate, Molasses, Municipal Solid Waste) (EUROSTAT, 2022).*

Figure 32 provides an overview of the availability of the industrial byproducts —Whey Protein Hydrolysate, Molasses, and Municipal Solid Waste—not included in the previous categories. In Brussels Capital, there is a minimal presence of Molasses (11.550 tonnes), while data on Whey Protein Hydrolysate and Municipal Solid Waste were not found by the pilot regions. This suggests that Brussels Capital might not be a significant player in either dairy processing or waste generation. The situation in Wallonia appears similar to that in Brussels, with a small amount of Whey Protein Hydrolysate and no data on Molasses and Municipal Solid Waste production. This implies that Wallonia's industrial profile may present some similarities with Brussels regarding dairy processing. A different profile is found in Flanders where a small, but notable, quantity of Whey Protein Hydrolysate (10.240 tonnes) and a substantial amount of Municipal Solid Waste (472.737 tonnes) was found, reflecting its higher population density and industrial activity,

leading to a greater waste production. This data reveals the different regional specializations in Belgium, with Flanders becoming the main waste management hub. However, Whey Protein Hydrolysate use is present but limited in both Flanders and Wallonia.

2.4 Spain (Andalusia Region)

2.4.1 Andalusia Biomass Availability

Spain's biomass potential is closely tied to its diverse agricultural activities and forestry sector. The country's extensive agricultural lands provide a range of crop residues and by-products, while its forested areas contribute wood and wood by-products. These resources are integral to Spain's growing bioeconomy. This section explores the specific types of biomass resources available in Andalucia, highlighting their potential for sustainable energy generation and economic development.

An analysis of primary biomass data from Andalusia sources clearly shows how the country's eight key biomass types can significantly contribute to the production of a wide array of biobased materials. **Table 4** illustrates that the total cultivated area for these major biomass types amounts to 515.486 hectares, yielding a combined primary biomass production of 2.212.032 tonnes[56].

Table 4 *Andalusian primary biomass availability (Juntadeandalucia, 2024).*

Type of biomass	Cultivated Area (Hectare)	Production Volume (Tonnes)
Alfalfa	7.130	218.935
Barley	90.560	177.751
Cotton	59.000	25.800
Maize	4.567	51.746
Rapeseed	2.730	4.068
Rice	22.209	186.984
Sugar beet	9.310	523.295
Wheat	319.980	1.023.453
TOTALS	**515.486**	**2.212.032**

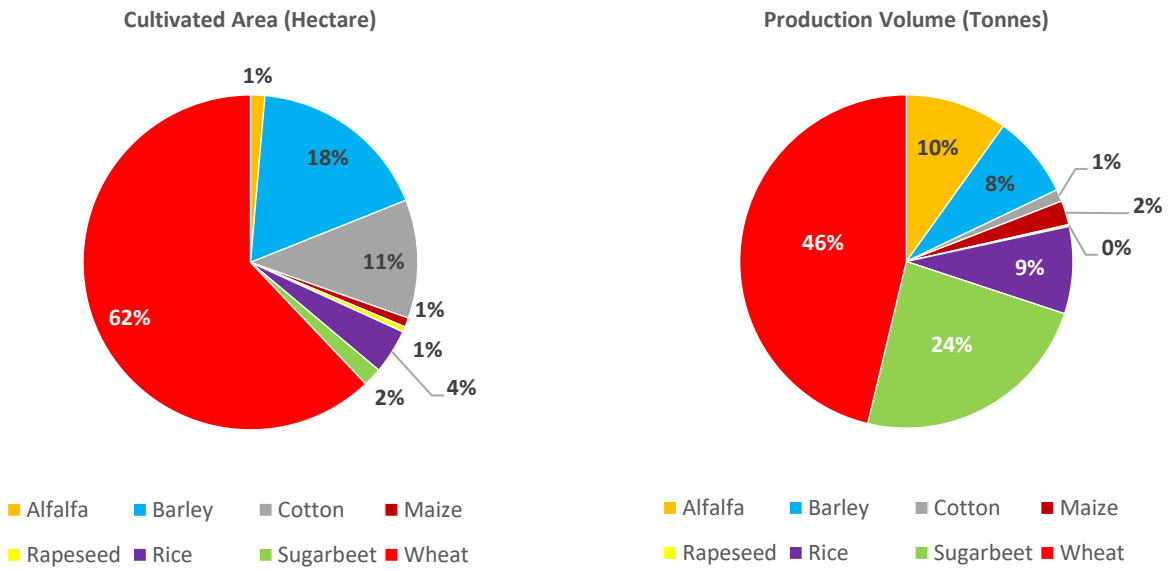

Figure 33 *Andalusia Cultivated Area and Production Volume percentages (Juntadeandalucia, 2024).*

The Andalusia's Cultivated Area and Production Volume calculated as a percentage are shown in **Figure 33**. Wheat dominates the ***Cultivated Area***, occupying 62% of the total agricultural land. This is followed by Barley (18%), Cotton (11%), and Alfalfa, Maize, Rice and Sugar beet and Rapeseed at under 5% each. The distribution of these crops reflects Spain's agricultural priorities and environmental conditions, where Wheat, Barley and Cotton are particularly well-suited to the country's diverse climate and soil types.

Examining the ***Production Volume***, *Wheat* emerges as the most significant contributor, representing 46% of the total biomass production. This dominance underscores its critical role in Spanish agriculture, where it is primarily used for food and feed. Sugar beet has a high contribution to biomass production, as 24% of biomass presence in Andalusia consists of this product. The remaining biomass sources, all under 10%, reflect their specialised uses or niche market demands.

2.4.2 Andalusia Biomass Distribution

Figure 34 shows the cultivated area and production volume of the eight key biomass considered in the study. ***Wheat*** dominates biomass production in Spain due to several factors. The country's climate, with optimal temperatures around 25°C, and soils that are deep, well-drained, and rich in organic matter, provide ideal conditions for wheat cultivation. Spain dedicates a significant portion of its agricultural land, about 2 million hectares, to wheat. This crop is a staple in the Spanish diet, supplying essential calories and protein, and supports the livestock industry. Additionally, wheat straw, a major agricultural byproduct, is widely available for biomass, bioenergy, and biofuel production, further solidifying wheat's prominence in Andalusia's agricultural landscape.

Sugar beet is another key crop in Andalusia, with a production volume of 523.295 tonnes. In Andalusia, sugar beet cultivation is flourishing due to a combination of favourable climate, economic incentives, and advanced agricultural practices[57]. The region benefits from a temperate, sunny, and humid climate, complemented by sufficient rainfall, which creates ideal conditions for growing sugar beets[58], such as rich soils in areas like Andalusia that further boosts productivity. Recent spikes in sugar prices have driven

a 20% increase in sugar beet cultivation expected in 2024. Additionally, the Common Agricultural Policy supports sustainable practices such as crop rotation[59], while advanced irrigation techniques optimize water use and improve soil health, enhancing both yield and sustainability[60].

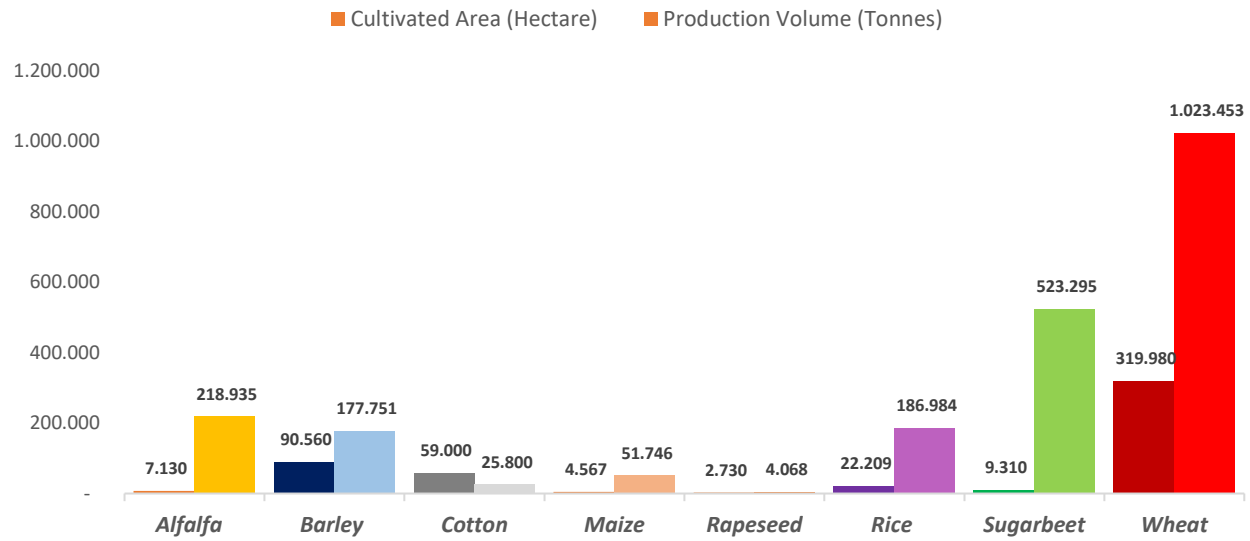

Figure 34 *Comparison of Production Volumes (tonnes) of primary biomass (Alfaalfa, Barley, Cotton, Maize, Rapeseed, Rice, Sugar beet, Wheat) (Juntadeandalucia, 2024).*

However, several other biomass types are present in Andalusia that could play a more significant role in the future of the region's bioeconomy but are currently underutilized. ***Alfalfa***, for instance, has an impressively high yield (31 tonnes/hectare), yet its cultivated area is limited (7,130 hectares). This crop could be further explored for bioenergy production due to its high biomass potential. ***Rice***, another crop with significant biomass potential (yield of 8 tonnes/hectare), is cultivated over 22,209 hectares, offering notable contributions to both food production and biomass usage, particularly from its residues like rice husks. Additionally, maize and rapeseed show potential, though their cultivated areas are relatively small, with ***maize*** yielding 11 tonnes/hectare over 4,567 hectares, and ***rapeseed*** producing 1 tonne/hectare over 2,730 hectares. Both crops could be promoted for biofuel production due to their adaptability to bioenergy purposes.

Barley, while occupying a substantial area (90,560 hectares), has a relatively low yield (2 tonnes/hectare), indicating potential inefficiencies or limitations in current farming practices. There may be opportunities to enhance barley's productivity through improved techniques, potentially increasing its utility as a biomass source. Finally, cotton is notable for its relatively large cultivated area (59,000 hectares) but extremely low production volume (25,800 tonnes) and zero yield in terms of biomass per hectare. This raises questions about its economic viability as a biomass source and suggests that other crops might provide better returns for biomass energy.

Overall, while wheat and sugar beet are the dominant biomass sources in Andalusia, other crops like alfalfa, maize, and rice offer significant opportunities for diversification in biomass production. With appropriate policy support, technological innovation, and market incentives, these underutilized biomass types could contribute more substantially to Andalusia's renewable energy landscape.

OTHERS INDUSTRIAL BYPRODUCTS

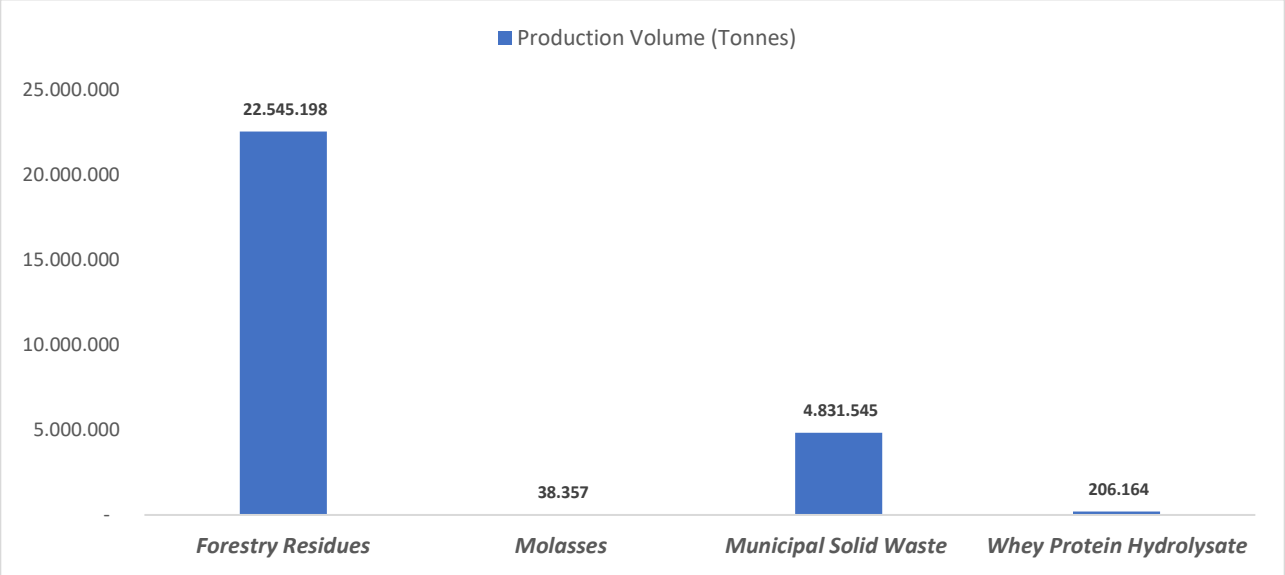

Figure 35 *Comparison of Production Volumes (tonnes) of industrial byproducts (Forestry residues, Molasses, Municipal solid waste, whey protein hydrolysate) (Juntadeandalucia, 2024).*

Figure 35 provides an overview of the availability of the industrial byproducts not included in the previous categories. Andalusia's notably high production of biomass is evident in its substantial outputs of forestry residues and municipal solid waste. The region generates an impressive 22.545.198[7] tonnes of forestry residues, a result of its extensive forested areas and active timber industry[61]. These residues, including tree branches, leaves, and sawdust, are byproducts of logging and forest management practices essential for maintaining forest health and supporting the timber sector. In addition, Andalusia produces 4.831.545 tonnes of municipal solid waste. This high figure is indicative of the region's large and growing population, along with significant urbanization and economic activity. The substantial waste production reflects high per capita consumption levels and a range of residential, commercial, and industrial activities.

The data presented in this section highlights the region's extensive forestry operations and its high urban waste generation, shedding light on the challenges and opportunities for sustainable management and energy production from biomass resources in Andalusia. In particular, Whey Protein Hydrolysate and Molasses (derived from the sugar production process) represent an important resource for further bio valorisation, in Andalusia 38.357 tonnes of Molasses[62] and 206.164 tonnes of Whey Protein Hydrolysate[63] are present.

Secondary biomass

Andalusia has provided data that focuses primarily on primary biomasses and industrial byproducts. However, information on secondary biomasses and their conversion rates was not included in the analysis. This omission leaves a gap in understanding the full potential of the country's biomass sector and its capacity to contribute to sustainable energy and resource management. Without these insights, it is difficult to fully assess the sector's overall impact and opportunities for improvement in biomass utilization.

[7] $1m^3$ off wood is equivalent to 1,38 tonnes

2.5 Croatia

2.5.1 Croatian Biomass Availability

Croatian's biomass potential is deeply anchored in its robust forestry sector and diverse agricultural activities, which together form the foundation of the country's bioeconomy. The nation's vast forested regions ensure a continuous supply of wood and wood by-products, while its fertile agricultural landscapes produce a variety of crop residues and energy crops. This section explores the specific types of biomass resources available across Croatia. By leveraging these abundant biomass resources, Croatia is strategically positioned to expand its renewable energy portfolio and advance towards a greener future.

Table 5 illustrates that the total cultivated area for these major biomass types amounts to 624.000 hectares, yielding a combined primary biomass production of 4.020.000 tonnes[64].

Table 5 *Croatian primary biomass availability (Croatian bureau of Statistics, 2023).*

Type of biomass	Cultivated Area (Hectare)	Production Volume (Tonnes)
Barley	67.000	286.000
Maize	266.000	1.974.000
Wheat	170.000	813.000
Rapeseed	15.000	43.000
Sugar beet	8.000	500.000
Alfalfa	27.000	200.000
Soya	71.000	204.000
TOTALS	**624.000**	**4.020.000**

The Croatia Cultivated Area and Production Volume calculated as a percentage are shown in **Figure 36**. Maize dominates the ***Cultivated Area***, occupying 43% of the total agricultural land. This is followed by Wheat (27%), Barley (11%), Soya (11%), and finally, Sugar Beet, Rapeseed and Alfalfa at less than 5% of the national cultivated land. The distribution of these crops reflects Croatia agricultural priorities and environmental conditions, where Maize and wheat are particularly well-suited to the country's diverse climate and soil types. Examining the ***Production Volume***, *Maize* emerges as the most significant contributor, representing almost half of the total biomass production. This dominance underscores its critical role in Croatian agriculture, where it is primarily used for human consumption, but also thrives in Croatian temperate climate. Wheat and Sugar beet are the other two most abundant crops with respectively 20%

and 13%. The remaining biomass sources, including barley, alfalfa, soya, and rapeseed, each contribute less than 10%.

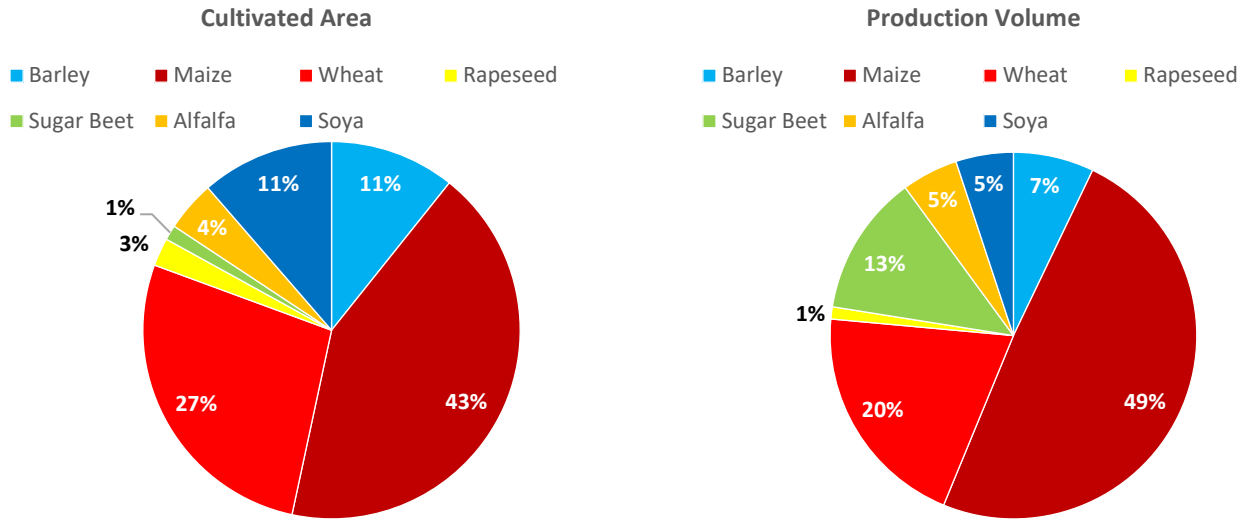

Figure 36 *Croatia Cultivated Area and Production Volume percentages (Croatian Bureau of statistics, 2023).*

2.5.2 Croatian Biomass Distribution

SOYA & MAIZE

Figure 37 highlights the production volumes of soya and maize, along with their secondary biomasses. **Soya** production reaches 204.000 tonnes, with the main byproducts being soybean meal (81.600 tonnes) and soybean oil (40.800 tonnes), followed by soybean fibre at 20.400 tonnes used for animal feed. In contrast, **maize** has the highest production volume, totalling 1.974.000 tonnes. Additionally, maize cobs and maize stover (the leftover stalks and leaves) show substantial byproduct volumes, amounting to 1.201.316 tonnes and 1.480.870 tonnes, respectively.

Croatia, situated in Southeast Europe, has a favourable climate for agriculture, primarily focusing on maize production as one of its key crops. The high volume of maize production indicated in the data reflects similar trends observed in Croatia, where maize is a staple in both human consumption and livestock feed.

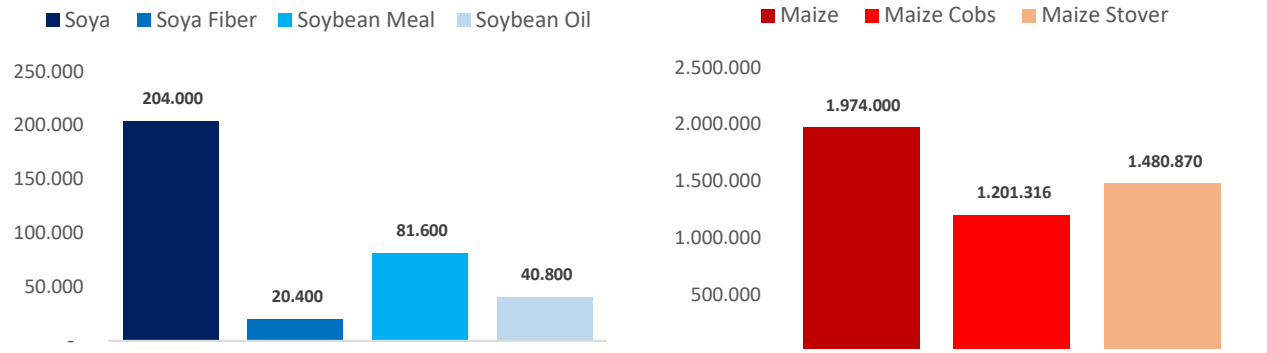

Figure 37 *Comparison of Production Volumes (tonnes) of primary biomass (soya; maize) and secondary biomass (soya fibre, soybean meal, soia oil; maize cobs, maize stover) (Croatian Bureau of statistics, 2023).*

The production of maize cobs and stover suggests an emphasis on maximising agricultural output, utilising all parts of the plant. In contrast, the soya production data, though lower than maize, points towards an emerging or supplementary role in the agricultural sector, potentially used for both domestic consumption and export.

BARLEY & WHEAT

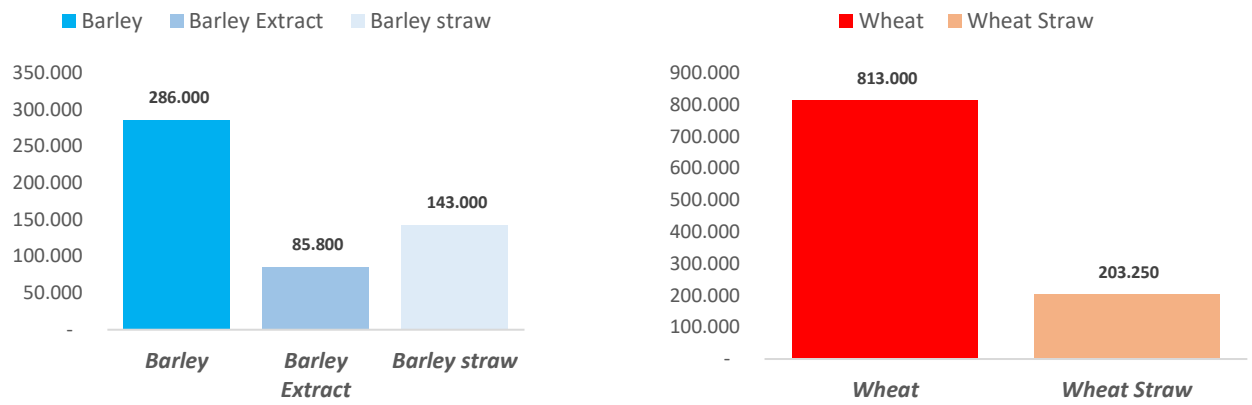

Figure 38 *Comparison of Production Volumes (tonnes) of primary biomass (barley; wheat) and secondary biomass (barley extract, barley straw; wheat straw) (Croatian Bureau of statistics, 2023).*

As illustrated in **Figure 23**, wheat is the second most cultivated grain in Austria, covering around 170.000 hectares[64]. It is primarily grown for food production, with an average annual output of approximately 813.000 tonnes. **Barley** is another important cereal crop in Croatia, mainly used for animal feed and malting. Barley cultivation spans about 67.000 hectares, emphasising its importance in both local consumptions.

ALFALFA, RAPESEED, SUGAR BEET & MISCANTHUS

Figure 39 presents the production volumes (tonnes) of primary and secondary biomasses not covered in the previous figure: sugar beet, alfalfa, alfalfa fibre, miscanthus, rapeseed, and rapeseed oil.

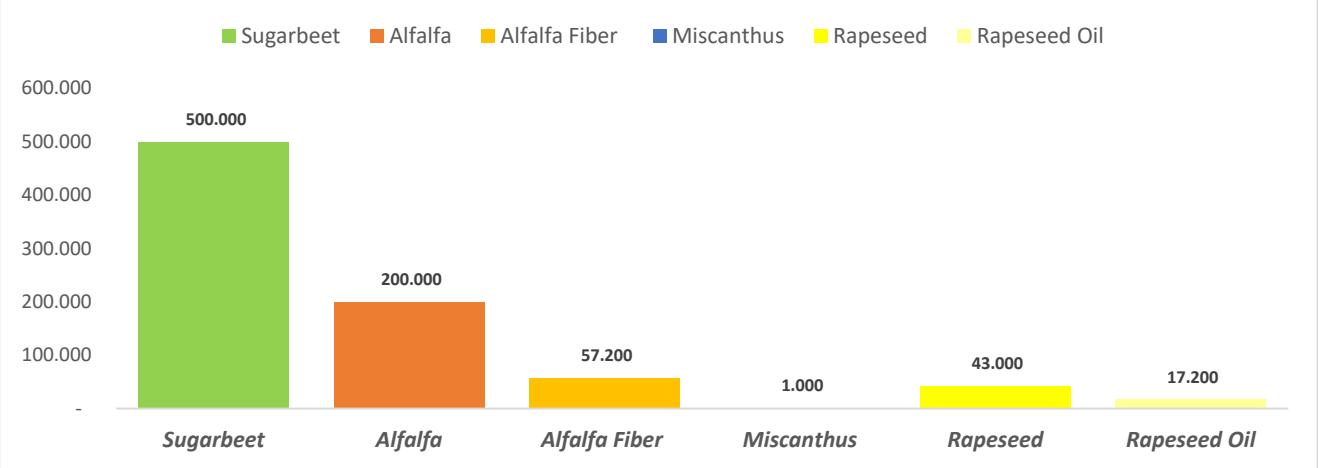

Figure 39 *Comparison of Production Volumes (tonnes) of primary biomass (sugar beet; alfalfa; miscanthus; rapeseed) and secondary biomass (alfalfa fibre; rapeseed oil) (Croatian Bureau of statistics, 2023).*

Among these, **sugar beet** stands out as a major product in Croatian agriculture, with a production volume of 500.000 tonnes. This significantly surpasses the production of other key crops such as soya and barley, underscoring sugar beet's dominant role in the agricultural sector. **Alfalfa** follows with a production volume of 200.000 tonnes, while its byproduct, alfalfa fibre, contributes 57.200 tonnes. **Rapeseed** has a production of 43.000 tonnes, and its derivative, rapeseed oil, is produced in smaller quantities, amounting to 17.200 tonnes.

OTHERS INDUSTRIAL BYPRODUCTS

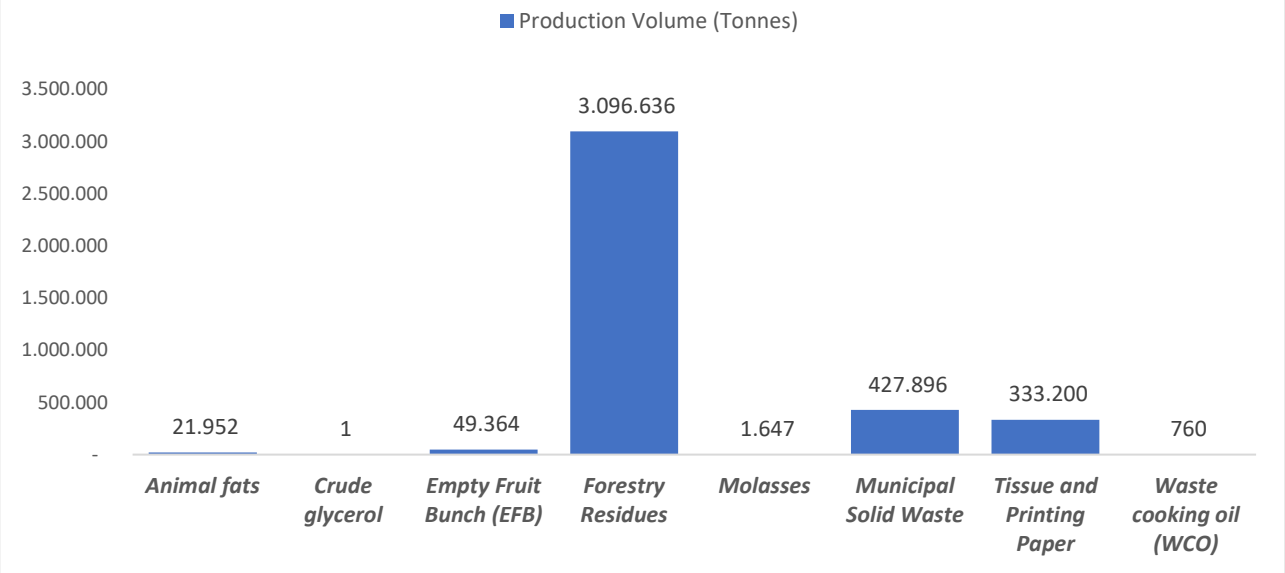

Figure 40 *Comparison of Production Volumes (tonnes) of industrial byproducts (Animal Fats, Crude Glycerol, Empty fruit bunch, Forestry residues, Molasses, Municipal solid waste, Tissue and printing pater, waste cooking oil) (Croatian Bureau of statistics, 2023).*

Figure 40 illustrates the production volume (tonnes) of various waste materials in Croatia. **Forestry Residues** dominate with a production volume of 3.096.636 tonnes, underscoring their significant potential for biomass utilization in Croatia. The **Municipal Solid Waste** follows with 427.896 tonnes, reflecting the importance of the need to implement effective waste management strategies in urban areas. **Tissue and Printing Paper waste** amounts to 333.200 tonnes, highlighting a considerable opportunity for recycling efforts. **Empty Fruit Bunch (EFB),** a byproduct primarily from the agriculture sector, amounts to 49.364 tonnes, which could be further exploited for energy production or agricultural reuse. **Waste Cooking Oil** (760 tonnes) presents a modest yet valuable resource for biodiesel production. Follows **Animal Fats** (21.952 tonnes) that can be utilized in biodiesel production or other industrial applications and **Molasses** (1.647 tonnes) a byproduct of sugar processing that can be utilised in bioethanol production. **Crude Glycerol** has the smallest volume of 1 tonne, being a by-product of biodiesel production, with applications in various chemical processes.

2.6 Slovenia

2.6.1 Slovenian Biomass Availability

This section explores the specific types of biomass resources available across all of Slovenia. By leveraging these abundant biomass resources, Slovenia is strategically positioned to expand its renewable energy portfolio and advance towards a greener future.

An analysis of primary biomass data from Slovenian sources clearly shows how the country's seven key biomass types can significantly contribute to the production of a wide array of biobased materials. **Table 6** illustrates that the total cultivated area for these major biomass types amounts to 119.045 hectares, yielding a combined primary biomass production of 1.973.181 tonnes[64].

Table 6 *Slovenia's primary biomass availability (Slovenia's Bureau of Statistics, 2023).*

Type of biomass	Cultivated Area (Hectare)	Production Volume (Tonnes)
Barley	19.284	50.484
Maize	67.804	1.774.880
Wheat	28.251	138.000
Rapeseed	2.831	7.297
Oat	875	2.520
TOTALS	**119.045**	**1.973.181**

The Slovenia Cultivated Area and Production Volume calculated as a percentage are shown in **Figure 41**. Maize dominates the ***Cultivated Area***, occupying 57% of the total agricultural land. This is followed by Wheat (24%), Barley (16%), and finally, Rapeseed and Oat at less than 2% of the national cultivated land. The distribution of these crops reflects Slovenia agricultural priorities and environmental conditions, where Maize and Wheat are particularly well-suited to the country's diverse climate and soil types.

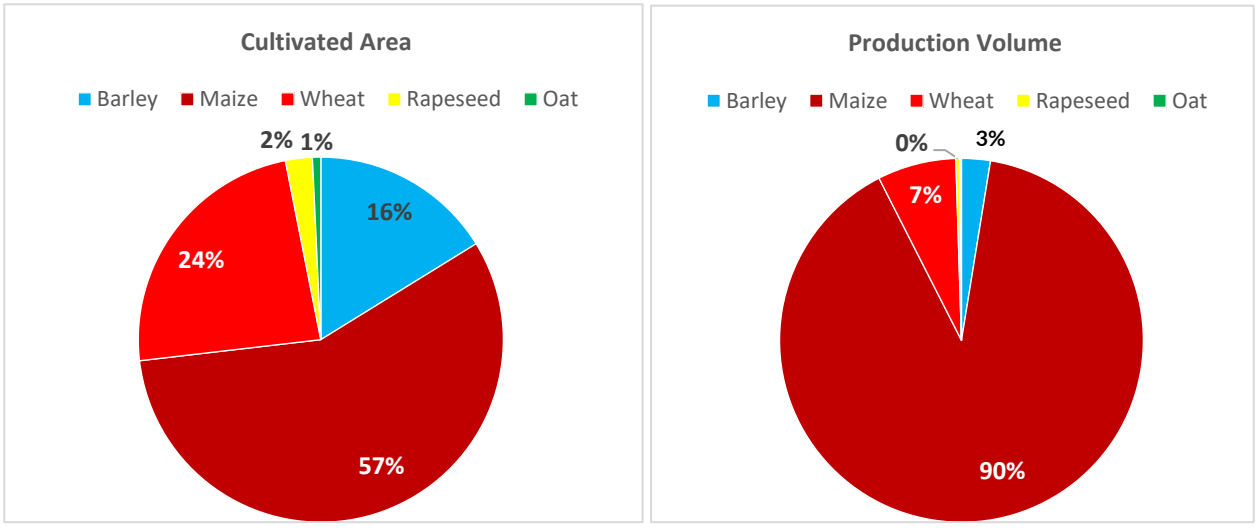

Figure 41 *Slovenian Cultivated Area and Production Volume percentages (Slovenia's Bureau of statistics, 2023).*

Examining the ***Production Volume***, *Maize* emerges as the most significant contributor, representing almost the total biomass production (90%). This dominance underscores its critical role in Slovenia agriculture, where it is primarily used for human consumption, but also thrives in the Slovenian temperate climate. Wheat and Barley are the other crops present with respectively 7% and 3%. The remaining biomasses are only present in small traces with an overall production that can be approximated to zero.

2.6.2 Slovenian Biomass Distribution

BARLEY & WHEAT

As illustrated in **Figure 42**, wheat is the second most cultivated grain in Slovenia, covering around 170.000 hectares[65]. It is primarily grown for food production, with an average annual output of approximately 813.000 tonnes.

Barley is another important cereal crop in Slovenia, mainly used for animal feed and malting. Barley cultivation spans about 67.000 hectares, emphasising its importance in both local consumptions.

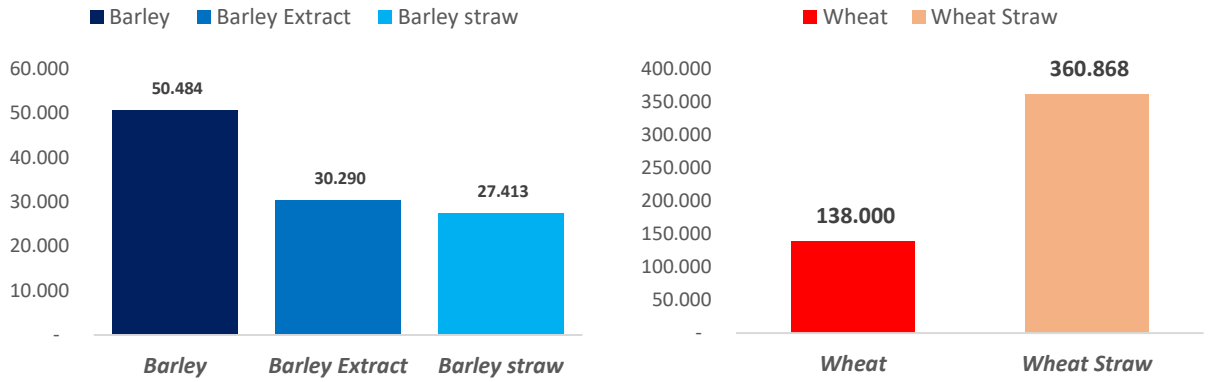

Figure 42 *Comparison of Production Volumes (tonnes) of primary biomass (barley; wheat) and secondary biomass (barley extract, barley straw; wheat straw) (Slovenia's Bureau of statistics, 2023).*

MAIZE & OAT & RAPESEED

Figure 43 illustrates the production volume of Maize and Oat alongside their secondary biomasses.

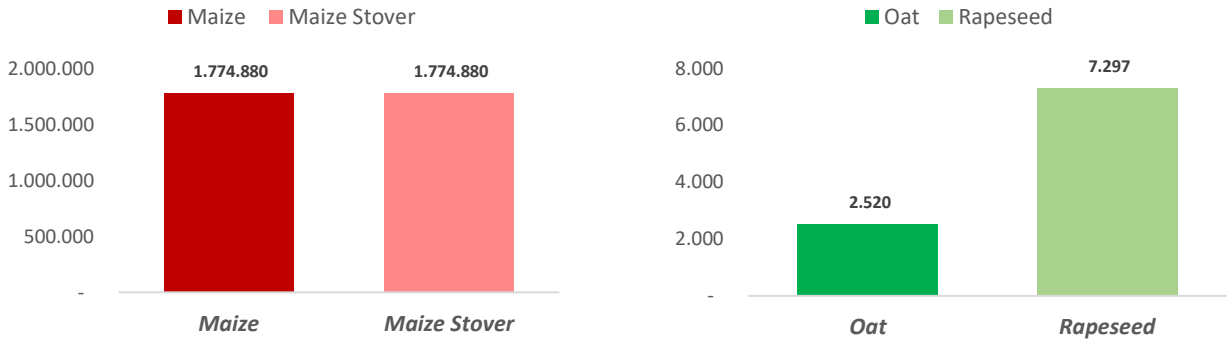

Figure 43 *Comparison of Production Volumes (tonnes) of primary biomass (Oat; Rapeseed; Maize) and secondary biomass (maize stover) (Statistik.at, 2023).*

OTHER INDUSTRIAL BYPRODUCTS

Figure 44 illustrates the production volume of various waste materials in Slovenia, measured in tonnes. **Tissue and Printing Paper waste** dominates with a production volume of 938.647 tonnes, underscoring their significant potential for biomass utilization in Slovenia. **Municipal Solid Waste** is the second-largest contributor at 385.200 tonnes, reflecting the importance of the need to implement effective waste management strategies in urban areas. **Forestry Residues** amounts to 49.046 tonnes, highlighting a considerable opportunity for recycling efforts. **Waste Cooking Oil**, with 3.680 tonnes, presents a modest yet valuable resource for biodiesel production. **Animal waste** contributes 54.750 tonnes and can be utilized in biodiesel production or other industrial applications. **Whey Protein Hydrolysate**, shows a production volume of 33.564 tonnes, indicating its potential for bioethanol production.

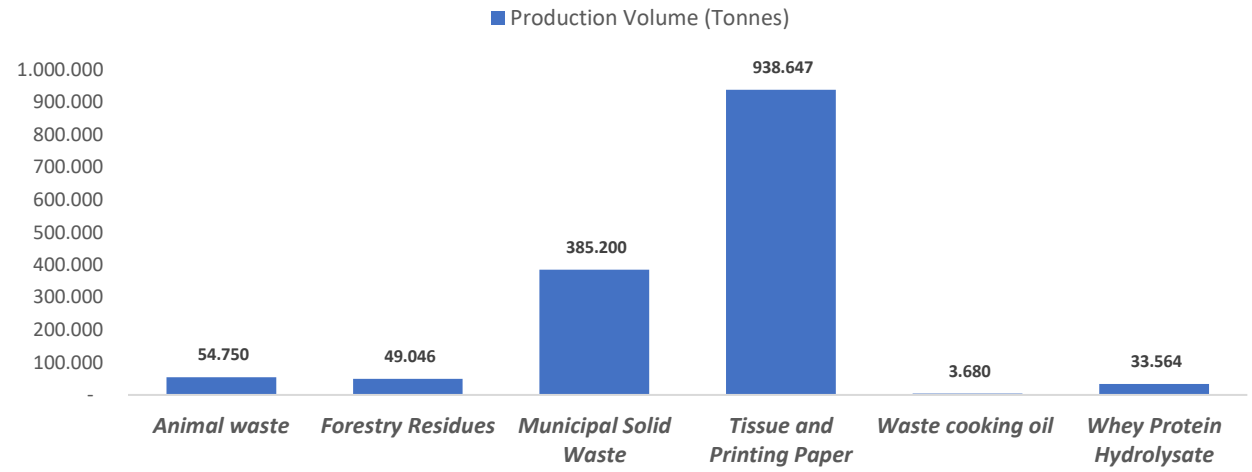

Figure 44 *Comparison of Production Volumes (tonnes) of Animal waste, Forestry residues, Municipal Solid Waste, Tissue and printing paper, Waste cooking oil, Whey Protein Hydrolysate (Statistik.at, 2023).*

3. Regional availability of technologies and implementation of Business models

The Regional Hub Handbook (D1.1) also includes mature and validated industrial technologies capable of converting the identified primary or secondary biomass into 12 promising biobased final products that are in significant or growing demand among bioeconomy stakeholders. The analysis also considers technologies that could produce these products from alternative biomass sources not specified in the Handbook, as well as the presence of industrial plants utilizing these technologies to produce the products as reaction intermediates. This approach is based on the principle that the industrial system could, in theory, be adapted to convert secondary biomass into the final products, ranking the technology as 'adaptable'.

This section of the report presents an extensive examination of innovative technologies leveraging biomass across different regions. The comprehensive study focused on identifying and analysing companies and research entities that are at the forefront of producing high-value molecules derived from bio-based raw materials. By systematically mapping these entities, the study aimed to provide a detailed overview of the current landscape of biomass utilisation and technological development within the pilot regions.

Identifying the regional distribution of technological advances and business models is essential for understanding where biomass utilisation is most prevalent and effective. This regional mapping is crucial because it reveals the strengths and weaknesses across different regions, offering valuable insights into areas of excellence and those requiring further attention. Moreover, the availability of technologies is critical to enabling industrial symbiosis and establishing new value chains; even if there is abundant biomass in a region, the absence of relevant technologies and processing plants at the territorial level will hinder the development of these value chains.

This study is essential to identify where to focus efforts, where to invest, and which products and types of biomasses are most promising to work with. By understanding these regional dynamics and the interplay between biomass availability and technological readiness, stakeholders can make informed decisions to strategically allocate resources, foster growth, and drive innovation. Additionally, the study highlights the diverse applications of biomass technologies, from biofuels and bioplastics production to bioenergy and biochemical products, demonstrating the versatility of biomass as a sustainable resource with significant potential to contribute to the circular economy. The mapping also includes a detailed analysis of the business models employed by companies and research institutions, providing essential insights into the viability and scalability of these technologies, as well as the operational strategies and challenges faced by these entities. The following subsections provide an overview of the technologies involved. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

3.1 Italy

Italy is increasingly recognizing the critical role of transitioning towards a circular economy, where waste and by-products from one process are converted into valuable resources for another. The country's strong agricultural and industrial sectors provide a rich and diverse source of biomass, including agricultural waste, forestry residues, and by-products from food processing industries. This abundance of raw materials has catalysed innovation in developing technologies that convert these resources into high-value chemicals, biofuels, and bioplastics, driving the nation's move towards a more sustainable and resilient economy.

The study revealed a substantial and growing push across Italy in the production of high-value molecules from biomass and agricultural waste. This trend is evident in the increasing number of companies and research institutions actively engaged in the development and commercialization of these innovative technologies. The focus has expanded beyond traditional biofuels, such as biodiesel and bioethanol, to include a broad spectrum of biochemicals and bioplastics that are essential for various industrial applications, demonstrating Italy's commitment to diversifying its bio-based economy.

Key technologies and production facilities were identified and mapped across the selected regions, providing a detailed overview of the current state of biomass utilisation in the country. Notably, many of these production plants are classified as 'adaptable', meaning they do not produce the specific molecules directly but generate them as intermediate products during the production process. For example, several biodiesel production facilities also produce glycerol as a by-product, and acetic acid is formed during the production of bioethanol. Among the most prominent molecules being produced are lactic acid and its derivative, polylactic acid (PLA), which are integral to the production of bioplastics. Biodiesel production, which generates glycerol as a by-product, and bioethanol production, with acetic acid as a secondary product, were also prominently featured in the study. These molecules are crucial to the sustainable production of chemicals and materials that can replace their fossil-fuel-based alternatives, contributing to a more circular and environmentally friendly economy.

The study did not identify specific technologies capable of directly converting the selected biomass types into the targeted products. This is largely because many plants process a mix of different biomasses and agricultural waste, or they use biomass with characteristics like those identified in the study. Nevertheless, the overall prospects remain positive, as many of the technologies mapped are adaptable. This adaptability suggests significant potential for future modifications and innovations, enabling these plants to process a broader range of biomass types. This flexibility could further strengthen Italy's ability to contribute to a sustainable bio-based economy.

Despite the overall progress, the study revealed certain gaps in Italy's production landscape. There is a notable absence of biobased production at scale for specific key molecules, such as sorbitol, lysine, glutamic acid, and 1,3-propanediol, which have significant industrial applications This gap suggests opportunities for further research and development to expand the range of bio-based molecules being produced in the country.

The study also highlighted the regional specialisations that have emerged across Italy. Lombardy, for example, has established itself as a leader in the production of lactic acid and PLA, while Piedmont is noted for its advancements in bioethanol and bioplastics production. Emilia Romagna has made significant progress in utilising agricultural waste for biodiesel production and converting wastewater sludge into bioplastics. These regional specialisations reflect the diverse industrial and agricultural bases of each area and underscore the potential for collaborations and knowledge sharing across regions.

The regions covered in this study include Lombardy, Piedmont, Veneto, Friuli Venezia Giulia, and Emilia Romagna, each contributing unique expertise and resources to Italy's growing bioeconomy.

LOMBARDY

Lombardy stands out as a central hub of innovation in biomass technologies, with several key players leading significant advancements in the sector.

- An innovative SME, associated with a prominent academic institution[66] has developed an **advanced bioprocess that is revolutionising the production of lactic acid and polylactic acid (PLA)**, crucial components in the creation of sustainable bioplastics and biobased materials. Their innovative approach leverages the **fermentation of a recombinant yeast strain, allowing for the synthesis of PLA in a single step**. This innovation not only streamlines the production process but also highlights Lombardy's leading role in biotechnology, particularly in the development of sustainable materials that contribute to the circular economy.
- One of Europe's leading producers of oleochemicals, including fatty acids and glycerine, is focused on operations that are deeply rooted in the principles of circular economy, as the company efficiently utilizers by-products from the food industry as raw materials for its production processes. This commitment to sustainable practices is further demonstrated by their involvement in the **production of adipic acid from vegetable oils and lignocellulosic biomass**. Adipic acid is a key building block in the manufacturing of various bio-based chemicals this innovative production of adipic acid from renewable resources like vegetable oils and lignocellulosic biomass reinforces Lombardy's prominence in biomass conversion and bio-based chemical development.

These companies exemplify Lombardy's strength and leadership in biomass technology, contributing to the region's economic growth but are also setting new standards for sustainability and innovation in the bioeconomy. Their work underscores Lombardy's ability to harness cutting-edge biotechnology and circular economy principles to create a more sustainable future, positioning the region as a beacon of progress in the global transition towards greener industrial practices.

PIEDMONT

Piedmont is another region in Italy with a strong focus on biomass technologies, with a particular emphasis in the production of sustainable chemicals and bioplastics. The region is home to several key players who are pushing the boundaries of what is possible with renewable resources.

- A leader in green chemistry[68] is at the forefront of producing furfural, a versatile chemical used in a variety of industrial applications, from starches, celluloses, and vegetable oils. This achievement underscores Piedmont's expertise in chemical synthesis, particularly in **harnessing renewable resources to create high-value chemicals**. By focusing on the conversion of abundant and renewable feedstocks into essential industrial compounds, this player exemplifies Piedmont's commitment to sustainable innovation.
- A flagship bioethanol facility within the region[69], showcasing Piedmont's leadership in advanced bioethanol. This state-of-the-art plant specialises in the production of **advanced bioethanol derived from lignocellulosic biomass**, which is composed of plant dry matter such as wood, straw, and other fibrous materials. It also generates **acetic acid as a secondary product**, demonstrating its efficiency, illustrating its efficiency in maximising the value extracted from biomass. This dual-output process highlights the plant's role in promoting a more sustainable and circular approach to industrial production, where even by-products are efficiently utilized.
- A company with a significant role in the region's bioplastics sector[70], **producing PLA** and polyhydroxyalkanoates (PHA) through **enzymatic hydrolysis and advanced polymerization techniques**. Their high-quality bioplastics can replace conventional plastics in a wide range of applications, supporting the global shift towards more sustainable materials and reinforcing Piedmont's leadership in cutting-edge materials innovation.

Collectively, these companies and facilities illustrate Piedmont's strong focus on and expertise in biomass technologies. The region's emphasis on sustainable chemical production and bioplastics not only contributes to the local economy but also positions Piedmont as a critical player in the global transition towards a more sustainable, bio-based economy. Through innovation and a commitment to utilising renewable resources, Piedmont is setting a benchmark for other regions to follow in the field of biomass technology.

EMILIA ROMAGNA

Emilia Romagna has emerged as a leader in biofuel technologies, with significant advancements in both biodiesel and bioethanol production through innovative approaches, driving the region's progress towards sustainable energy solutions.

- A key player in the biofuel industry [71], uses **advanced transesterification processes to convert vegetable oils into biodiesel**, a key renewable fuel. This advanced technology not only enhances the efficiency of biodiesel production but also underscores Emilia Romagna's commitment to reducing reliance on fossil fuels and advancing renewable energy sources.
- A pioneer in bioethanol from agricultural by-products [72] from the winemaking industry, transforms the **residues into bioethanol**. This innovative approach not only adds significant value to agricultural waste but also contributes to the circular economy by turning what would otherwise be discarded into a high-value renewable fuel. This work exemplifies the region's dedication to sustainable practices and the efficient use of natural resources.
- A bioplastics innovator [73] has developed an **innovative process for converting wastewater sludge into bioplastics**, particularly polyhydroxyalkanoates (PHA). This technology addresses waste management and renewable and biodegradable production materials challenges simultaneously, reducing the environmental burden of waste disposal and rising the growing demand for sustainable alternatives to conventional plastics. This positions Emilia Romagna as a leader in integrated biomass solutions, demonstrating the region's ability to innovate at the intersection of waste management and renewable material production.

Collectively, these efforts position Emilia Romagna as a leader in the bioeconomy, showcasing its ability to harness diverse biomass resources to produce both energy and materials in a sustainable manner. The region's focus on advanced technologies and innovative solutions is paving the way for a more sustainable future, reinforcing its position as a key player in the global shift toward renewable energy and sustainable materials.

VENETO

Veneto has emerged as a dynamic player in the field of biomass technologies, with a strong focus on bioplastics and biofuels. This region's commitment to sustainability is evident through its innovative use of local resources and cutting-edge technologies.

- A bioplastics innovator [74] operates a pilot plant dedicated to the **production of polyhydroxyalkanoates (PHA) from agricultural waste**. This initiative not only showcases Veneto's commitment to transforming agricultural residues into high-value bioplastics but also highlights the region's broader dedication to sustainable production practices. By focusing on PHA, a biodegradable polymer with wide-ranging applications, it demonstrates Veneto's dedication to creating eco-friendly materials while leveraging local resources for sustainable production practices.

- A key biofuel facility [75] plays a significant role in the industry, becoming part of Italy's strategy of integrating renewable sources into its energy matrix. The refinery specialises in the **production of biodiesel through the transesterification of vegetable oils and animal fats**. The facility significantly contributes to reducing dependence on fossil fuels and integrates renewable energy into Italy's energy mix, enhancing both regional and national energy security.
- A bioethanol technology pioneer [76] contributes to the region's technological innovation by providing a pilot plant for bioethanol production. This facility serves as a crucial platform for **real-time experimentation and optimization of bioethanol production processes**. By enabling both research and industrial applications, it supports the ongoing development and refinement of bioethanol technologies, positioning Veneto as a key player in the advancement of biofuels.

Collectively, these initiatives underline Veneto's leadership in biomass technologies, highlighting its ability to transform local resources into sustainable energy and materials. The region is firmly positioned as a key player in Italy's transition to renewable energy and sustainable industrial practices.

FRIULI VENEZIA GIULIA

Unlike other regions where a single company may dominate the biomass landscape, Friuli Venezia Giulia's approach is more decentralized, relying on collective efforts to drive innovation and development in biomass technologies. This collaborative model underscores the importance of regional cooperation in advancing sustainable energy practices, demonstrating how community involvement can be a powerful force in the bioeconomy.

The initiatives in Friuli Venezia Giulia underscore the region's proactive commitment in promoting biodiesel production from a variety of vegetable oils. This effort is marked by strong collaboration among a wide range of stakeholders, including local agricultural operators, showcasing a community-driven approach to biomass development. Rather than being led by a single dominant company, the region's collective efforts emphasise the importance of regional cooperation in advancing biomass technologies. This collaborative initiative not only highlights Friuli Venezia Giulia's role in promoting sustainable energy solutions, but also demonstrates the power of using local resources and shared innovation to drive progress in the bioeconomy.

3.2 Austria

The recent mapping of production technologies and facilities in Carinthia has revealed promising insights, particularly in the fields of lactic acid and glycerol production. These findings underscore Carinthia's emerging role as a key player in sustainable chemical production and highlight the region's potential to further expand its bio-based industrial sector.

Carinthia is already home to operational facilities that are producing lactic acid and glycerol as byproducts. These could potentially be marketed as standalone products. For instance, glycerol, a valuable by-product of biodiesel production, is generated by companies which transforms waste oils and fats into biodiesel [77].

In addition to these existing operations, Carinthia hosts facilities with significant potential for adaptation to produce other bio-based chemicals. For instance, a leader in the paper industry [78], both present promising opportunities for the production of bio-based chemicals such as sorbitol. These facilities, while not currently dedicated to the specific molecules under study, could provide the necessary technological infrastructure to be adapted for this purpose. This highlights Carinthia's potential to diversify and expand its range of bio-based products, further strengthening its contribution to the bioeconomy.

A list of major target companies for different target products can be found below.

POTENTIAL LACTIC ACID PRODUCTION

- **O**ne of Carinthia's largest and most renowned breweries [79] is pioneering lactic acid production in the region. Utilizing **fermentation processes to extract lactic acid from barley**, the company contributes to industries like food preservation, pharmaceuticals, and biodegradable plastics. This innovation exemplifies how traditional industries can pivot towards the bioeconomy.
- Another biotechnology company, with expertise in **enzymatic hydrolysis to produce hydrolysed proteins**, has the potential to enter the lactic acid market. Their expertise in biotechnological processes positions them for future diversification into bio-based products.
- A dairy cooperative [80] integrates **sustainable farming practices with the production of lactic acid from hydrolysed proteins**. Their commitment to high-quality dairy and sustainable operations makes them a vital contributor to Carinthia's bioeconomy.

POTENTIAL GLYCEROL PRODUCTION

- A key player in Carinthia's circular economy converts **waste cooking oils and fats into biodiesel**, generating glycerol as a by-product. This glycerol is valuable in the pharmaceutical, cosmetic, and food industries, showcasing the company's role in sustainable resource utilization.

POTENTIAL SORBITOL PRODUCTION POTENTIAL

- A prominent paper and packaging producer in Carinthia, is distinguished by its state-of-the-art production facilities and forward-thinking corporate strategy. Although the company primarily focuses on kraft paper and specialty pulp, its **advanced processing** capabilities indicate **significant potential for diversification into bio-based chemical production**, such as sorbitol. Sorbitol could be manufactured by harnessing the existing infrastructure and expertise in biomass processing. This expansion would further broaden the region's bio-based product portfolio and enhance its contribution to the bioeconomy.

Overall, Carinthia's industrial landscape is well-positioned for growth in the bio-based sector, with existing technologies and facilities that can be adapted to meet future demands. This adaptability, combined with the region's current capabilities, ensures that Carinthia will continue to play a significant role in the development of a sustainable bio-based economy. Potential barriers refer to the fact that no platform chemicals are currently produced in this way, and mapping secondary biomass is challenging due to limited data availability. The process relies heavily on conversion factors, and data gaps remain, making accurate assessments difficult.

3.3 Belgium

Belgium is a global leader in the bio-based industry, with a strong presence in sustainable chemistry and biotechnology across its key regions: Flanders, Brussels, and Wallonia. These regions are central to Belgium's commitment to developing and scaling environmentally friendly, sustainable solutions. They foster a dynamic ecosystem of companies, research institutions, and pilot plants that are driving advancements in bio-based chemicals and materials. By leveraging its strategic geographic location, skilled workforce, and advanced infrastructure, Belgium has created an environment that encourages innovation and collaboration within the bioeconomy.

Flanders, Brussels, and Wallonia together host a diverse network of enterprises, ranging from small start-ups to large multinational corporations, all dedicated to developing sustainable technologies. This network is further strengthened by numerous research centres and universities, which play a pivotal role in pioneering breakthroughs in bio-based chemistry, biotechnology, and green processes. Additionally, the regions feature pilot facilities and industrial hubs that enable the transition from laboratory-scale innovations to industrial-scale production, facilitating the commercialization of new bio-based products.

FLANDERS

Flanders is at the forefront of Belgium's bio-based industry, boasting a robust infrastructure and a strong industrial base that focuses on sustainable chemistry and biotechnology.

- **Glycerol:** Flanders hosts companies [81-83] leading in producing eco-friendly chemicals, such as a pioneer in biodegradable cleaning products and a company specializes in oleochemicals, including glycerol, derived from natural oils and fats. A Pilot Plant[84] in Ghent is a key facility for scaling up biotechnological processes, providing services from lab research to industrial production, including glycerol.
- **Succinic Acid:** A collaboration between industry and academia [85] is advancing the production of bio-based succinic acid, a crucial component for biodegradable plastics and other sustainable materials. This partnership underscores the region's dedication to green chemistry.
- **PHA (Polyhydroxyalkanoates):** Significant progress has been made in producing PHA, a versatile bioplastic, reinforcing Flanders' position as a leader in sustainable materials development.
- **Lysine: Advanced biotechnology and fermentation** techniques are utilized **to produce lysine** [86], an essential amino acid with applications in food and pharmaceuticals, showcasing the integration of biotechnology into the region's industrial landscape.

BRUSSELS

Brussels is an important hub for bio-based technologies, particularly in fermentation and bio-based chemical production.

- **Lactic Acid:** Companies [87-88] in the region are leaders in the **production of lactic acid, using sugar-rich biomass such as maize and sugar beets**. These firms are also pivotal in the commercialization of bioplastics like PLA (Polylactic Acid), a sustainable alternative to traditional plastics.
- Although there is no direct producer of glycerol from biomass in Brussels, a specific company [89] generates **glycerol as a by-product of its biodiesel production**, **integrating sustainable practices** into the region's chemical sector.
- Organizations promoting bioenergy and bio-based industries across Europe [90] supports the growth of bioenergy and bio-based industries across Europe, promoting the use of various **biomass feedstocks to produce chemicals like sorbitol**.

WALLONIA

Wallonia, with its strong industrial heritage, plays a significant role in Belgium's green chemistry sector, focusing on sustainable production and innovation.

- A prominent producer in Wallonia focuses on creating **glycerol and other oleochemicals from renewable raw materials**. The company is a leader in sustainable chemical production, serving industries ranging from cosmetics to food.
- The region was previously home to a pioneer in bio-based succinic acid production through fermentation [91]. While the company is no longer operational, its influence continues to inspire advancements in green chemistry in Wallonia.

Each of Belgium's regions offers unique strengths and opportunities in the bio-based and sustainable chemistry sectors. Flanders leads with its advanced infrastructure and industrial capacity, Brussels excels in fermentation and bio-based chemical production, and Wallonia draws on its industrial heritage to drive innovation in green chemistry. Together, these regions are positioning Belgium as a key player in Europe's transition to a more sustainable, bio-based economy.

3.4 Spain

The mapping of biomass and agricultural waste technologies in Andalusia highlights the region's commitment to sustainable development through the utilization of bio-based resources. Andalusia is making significant advancements in biomass technology, as evidenced by key facilities engaged in the production of essential molecules such as lactic acid and biodiesel, the latter also yielding glycerol as a valuable by-product. However, despite this progress, there are notable gaps in the production of other crucial bio-based chemicals, such as sorbitol, furfural, acetic acid, and 1,3-propanediol, which are integral to various industrial processes.

The absence of large-scale production of these chemicals can be attributed to several factors. First, the current industrial focus in Andalusia is predominantly on the production of biofuels and related by-products like glycerol, which aligns with the region's strong emphasis on renewable energy and circular economy principles. Additionally, the infrastructure and expertise required to diversify into the production of more complex bio-based chemicals are still developing. While there is potential for growth, the transition to manufacturing these chemicals at scale will require significant investment in research, technology, and infrastructure[92,93].

A list of major target companies for different target products can be found below.

LACTIC ACID PRODUCTION

- A prominent company specializes in the production of plant-based proteins [94], has diversified its operations to include the production of food ingredients for industries such as pharmaceuticals and cosmetics. The company utilizes **fermentation and enzymatic hydrolysis of whey protein hydrolysate to produce lactic acid**, which is a critical component in various applications, including the production of biodegradable plastics. This facility underscores Andalusia's capacity to contribute to sustainable industrial processes through bio-based innovations.

GLYCEROL PRODUCTION

- A major player in Andalusia's biofuel sector [95], with an impressive production capacity of 240,000 tonnes of biodiesel per year, 480,000 tonnes of refined oil for hydrotreatment (HVO), and 20,000 tonnes of glycerine annually, finds applications across multiple industries, including pharmaceuticals and cosmetics. It exemplifies the region's ability to integrate circular economy

practices into its industrial activities, enhancing the overall sustainability of its bio-based production.

GLYCEROL, LYSINE, AND GLUTAMIC ACID PRODUCTION

- A company at the forefront of **processing sugar molasses distillation stillage** [96], operating under a circular economy model, extracts and optimizes resources from molasses to produce soluble molasses condensate (C.M.S.), rich in carboxylic acid groups, vegetable proteins, trace elements, and short-chain organic acids. Through this process, the division also produces lysine and glutamic acid, essential amino acids used in the animal feed and food industries. This approach not only maximizes resource efficiency but also contributes to Andalusia's growing bioeconomy.

SUCCINIC ACID AND PHA PRODUCTION

- An Organic Recycling Facility transforms **urban, agricultural, and livestock residues into compost, organic fertilizers, and biofuels**. The company [97] has also pioneered the production of succinic acid and polyhydroxyalkanoates (PHA), which are vital for creating biodegradable plastics and other bio-based materials. These innovations are crucial for improving soil health, enhancing food quality, and reducing greenhouse gas emissions, underscoring the facility's role in Andalusia's sustainable development.

While Andalusia has made significant advances in the production of certain bio-based chemicals, there remains considerable untapped potential in the region. By addressing the current gaps and expanding its technological capabilities, Andalusia can further establish itself as a leader in the bioeconomy, driving innovation and sustainability in both local and global markets.

3.5 Croatia

Croatia is in the early stages of developing its capacity for sustainable chemical production, particularly in areas like glycerol, polyhydroxyalkanoates (PHA), succinic acid, and sorbitol. While there are promising initiatives and investments in green technologies and circular economy practices, the infrastructure and technological advancements required for large-scale production of bio-based chemicals from biomass are still underdeveloped. This section outlines key players and their current efforts, along with the challenges they face in scaling these sustainable solutions.

GLYCEROL, PHA AND SUCCINIC ACID PRODUCTION

- A leading Croatian company specialising in the ecological disposal of animal and plant by-products [98] and biodegradable waste processes these **by-products into raw materials for biodiesel and pet food**, aligning with circular economy principles. However, its operations focus on waste processing rather than fully utilising biomass for large-scale bio-based chemical production.
- A company dedicated to bridging research and practical application [99] focuses on the development of **biodegradable and compostable materials from biological sources**. Despite significant progress in creating prototypes to replace traditional plastics, these innovations are not yet fully commercialised as the lack of advanced production facilities limits the readiness of these materials for large-scale industrial use.
- Different University Research are based on Bio-Based Chemicals [100], play a key role in Croatia's bioeconomy through research on **bio-based materials and chemical engineering**. However, a major hurdle remains in transitioning from lab-scale research to industrial-scale production. The

necessary infrastructure and technological advancements required for large-scale production of bio-based chemicals like PHA and succinic acid from biomass are not yet fully developed. The Faculty of Forestry and Wood Technology focuses on **sustainable forest management, conservation practices, and the development of eco-friendly technologies related to wood processing**. The faculty is also involved in interdisciplinary projects that connect forestry with other sectors, promoting the idea of a **bio-based economy that benefits both the environment and the economy**, addressing pressing environmental challenges and promote sustainable practices in forestry and wood utilisation.

SORBITOL PRODUCTION

- A company [101] involved in packaging and paper production integrates. Although there is interest in bio-based chemicals such as sorbitol, the company currently lacks the capability to produce these chemicals on a large scale from biomass. This gap highlights Croatia's broader challenge in transitioning from conventional production methods to more sustainable alternatives using renewable resources.

Croatia is making strides in bio-based chemical production technologies, but significant gaps remain in infrastructure and industrial-scale capabilities. Companies and research institutions are pioneering innovative approaches, yet commercialization and scalability are limited. To unlock its full potential in sustainable chemistry, Croatia needs targeted investments in infrastructure, technology development, and the scaling of bio-based solutions. Addressing these challenges will position the country to better contribute to the global shift toward a sustainable bioeconomy.

3.6 Slovenia

In Slovenia, no companies or production facilities currently manufacture the specific products studied—such as lactic acid, adipic acid, and furfural—directly from biomass or waste. However, there are opportunities to integrate bio-based production into existing industries, transforming traditional processes into more sustainable operations. This section identifies key actors and the potential for future advancements in Slovenia's bio-based chemical industry.

LACTIC ACID PRODUCTION

- The Slovenia's largest company in water supply [102], wastewater treatment, and waste management, operates the **Regional Waste Management Centre in Ljubljana (RCERO Ljubljana)**, one of Europe's most advanced waste treatment plants. Although the facility excels in waste management, it does not currently produce lactic acid or other bio-based chemicals from waste. However, the infrastructure and expertise at RCERO Ljubljana provide a foundation for exploring lactic acid production from waste, adding value to waste management processes.

ADIPIC ACID PRODUCTION

- A leading Slovenian institute focuses on materials science [103], life sciences, and chemical engineering. While the Institute is heavily involved in biotechnology and sustainable development research, it does not currently produce adipic acid from biomass at an industrial scale. However, its alignment with EU priorities, such as Horizon 2020, positions the Institute to explore bio-based chemical production in the future, offering Slovenia a potential path to innovate in the production of adipic acid from renewable sources.

FURFURAL PRODUCTION

- A well-established company [104] specializes in plant extracts for industries such as leather, animal nutrition, and food. While is does not currently produce furfural from biomass, its expertise in plant-based extraction processes could be expanded to include furfural production. An investment in technology and process development and diversifying into furfural production from biomass would enhance its role in Slovenia's bio-based economy and contribute to the production of high-value chemicals.

Slovenia is poised to explore significant opportunities in the bio-based chemical industry. While no companies currently produce bio-based chemicals like lactic acid or furfural from biomass, existing companies and research institutions have the potential to integrate biomass-based production into their operations. However, a clear gap exists between current research capabilities and industrial production. Bridging this gap will require scaling up from research to industrial application, investing in new technologies, and fostering collaboration between industry and academia. Although Slovenia is at the beginning stages, significant efforts could develop a robust bio-based sector.

4. Bio-based Industries Innovation Ecosystem Mapping

4.1 Introduction

While the geographic proximity of biobased materials and technologies is recognised as a primary driver of industrial symbiosis in bio-based industries[105], the regional innovation ecosystems also play an important role in facilitating and accelerating industrial symbiosis[106]. The framework conditions that enable the development of bio-based business models are highly complex and operate at multiple levels, from national innovation policies that favour the bioeconomy at the macro-level to firm-level strategies and actions that enable or hinder resource flows at the meso- and micro-level. Here, however, we focus on the meso-level regional triggers, enablers and barriers to bio-based circular business by adopting an innovation ecosystem approach.

In their analysis of circular innovation ecosystems, Konietzko et al.[107] describe an innovation ecosystem as *'a set of actors – producers, suppliers, service providers, end users, regulators, civil society organisations – that contribute to a collective outcome'*. To support innovation in an ecosystem, interactions between ecosystem members should jointly create value for all actors. In the development of circular business models, the focus is often placed on the relationships between business actors in a value chain – defined as *'the full lifecycle of a product or process, including material sourcing, production, consumption and disposal/recycling processes'* [108]. Whilst applying an innovation lens to the value chain is undoubtedly important, there is also a critical role to be played by other regional actors beyond the value chain to accelerate innovative solutions. Innovation ecosystem actors – including business and innovation support organisations, promotional bodies, delivery actors (such as government, development agencies, professional networks and incubators), policymakers, funding bodies and research organisations – play different, but synergistic roles in supporting the development of resilient bio-based industrial symbiosis.

4.2 Template and Guidelines

The starting point for determining the strength or weakness of a regional innovation ecosystem is to determine the level of awareness of the relevant regional entities of innovation ecosystem actors. Therefore, the SYMBIO pilot regions were invited to start the ecosystem mapping through the compilation of a standardised ecosystem template (Annex 1). Partners were asked to populate the templates with relevant information, including organisation/initiative names, and a brief description of their activities related to bio-based innovation. The templates include the following categories:

1. **Support Organisations.** Business and innovation support organisations are particularly important in the development of circular bio-based business. Such organisations can empower new and small bio-based businesses to undertake innovation and can break down silos across the value chain. Individual actors might find it challenging to identify partners who are open to exploring new business models; innovation support organisations can help by acting as intermediaries between businesses, facilitating resource exchange, identifying funding opportunities for emerging projects, supporting in securing and managing innovation funds and co-ordinating thematic groups and networks that reveal the potential for industrial symbiosis.
2. **Promotion Agencies.** There are increasing numbers of successful examples of bio-based circular businesses; however, the sector is still relatively immature. Promotional bodies that are dedicated to bio-based business, circular economy activities or aligned sectors play a valuable role in raising awareness of the circular bioeconomy across all stakeholders. Well-designed promotion (through,

for example, awards and labelling) can encourage behavioural change amongst producers and consumers, stimulating both supply and demand for bio-based circular products.

3. **Research Institutions.** Research institutions play multiple roles in supporting the development of bio-based circular businesses. Collaborations with researchers are often the starting point for the exploration of feedstocks for which applications are not yet well enough developed to be of interest to potential innovation funders. Access to research funding for lower technology readiness level (TRL) opportunities can be facilitated by research institutions and research institutes can provide access to pilot-scale facilities for research and development activities, overcoming common technical and economic barriers to bio-based innovation.
4. **Educational Institutions.** Educational institutions can provide similar support to research institutions and may even provide more readily available access to funding for low-TRL level exploration via funding routes for academic-industry collaboration. In addition, educational institutions are the source of the future workforce for the bio-based industries. The opportunities in the bioeconomy can be highlighted through live projects and research challenges for undergraduate and postgraduate students.
5. **Delivery Actors.** Delivery actors refer to organisations, associations, networks and clusters. Coordinating bodies play a critical role in accelerating bio-based circular business models, often providing financial and regulatory support and lobbying for policy development that levels the playing field for innovation. They can also support pre-competitive innovation, in which companies work together to overcome shared systemic and structural barriers to innovation. This can include developing standards and voluntary agreements and sharing data.
6. **Policymakers.** The acceleration of a regional circular bioeconomy is a complex systemic change. Economic, scientific, educational and environmental policy has the potential to play a key role in enabling or deterring innovation.
7. **Funding Providers.** Funding providers can be public or private investors. Their importance is clear as facilitators of research and development and support.
8. **User Organisation.** User organisations are those businesses that exist within the value chains for biobased businesses. Their role in the innovation system has already been outlined in Sections 1 and 2.

4.3 Limitations and Challenges

The process of data collection for mapping bio-based innovation ecosystems faces two key challenges: achieving comprehensiveness and ensuring standardisation.

Comprehensiveness can be limited by the limited knowledge partners may have about the entire ecosystem. They may focus on their established network, potentially missing smaller or niche actors, or prioritising those relevant to their specific knowledge or bio-based sector. Additionally, identifying hidden actors in early development stages might be difficult to identify without dedicated research, as they are often less visible within the ecosystem.

Standardisation poses another challenge, stemming from potential variations in how partners interpret the eight ecosystem categories outlined in Section 4.2. This can result in inconsistent classification of actors across regions. Furthermore, the level of detail provided for each actor might vary, hindering comparative analysis. Finally, terminology differences (e.g., "development agency" vs. "business incubator") can further create ambiguity and inconsistencies in the data.

However, it is important to note that the design-driven methodology for ecosystem mapping, which includes co-development workshops to review and refine the preliminary ecosystem maps, will help mitigate some of these challenges. This collaborative approach aims to enhance both the comprehensiveness and consistency of the mapping process.

4.4 Innovation ecosystem actors in the SYMBIO's Pilot Regions

In this section, we describe some of the key actors and initiatives in the different categories of the innovation ecosystem related to SYMBIO's Pilot Regions, divided by country of origin. The full ecosystem maps and dataset are provided in Annex 2.

4.4.1 Italy

Business support

Business support is available across the regions for bio-based businesses. A total of **27 organisations and initiatives** were identified across the region. These include national-level entities (4) and region-specific hubs in Lombardy (8), Piedmont (4), Emilia-Romagna (3), Friuli-Venezia Giulia (4), and Veneto (4).

At the **national** level, Consorzio Italbiotec, Assobiotec and ENEA are key ecosystem actors.

- **Consorzio Italbiotec**[109] is Italy's leading biotechnology non-profit organisation, bringing together 36 Centres of Excellence across Italy and more than 100 biotechnology SMEs. It provides support for businesses looking to undertake sustainable innovation in life sciences, the bioeconomy and agrifood. This includes funding application support and award management, innovation management, training, and communication and dissemination activities.
- **Assobiotec**[110], the Italian Association for the Development of Biotechnology, is a professional body that supports the growth of the biotechnology industry. It brings together more than 100 companies and science and technology institutes in the healthcare and bioeconomy sectors. Assobiotec offers business services designed to promote technological research and innovation in biotechnology and to attract investment in Italian biotechnology industry sectors.
- **Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)**[111], also plays a significant role in supporting the bioeconomy in Italy.

In **Lombardy**, the most relevant organization in the sector is the **Lombardy Green Chemistry Association (LGCA)**[112], a cluster that provides support for industrial research and innovation through knowledge transfer, new business opportunity identification, networking, consortium building, policy and governance, business development and market entry. The cluster is involved in different regional and EU-funded programs, including the most relevant to the region: **RuralBioUp**[113], an EU-funded project that has established an innovation hub in Lombardy to support micro- and small enterprises in rural bio-based industries to scale up inclusive and sustainable business activities and **ForestEcoValue**[114], an Interreg Alpine-Space funded project that supports the development of sustainable business models across circular, green and bio value chains. Its Living Lab in **Piedmont** focuses on business experimentation in sustainable forestry practices, ecosystem services and market opportunities in the forestry sector. Other associations and hubs promoting innovation in Lombardy are summarized in Annex 2.

In **Friuli-Venezia Giulia,** although not bio-industry specific, several innovation hubs are present in the area:

- **TEC4I FVG | Friuli Innovazione scarl**[115] is a regional innovation hub that fosters technology transfer and supports the growth of innovative enterprises, including bio-based industries.

- **IP4FVG Digital Innovation Hub**[116] is a potential business support agency to help bio-based businesses undertake digital transformation. The hub provides specialised skills and infrastructure to support businesses to adopt and use digital technology to increase the overall business value.

Alongside different entities, such as **Piemonte Innova** and **Finpiemonte**, that support digital transformation and innovation in the region, also different regional incubators are present in **Piedmont** to provide business development services and access to funding.

Promotion

7 organisations and initiatives in **Italy** support the promotion of the bioeconomy, including **4 national bodies, 1 organisation in the Lombardy region and 2 organisations in the Emilia-Romagna region.** No promotion actors were identified in the Piedmont or Friuli-Venezia Giulia region.

At the **national level**, **BeIT**[117] is the national branding campaign launched by the Ministry of Foreign Affairs and International Cooperation, in collaboration with the Italian Trade Agency. Italian businesses are promoted to the export market through the campaign's promotion of the 'Made in Italy' brand and the bioeconomy has been identified as a strategic priority for the Made in Italy label. Moreover, the **Italian Bioeconomy Strategy (BIT)**[118] outlines the country's vision for promoting sustainable bio-based solutions in key sectors like agriculture, forestry, food production, and waste management.

In Italy, several fairs are focused on promoting the bioeconomy, sustainability and circular economy. In **Lombardy**, the **Bioeconomy Trade Fair**[119] provides a space for companies across the bioeconomy to promote their business activities, products and services. In **Emilia-Romagna**, **Ecomondo**[120] is a long-established exposition event for the green and circular economy in Europe. Taking place every year in Rimini, it is now the 27th edition and promotes itself as the global standard for green trade fairs in Europe.

Several initiatives are organized by Italy's pivotal organizations on the bioeconomy to promote this topic and foster networking opportunities and collaborations. In **Lombardy**, the **Bioeconomy Dialogues**[121] organised by LGCA promotes the exchange of knowledge and networking between research organisations, along with the **Bioeconomy Day** organized by SPRING to promote sustainability and circular economy.

Delivery actors

Alongside the previously identified organizations and clusters, many other organisations, associations, networks and clusters are present in Italy as delivery actors in the bio-based and innovation sector. The Italian bio-based innovation ecosystem has identified **18 delivery actors**, **12** at the **national level, 3** in the **Lombardy** region, **2** in **Piedmont**, and **1** in the **Friuli-Venezia Giulia** region.

At the **national** level, alongside **ENEA** and **Assobiotec** (see 'Business Support section'), the most relevant delivery actors are:

- **Terra Next**[122], an accelerator programme designed to support businesses in the bioeconomy. In addition to its business support activities, Terra Next is also measuring the environmental impact of the bioeconomy through life cycle assessment which it uses to promote the sustainable benefits of the bioeconomy to national government.
- **Sustainable Processes and Resources for Innovation and National Growth (SPRING)**[123], the Italian Circular Bioeconomy Cluster with over 150 member organisations ranging from large multinational organisations through SMEs, universities, research and technology institutions and business associations, to small farmers. SPRING supports a range of activities that promote and

deliver bioeconomy futures including the Bioeconomy Day, a national day raising the profile of the bioeconomy, and BioInvestIT, an investment brokerage platform. Moreover, SPRING is involved in different national and EU projects that promote innovation in the bioeconomy sector.

- **National Research Council (CNR)**[124], Italy's largest public research body, actively involved in bioeconomy-related research in areas like biotechnology, bioenergy, and sustainable agriculture.
- **Superior Institute for Environmental Research and Protection (ISPRA)**[125], a national-level school, which will respond, in a systematic and highly qualified way, to training needs on environmental protection issues.
- Key Government Departments are involved in shaping the bioeconomy ecosystem in Italy, such as the **Ministry of Ecological Transition**, the **Ministry for Research and University**, and the **Ministry of Agricultural, Food, and Forestry Policies**.

In **Lombardy,** alongside **LGCA, Federated Innovation @Mind**[126] promotes novel ways of working that are designed to overcome barriers to collaboration and cooperation. Its mission statement is 'to develop a unique operating model beyond open innovation and traditional corporate innovation'. This is an important objective in the bioeconomy sector, where actors across the value chain could have different opportunities and capacities to benefit from innovation. Federated Innovation @Mind develops and supports innovation based on challenges, which include green chemistry, green technology, and circular economy innovations.

Funding

The key funding mechanism identified across the regions is the **European Regional Development Fund (ERDF/FERS)**. Each of the four regions in Italy receives these funds, and the bioeconomy is a priority across all areas.

Research

There are **21** research support organizations and initiatives in Italy, including **11** at the **national level,4** in the **Lombardy** region, **2** in **Piedmont, 2** in **Emilia Romagna, 1** in **Friuli-Venezia Giulia** and **1** in **Veneto**.

The most relevant at the **national level**, alongside CNR and ISPRA, are:

- **Council for Agricultural Research and Analysis of Agricultural Economics (CREA)**[127], with expertise ranging from the agricultural, livestock, fish, forestry, agro-industrial, and nutritional sectors to the socioeconomic sphere. It supports the research in the agri-food value chains, including forestry and wood, and a wide range of fruits and crops.
- **National Agency for New Technologies, Energy and Sustainable Economy Development (ENEA)**[111], working in the fields of energy, environment and new technologies to support competitiveness and sustainable development policies.
- **Italian Institute of Technology (IIT)**[128], scientific research with the main goal of science advancement through projects and discoveries oriented to applications and technology.

Technological clusters[129] in Italy, particularly in regions like Lombardy, Piedmont, Veneto, Friuli-Venezia Giulia, and Emilia-Romagna, are key drivers of innovation, research, and technology transfer in various industrial sectors, including bio-based industries. These clusters foster collaboration between companies, research institutions, universities, and government bodies, enhancing the development and commercialization of cutting-edge technologies. As previously mentioned, in Lombardy, the Lombardy Green Chemistry Association promotes bio-based innovation, while Piedmont's BioPmed focuses on biotechnology and health. Veneto's Venetian Cluster supports eco-sustainable technologies, and Friuli-Venezia Giulia hosts clusters like Friuli Innovazione, which promotes technology transfer across industries.

Emilia-Romagna is home to Clust-ER, a network supporting sectors like agrifood and bioeconomy. These clusters are critical for linking research and industry, fostering technology transfer, and facilitating access to funding, driving regional and national innovation ecosystems.

Education

The Italian education ecosystem includes **29** universities, projects and initiatives that support the bioeconomy. This includes **11** o in the Lombardy region, 7 across Piedmont, 4 across Emilia Romagna, **4** across the Friuli Venezia Giulia region and **3** in **Veneto**.

Two **cross-regional initiatives** are of note. The first, **BIOCIRCLE**[130] is an interdisciplinary advanced program for the training of professionals in the fields of bioeconomy offered by 4 Universities (the University of Bologna, University of Milano-Bicocca, University of Naples Federico II, and the University of Turin), 4 non-academic partners (Intesa Sanpaolo, Novamont SpA, GFBiochemicals SpA, and PTP Science Park in Lodi), and 2 Italian Technological Clusters (Cluster SPRING and Cluster CLAN agrifood). Second, **The Adrion Masters on Bioeconomy and Circular Economy** is a master's degree programme hosted by the University of Bologna, Emilia Romagna and involves a network of seven universities from across the Adriatic-Ionian area.

Almost all Italian universities offer options and programmes in the field of sustainability and circularity. In **Lombardy,** the primary university supporting the circular bioeconomy is the **University of Milano-Bicocca**[131] with the BIOCIRCLE Master's Programme previously mentioned. Moreover, this university is a centre of excellence for research in the bioeconomy.

In **Piedmont**, the **University of Eastern Piedmont**[132] is also a partner in the Biocircle Master's Programme. The university also has a relevant collaboration with Novamont, a large industrial actor in the bioeconomy, which delivers education and training programmes in bioeconomy skills and knowledge.

In the **Emilia-Romagna** region, the **University of Bologna**[133] offers different opportunities for education and research in the bioeconomy, circular economy and sustainability from foundation to post-graduate. One relevant initiative in which the university is involved is the **Adrion Master's on Circular Economy and Bioeconomy (AMOCEAB)**[134], a project that aims to address skills gaps in the bioeconomy in the Adriatic-Ionian region.

In **Friuli-Venezio Giulia**, the **University of Trieste**[135], and in **Veneto** the **University of Padua**[136], **Ca' Foscari University of Venice**[137], and **the University of Verona**[138] provides academic study and research opportunities in bioeconomy disciplines.

Users

The Italian bio-based circular innovation ecosystem users include **21** clusters, consortia and foundations (**8** at the **national** level, **4** in **Lombardy**, **6** in **Piedmont**, **2** in **Emilia-Romagna** and **1** in **Friuli-Venezia Giulia)**. Amongst industrial partners, **25** businesses were identified in the **Lombardy** region, **34** in the **Piedmont** region, **5** in the **Emilia-Romagna** region and **3** in **Friuli-Venezia Giulia.**

Clusters representing businesses in the bioeconomy value chain include **Alta Lombardia Wood Consortium**[139] in **Lombardy,** which represents a cluster of businesses in the forestry and wood value chain. In **Piedmont, C-Green**[140] includes members from across the Green Chemistry and Advanced Materials sector. In **Emilia-Romagna, Clust-ER Agri-food** represents members from across the agri-food sector, whilst in **Friuli-Venezia Giulia, the Agrifood Agency**[141] is the voice for its agri-food sector.

4.4.2 Carinthia

Business support

A total of **25** organisations and initiatives have been identified that support bio-based business and innovation in the Carinthia region. These include **6** at the EU level that have regional partners, **11** at the national level and **8** specifics to the Carinthia region. The most relevant are:

- **The Carinthian Economic Development Fund Programme** offers different forms of business support including network programmes such as **First Green**, **Innovations Talent**, **Cooperation Talent, Internationalisation Talent** and **First network**[142]. The programmes are suitable to all business networks and offer tailored support at all stages of the innovation pipeline from start-up through to scale-up. Specific aspects of the programmes include support for collaboration working across value networks and internationalisation of business.
- **Start R&D** and **Produktion EFRE|JTF.invest** programmes offer a range of R&D support opportunities, including introduction to R&D processes, support for knowledge and technology access and support in attracting investment.
- **Build!**[143] **i**s a start-up incubator in the Carinthia region that offers support for technology-oriented, knowledge-based and scalable start-ups. It has a focus on IOT business solutions but also supports businesses that are aligned with regional priority areas, including bioeconomy businesses. Build offers three different programs – Up, Move, Run and Up that support the entire innovation pipeline, from preliminary idea scoping to scale-up.

Promotion

20 promotion actors and initiatives in the field of bioeconomy were identified. These include **8 national** initiatives and **12 locals** to the Carinthia area. The most relevant are:

- **KWF Forschungs- und Innovationspreis Kärnten** are innovation awards funded by the Carinthian Economic Development Fund (KWF). The awards include a 'special prize' category for 'Green technologies – R&D for the future'.
- **Nachhaltigkeitstag Kärnten der Wirtschaftskammern Kärnten** was held on 14th March 2024 and was Carinthia's first Sustainability Day. It is intended that, with support, this will become a yearly event that raises awareness of sustainability initiatives in the region.

Delivery actors

33 delivery actors have been identified that support the development of the circular bioeconomy in Carinthia, including **11** at the **national** level and **22** at the **regional** level, some of which operate across the Alps-Adriatic Region, crossing national boundaries. The most relevant are:

Biobase[144], an innovation platform for the bioeconomy and circular economy acting as a central information hub and service agency for business, science, administration and politics.

- **Stadtwerk Klagenfurt**[145] manages municipal utilities for Klagenfurt region. It has recently been funded to support the City of Klagenfurt to develop a circular economy through the EU-funded InvestCEC[146]. Klagenfurt will act as a living lab for experimenting with circular solutions, including bio-based initiatives.

Policy

12 policy mechanisms were identified that are important in supporting the circular bioeconomy **in Carinthia**: 4 **supranational policies** (The UN Sustainable Development Goals, the European Green Deal, including the Circular Economy Package and the Ecodesign for Sustainable Development Regulations, and the EU Bioeconomy Strategy and Action Plan) and **8 national** policies. The Carinthian regional policies include the **Sustainability Coalition**[8] [147], the regional agency with responsibility for delivering natural resource policy. In addition, the local development policies that inform the strategy for the **Carinthian Economic Development Fund**[9] [148] shapes the regional approach to the bioeconomy.

Funding

14 potential funding interventions were identified that have the potential to support the growth of the bioeconomy in Carinthia, including **4 at the international or EU level, l**, **7 national** and **3 regional** funding mechanisms.

The **Carinthian Economic Development Fund** offers funding to organisations looking to undertake innovation that will contribute to local economic growth. In addition, the local administration of the **Just Transition Fund (JTF)**[149] covers the areas of Völkermarkt, Wolfsberg, St. Veit, Feldkirchen and Villach Land, which have all been identified as being disproportionately affected by greenhouse gas emissions and/ or the transition to low carbon industry. The strategy includes funding available for sustainable development of the bioeconomy.

Research

36 actors and activities that support research in the Carinthian sustainable bioeconomy have been identified. These include European projects and networks that include Carinthian partners, national universities and research centres, regional universities and research centres, and localised projects.

At the national level, the **Fraunhofer Institute of Austria**[150] supports research and innovation in sustainable production and logistics. Meanwhile, the **Wood K+ network**[151] is undertaking fundamental and applied research projects that support knowledge and innovation development for the forestry and wood sector.

Education

2 universities were identified in the Carinthia region that contribute to the bioeconomy innovation ecosystem:

- **University of Klagenfurt**[152] offers programmes in sustainable business through the Institute of Management and Entrepreneurship and in sustainable tourism.
- **University of Applied Sciences Kärnten**'s programmes[153] contribute at undergraduate and postgraduate levels to the green economy, including Green Transition Management, Green Additive Manufacturing and a master's in architecture with a focus on circularity in buildings.

Users

A total of **72** businesses operating in the Carinthian bioeconomy were identified. This included **8** in the forestry and wood processing sector, **5** in the beverage industry, **14** dairies, **1** meat business, **13** energy companies, **10** waste processors, **9** circular economy and plastics specialists, **6** retailers and **6** actors from the chemical industry. The most relevant are:

- **Hirter Bier**[79] one of Carinthia's largest breweries and a key actor in the local circular bioeconomy. The company has developed its fermentation processes to be able to extract lactic acid from barley

[8] Sustainability coalition presents government programme 2023-2028 - Province of Carinthia (ktn.gv.at).
[9] Strategy of the KWF – Carinthian Economic Development Fund

residue. The lactic acid produced is a feedstock for businesses across the bioeconomy, including pharmaceuticals and bioplastics.
- **Öli**[154] collects waste oil from homes, restaurants and catering establishments across Austria, Germany and Italy for processing into biodiesel.

4.4.3 Belgium

Business and innovation support

10 business and innovation support organisations were identified in the Belgian ecosystem, including **2** at the **national** level, **1** in the **Brussels** region, **4** in **Flanders** and **3** in **Wallonia**.

Nationally, the **Bio Base Europe pilot plant**[84] offers businesses support in process development and scale-up for innovative bio-based solutions. It provides pilot-scale access to different biotechnology processes, including biomass pretreatment, biocatalysis, fermentation, green chemistry, recovery and purification and analysis and assay.

In **Brussels,** the **B2BE Facilitator**[155] is a matchmaking service provider for businesses in bioeconomy value chains. Adopting best practices in industrial symbiosis, the facilitator runs six-month-long programmes focusing on specific value chains or biomasses. Within a challenge entrepreneurs from relevant bioeconomy sectors, including the agriculture, horticulture, marine and food sectors are brought together with industrial partners and supported to develop novel bioeconomy solutions.

In **Flanders,** the most relevant reality is the **Flanders Biobased Valley**[156], a not-for-profit organisation supporting the development of the biobased economy in the region. It provides knowledge and access to equipment for businesses looking to undertake technological innovation on bio-based products, facilitates networking and partner matching, helps organisations apply for and manage project funding, and supports communication and dissemination of innovation.

In **Wallonia**, **Valbiom**[157] is a systemic innovation organisation focusing on bioeconomy and working across the micro (business), meso (value network) and macro (district, city, region) levels to support the development of master plans and methods to undertake sustainable bioeconomy innovation. This includes supporting networking and matchmaking, pre-feasibility and feasibility studies, project development and funding strategies and dissemination and communication.

Promotion

7 key opportunities for promoting biobased activity in Belgium have been identified in Brussels, reflecting the key role that the European Union plays in promoting bioeconomy innovation in Europe.

Among them, the most relevant is the **EU Green Week.**[158], an annual event held in Brussels focusing on building support for EU environmental policies. The Green Week centres on a different aspect of EU policy every year, bringing together policymakers, advocates and stakeholders who influence or are influenced by the policy. The event consists of a conference and a series of 'fringe' events.

Delivery actors

9 delivery actors were identified, including 3 **national** actors, **2** based in **Brussels** and **4** from the **Flanders** region.

The **Belgian Science Policy**[159] Delivers scientific research across a variety of bioeconomy-related disciplines in Belgium. It is responsible for 10 federal scientific institutes across Belgium, where

researchers and innovators can access research materials and equipment. BELSPO aims to promote sustainable development through scientific research.

In **Brussels**, the **Bio-based Industry Consortium (BIC)**[160] is a non-profit organisation that promotes public-private partnerships to build strength in the bioeconomy. Its members cover the whole value chain from primary production to market entry.

The most relevant in **Flanders** is the **VIB**[161], the region's life sciences hub. It is a research and knowledge transfer organisation with objectives to translate research into products for patients, farmers and consumers and create new economic activities and new jobs.

Policy

11 policies were identified as important in shaping the circular bioeconomy innovation ecosystem. This included 3 **at the EU level and 8 regional policies**. The Europe 2020 Strategy and the EU Bioeconomy and Circular Economy strategies were seen as creating the overarching framework.

In **Flanders,** the regional strategy – **Bioeconomy in Flanders, the vision and strategy of the Government of Flanders for a sustainable and competitive bioeconomy in 2030**[162] **–** has been shaping the approach adopted in the region since 2013.

The Walloon Waste and Resources Plan (PWD-R)[163] raises the profile and importance of the transition to a circular economy, moving beyond waste management and recognising the value-creation opportunities that industrial symbiosis can bring.

In **Brussels**, **Be Circular, Be Brussels**[164] is the circular economy strategy for Brussels and its surrounding area.

Funding

13 funding opportunities were identified that could support innovation in the bioeconomy in Belgium: **6** are **European Union** funding mechanisms.

The majority of the regional level funding addresses the **Flanders** region and is managed and administered by **VLAIO, Flanders Innovation and Entrepreneurship**[165]**.** Funding is available for activities at all stages and all technology readiness levels.

Research

TFour universities were identified as being important in supporting the bioeconomy innovation ecosystem.

In **Brussels**, the **Vrije Universiteit Brussel**[166] and the **Université Libre de Bruxelles**[167] have departments that contribute to education, research and innovation in the region.

In **Flanders, Ghent University**[168] is the main university supporting bioeconomy initiatives.

The **Katholieke Universiteit Leuven** also supports bioeconomy initiatives through the Alliance of Biodiversity International and CIAT Europe.

Users

2 users of the bioeconomy were identified by the Belgian partners, the multinational companies **Ecover** and **BASF Antwerpen**.

4.4.4 Croatia

Business and innovation support

24 support organisations and innovation spaces were identified that could support the bioeconomy in Croatia. The most relevant are:

- The **Business Innovation Centre of Croatia (BICRO)**[169] provides financial support, mentorship and guidance for start-ups and small and medium-sized businesses
- **Startup Factory Zagreb (ZICER)**[170] offers support specifically to startup businesses throughout their development. It includes incubator and accelerator programmes, networking opportunities, co-working spaces and access to prototyping laboratories.
- **Crohub**, a platform that supports Croatian startups by providing resources, networking opportunities, and mentorship to help them grow and succeed in the global market.
- **HAMAG-BICRO** (Croatian Agency for SMEs, Innovations, and Investments), offers various support programs and financing options for small and medium-sized enterprises in Croatia.
- **The Croatian Association of Employers (HUP)** represents employers and entrepreneurs. By establishing regional offices in Rijeka, Osijek, Split and Varaždin, a strong network of entrepreneurs covering all counties was organized.
- **The Croatian Chamber of Economy** provides business support services, training programs, and networking opportunities for entrepreneurs and small businesses in Croatia.

Promotion

25 organisations and initiatives related to the promotion of the bioeconomy were identified in Croatia. Amongst them, the **Croatian Biomass Association (CROBIOM)**[171] organises workshops, conferences and events focused on biomass utilisation and renewable energy.

Delivery Actors

23 delivery actors were identified as supporting the circular bioeconomy in Croatia, including **7 governmental** organisations, **11 networks and clusters**, and **5 intellectual property specialists**.

Policy

Croatia's circular bioeconomy innovation ecosystem is significantly influenced by various policies and strategic frameworks at EU, national, and regional levels.

There are **10 legal frameworks at national level**: National Development Strategy of the Republic of Croatia until 2030 ("Official Gazette", No. 13/21); Agricultural Strategy until 2030 ("Official Gazette", No. 26/22); Low-Carbon Development Strategy of the Republic of Croatia until 2030 with a Perspective to 2050 ("Official Gazette", No. 63/21); Energy Development Strategy of the Republic of Croatia until 2030 with a Perspective to 2050 ("Official Gazette", No. 25/20); Integrated National Energy and Climate Plan of the Republic of Croatia; Law on Renewable Energy Sources and High-Efficiency Cogeneration ("Official Gazette", No. 138/21); National Recovery and Resilience Plan; Strategic Plan for the Common Agricultural Policy of the Republic of Croatia for the period 2023-2027; Draft National Plan for the Development of Wood Processing and Furniture Production of the Republic of Croatia for the period 2022 to 2030; Program for Fisheries and Aquaculture of the Republic of Croatia for the programming period 2021-2027.

Croatia is also a part of the **BIOEAST initiative**, which aims to support the development of knowledge and cooperation-based circular bioeconomy to enhance inclusive growth in the BIOEAST countries and also to

create new value-added jobs, especially in rural areas, maintaining or even strengthening environmental sustainability.

Funding

5 major national funding and co-funding mechanisms for the Croatian circular bioeconomy were identified, such as: Competitiveness and Cohesion Program, Integrated Territorial Program, Strategic Plan for the Common Agricultural Policy of the Republic of Croatia for the Period 2023-2027, Modernization Fund, Environmental Protection and Energy Efficiency Fund and National recovery plan.

Meanwhile, the **Croatian Strategic Plan form the Common Agricultural Policy** [172] has a range of funding opportunities targeting different aspects of the bioeconomy including promotion of wood and non-wood forest products and services, support for diversification activities and funding for knowledge transfer to support innovation.

Research

In Croatia, various research organisations play a pivotal role in advancing the circular bioeconomy. These institutions are engaged in innovative practices that enhance sustainability, optimise resource use, and promote the development of green technologies. This report outlines the most significant organisations contributing to the circular bioeconomy landscape in Croatia.

31 research organisations and initiatives that could contribute to a circular bioeconomy in Croatia were identified. The most relevant were:

- **Ruđer Bošković Institute**[173], as Croatia's largest scientific research institute, the Ruđer Bošković Institute has been actively involved in bioeconomy research and innovation. Notably, it participates in the Interreg Adrion Bioeconomy Research Driven Innovation (BIO ECO R.D.I) project, establishing collaborative networks among businesses and academic institutions to expedite the growth of the bioeconomy in the Adriatic-Ionian region.
- **Croatian Forest Research Institute**[174], internationally recognized research centre focuses on forestry and related industries. Its research themes prioritise sustainable forest management and forest utilisation strategies that support the bioeconomy. The institute is influential in advancing practices that optimise the use of forest resources while maintaining ecological balance.
- **Faculty of Food Technology in Osijek**, emphasises food science and technology, dedicating its research to food production, safety, and innovation in food processing. Its contributions are vital for ensuring that food systems are efficient, sustainable, and capable of minimising waste.
- **University of Zagreb - Faculty of Agriculture,** specialising in agricultural sciences, this faculty conducts research in crop production, soil management, and sustainable practices. By promoting sustainable agriculture, it supports the transition to a more resilient and circular bioeconomy.
- Energy Institute Hrvoje Požar: As a leading institution focused on energy efficiency and renewable energy technologies, the Energy Institute plays a significant role in fostering innovations that contribute to the circular economy by improving energy use and reducing carbon footprints.
- **Institute for Agriculture and Tourism (IPTPO**), which aims to conduct top scientific research and professional work in the field of biotechnical and social sciences and to transfer knowledge that contributes to the preservation of biodiversity and natural resources and the sustainable development of the economy and rural areas in national and international frameworks.

- **Faculty of Forestry and Wood Technology in Zagreb,** specialises in sustainable forestry management, wood technology, and environmental conservation, advocating for sustainable practices in the utilisation of forest and wood resources.
- **The Institute for Development and International Relations (IRMO)**, conducts research that supports policy development and the implementation of sustainable practices in various sectors, including the bioeconomy.
- **Competence Centre Ltd for Research and Development (Cekom)** was established with the aim of strengthening the innovation potential of the Vukovar-Srijem County economy and harmonizing research and development strategic plans with the needs of the economy, acting in the public interest.
- **Digital Innovation Hub Croatia**, a platform that connects businesses with technology providers and researchers to drive innovation and enhance business growth, particularly in the field of sustainable technologies.
- **Institute for Research and Development of Sustainable Ecosystems IRES**, focused on advancing sustainable ecosystem practices, this institute engages in multidisciplinary research that supports the principles of the circular bioeconomy.
- **Agricultural Institute Osijek**, a public research institute in the Republic of Croatia in the scientific field of biotechnology which through scientific research and through finding innovative solutions contributes to the development and advancement of science (plant science) and agricultural production.

Education

19 educational actors were identified as having a contribution to the bioeconomy innovation ecosystem in Croatia. Among these, the **Agronomic Faculty of the University of Zagreb** offers a master's degree in Renewable Energy Sources in Agriculture[175], a programme designed to develop professionals who can balance the advantages and disadvantages of growing energy crops and therefore contribute to a sustainable renewable bioenergy sector. Additionally, the Faculty of Agriculture features various related programs, including studies in Agricultural Technology, further expanding opportunities for students to engage in sustainable practices and technologies.

The most relevant:

- **Faculty of Food Technology in Osijek, Faculty of Food Technology and Biotechnology at the University of Zagreb**: These faculties provide comprehensive education focused on food technology, which is vital for developing sustainable food systems and reducing waste. They prepare graduates to innovate in food production processes, ensuring efficiency and sustainability.
- **University of Zagreb - Faculty of Chemical Engineering and Technology**: This faculty supports the bioeconomy by educating students on chemical processes that can contribute to developing bio-based materials and energy. The curriculum encourages research and innovation in green technologies and sustainable practices.
- **University of Zagreb Faculty of Electrical Engineering and Computing**: This university is Croatia's leading academic and research institution in the field of electrical engineering, computing, and information and communication technology. One of the courses at the University is related to the basic principles and concepts of the circular economy.

- **Faculty of Forestry and Wood Technology in Zagreb**: This faculty specialises in sustainable forestry management, wood technology, and environmental conservation, advocating for sustainable practices in the utilisation of forest and wood resources.
- **Križevci University of Applied Sciences**: This institution focuses on applied research that can drive practical solutions in the bioeconomy, particularly in sustainable agricultural practices and innovative food technologies.
- **University of Split:** The Faculty of Chemistry and Technology is a university that deals with scientific and educational work in the field of chemistry and chemical engineering which includes bioeconomy.
- **University of North:** The study of packaging, recycling and environmental protection is a technical study that provides students with theoretical and practical foundations for understanding and effective work in a modern production environment. The study acquaints students with modern technologies and key knowledge in the fields of design, engineering, production and protection of packaging, graphic technology, recycling, environmental protection, chemistry and disposal of various materials required for packaging certain food and non-food products.
- **Križevci University of Applied Sciences:** This institution focuses on applied research that can drive practical solutions in the bioeconomy, particularly in sustainable agricultural practices and innovative food technologies.

The landscape of education and research related to the bioeconomy in Croatia is rich and diverse, characterised by a strong emphasis on sustainable agricultural practices, renewable energy, and food technology. Institutions such as Universities and their faculties, alongside various research institutes, contribute significantly to developing professionals equipped to advance sustainable solutions within the bioeconomy. By fostering innovation and collaboration among these educational actors, Croatia is well-positioned to enhance its bioeconomy and make meaningful progress toward sustainable development goals.

Users

109 businesses operate in the bioeconomy sector in Croatia, including multinational organisations, such as Heineken and Coca-Cola, and local businesses. **123** operate in cluster, cooperative and producer groups.

4.4.5 Slovenia

Business support

5 support business mechanisms relevant to the circular bioeconomy in Slovenia were identified. Among the most relevant:

- **University of Ljubliana Incubator**[176], provides pre-incubation and incubation programmes for entrepreneurs that take innovators from any sector from initial idea to market. The pre-incubation programme supports individuals or teams with an early idea to establish a business to take it forward. The incubation programme supports businesses to develop their business to a point where it is ready for further investment or launch.
- **Center Rog**[177] is a creative hub that supports creative innovation, providing access to co-working spaces and maker spaces. As an organisation, Center Rog has strong environmental and

social values and issues regular calls for projects and partners that have a demonstrable sustainability impact.

Promotion

4 promotion mechanisms relevant to Slovenia's bioeconomy were identified. The most relevant:

- **Technologies and Business Models for the Circular Economy (TBMCE)**[178], an international scientific research and professional development conference held annually in Slovenia and supported by the Štajerska Chamber of Commerce. It incorporates thematic areas related to the bioeconomy including renewable energy, biomass and alternative raw materials and bioprocessing.
- **Strategic Research and Innovation Partnership – networks for the transition into circular economy (SRIP – Circular Economy)**[179], an initiative developed by the Chamber of Commerce and Industry of Štajerska. It brings together Slovenian businesses, education and research institutions, NGOs and other stakeholders in the bioeconomy. Amongst their activities, SRIP-Circular Economy organises circular economy excursions to companies within the EU to promote Slovenian circular economy initiatives and share best practices.

Delivery actors

14 delivery actors in the Slovenian bioeconomy ecosystems were identified, including government departments, regional development agencies and professional networks. The most relevant are:

- **Ministry of Natural Resources and Spatial Planning,** responsible for the management of the natural environment, water resources and physical space. It delivers policy and action plans, and issues licenses related to the efficient and economic use of natural resources.
- **CER**[180], the largest network of sustainable businesses in Slovenia. It represents more than 100 members from across a range of business sectors, including bioeconomy actors, and supports its members through networking and advocacy at regional and national government levels.

Policy

3 policies were identified that influence the circular bioeconomy in Slovenia:

- **Slovenia's Smart Specialisation Strategy**[181] incorporates bioeconomy and circular economy themes. These include sustainable food production, renewable energy, biomass and alternative raw materials, secondary raw materials, green technologies and processes and circular business models.
- **Deep Demonstration**[182] is a collaboration between the Slovenian Government and EIT Climate-KIC that applies systems innovation to develop radical transition pathways to a circular, low carbon and regenerative economy.
- **Circular Bioeconomy Strategy of Podravje Region**[183] was developed via the Circular Cities and Regions Initiative. It identifies four priority areas: developing new biobased materials, reclaiming resources, production of regional resources and capacity building to support a circular bioeconomy. An action plan of 12 actions to be taken forward to contribute to the priority areas is now being taken forward.

Funding

4 possible funding mechanisms were identified to support circular bioeconomy initiatives. These include EU structural funding and private investment. No national schemes were identified by the Slovenian partners.

Research

3 research support organisations were identified that could support the bioeconomy ecosystem in Slovenia:

- **Kmetjiski Inštitut Slovenje**[184] is the agricultural institute of Slovenia. It has a broad range of competencies that would support research in many of the agri-food bioeconomy value chains of the region.
- **The Pulp and Paper Institute**[185] supports businesses wishing to make use of biomass in print and packaging materials. It can undertake research into the chemical and microbial composition of materials and run experimental trials on alternative materials.
- **Innorenew Centre of Excellence**[186], a research institute that explores sustainable building, particularly in relation to the use of wood within construction. It is developing new approaches and processes for a sustainable built environment.

Education

2 universities were identified as providing knowledge, skills and training for the Slovenian bioeconomy:

- **University of Maribor**[187], home to a department of Agriculture and Life Sciences, where students can study a range of topics related to bioeconomy value chains.
- **University of Ljubliana**[188], the oldest university in Slovenia. Its departments of Pharmacy, Mechanical Engineering and Biotechnology all provide knowledge and skills that support actors at different points in bioeconomy value chains.

Users

A total of **70 businesses** contributing to a range of different bioeconomy value chains were identified as operating in Slovenia. Businesses were provided from the beverages, meat, dairy, cereal, forestry and wood sectors, as well as actors from the waste processing, chemical and plastics sectors.

5. Data Harmonization

5.1 Harmonization

To ensure the reliability and comparability of the data across the studied regions, a rigorous process of harmonization and standardization was implemented. This approach was essential to create a comprehensive study that accurately reflects the landscape of biomass utilization and technological development within the pilot regions. The harmonization process focused on aligning data from multiple sources, ensuring uniformity in data collection methodologies, and integrating information in a manner that allowed for meaningful comparisons between regions.

Primary biomass harmonization

The first step in this process involved the systematic collection of data on primary biomass types, ensuring consistency across all regions. Primary biomass refers to raw materials such as agricultural crops, forestry products, and other natural resources directly extracted from ecosystems. For each region, data were collected for the reference year of 2022, sourced primarily from official national statistical bodies. These sources included national statistical agencies, agricultural and forestry reports, and industry-specific studies, providing detailed insights into the production and consumption patterns of biomass in each region. This method ensured that the most recent and reliable data were used, enabling a clear understanding of biomass availability and its utilization.

In cases where official national data were incomplete or unavailable, additional data were obtained from Eurostat, the statistical office of the European Union. Eurostat provides a standardized set of statistics across various sectors, including agriculture and forestry, which served as a valuable supplementary source. By using Eurostat, the study ensured that the dataset remained comprehensive and consistent, thus maintaining the integrity and comparability of the analysis. This dual-sourcing approach avoided data gaps that could have skewed the findings.

Secondary biomass harmonization

Once the primary biomass data were collected, the next step was to estimate the availability of secondary biomass. Secondary biomass includes residues, by-products, and other forms of biomass derived from primary sources, such as crop residues, forestry by-products, and industrial waste. To estimate secondary biomass, specific conversion rates were applied to the primary biomass data. These conversion rates, drawn from scientific literature, industry standards, and technical reports, are critical to accurately assess the potential output of secondary biomass from the primary sources identified in the study. The careful selection of conversion rates, based on the relevance to specific biomass types and targeted bio-based products, ensured that the estimates were robust and reflective of real-world conditions. The data related to the conversion rate has been omitted as it pertains to sensitive aspects of the project's exploitation strategy and cannot be disclosed publicly.

Technologies and companies' harmonization

A key component of the harmonization process was the identification of companies and technologies capable of converting the selected biomass types into the target bio-based products. This involved a thorough search for companies actively engaged in the development and deployment of technologies related to bio-based chemical production. The goal was to map not only the current production capabilities but also the potential adaptability of existing technologies to new biomass sources.

For a fair and comprehensive evaluation, a broad definition of "adaptable" technologies was adopted. Technologies were considered adaptable if they met one or more of the following criteria:

1. **Production from Similar Biomass:** Technologies currently producing the target bio-based products from biomass types similar to those identified in the study, or from agricultural waste in general, were included. This acknowledges the flexibility of industrial processes to adapt to different but similar biomass sources.
2. **Intermediate Product Production:** Some technologies produce the target bio-based products as intermediate by-products within broader production processes. These intermediate products,

while not the primary output, still contribute to the overall production chain and could be refined further to meet the study's targets.

By incorporating technologies that met these adaptability criteria, the study provided a realistic picture of the current capabilities and future potential within the regions. This approach highlighted how existing technologies could be modified or leveraged to produce the desired bio-based products, even if direct production pathways were not yet fully established.

The harmonization process also involved standardizing how companies and technologies were categorized and assessed across the regions. This ensured that comparisons between regions were valid and meaningful. Any identified trends or gaps in technological capabilities could thus be accurately attributed to regional characteristics, rather than inconsistencies in data collection or interpretation. This standardization was essential for producing a reliable analysis of the bioeconomy landscape and allowed for clear insights into opportunities for industrial symbiosis and circular economy practices.

Bio-based Industries Innovation Ecosystem Map harmonization

To mitigate the inconsistency in the ecosystem data collection, the template provided to all pilot regions included a detailed description of the information to be included in each category along with examples. Partners were encouraged to offer additional information about each actor or initiative, such as website links and project descriptions, thereby enhancing the overall data quality.

Following the initial data collection, a harmonisation process was implemented to ensure consistency and comparability across regional data sets. This process included:

- **Data Cleaning:** Addressing missing entries, inconsistencies, and duplicate entries in the collected data.
- **Categorisation Validation:** Reviewing the assigned categories for each actor to ensure accuracy and consistency with the established framework.
- **Complementary Desk Research:** Conducting additional research to identify potential actors not captured through the partner-driven approach. This research involved industry reports, government databases, and targeted web searches.

Final implications of the harmonization process

The harmonization process undertaken in this study has yielded significant implications for understanding and advancing the landscape of biomass utilization and technological development across the pilot regions. By implementing a systematic approach to data collection, standardization, and analysis, we have established a robust framework that not only enhances the reliability of our findings but also facilitates meaningful comparisons among diverse regions.

Furthermore, by recognizing companies and technologies capable of processing various biomass types, we have created a dynamic map that not only highlights current production capabilities but also points toward future opportunities for technological adaptation.

5.2 Limits

While significant efforts were made to harmonize and standardize the data, several limitations were encountered during the data collection process and the search for relevant technologies. These limitations may affect the completeness and precision of the study's conclusions.

Data Availability on Secondary Biomass

One of the primary challenges was the availability of data, particularly for secondary biomass. While primary biomass data were relatively accessible, the conversion of these data into secondary biomass posed several challenges. Estimating secondary biomass requires specific conversion rates, which vary depending on the type of primary biomass and the production processes involved. However, many of these conversion rates are not well-documented, and in some cases, assumptions had to be made based on general industry reports or expert estimates. These assumptions introduce a degree of variability into the study, as the selected conversion rates may not perfectly reflect regional differences in production processes or biomass characteristics.

Challenges in Identifying Emerging Technologies

The identification of technologies capable of converting biomass into bio-based products was also limited by the availability of data on these technologies. This challenge was particularly evident in regions where such technologies are less prevalent or underdeveloped. Additionally, many of the technologies considered in the study are still in the early stages of development, with limited publicly available documentation. As a result, there was a scarcity of detailed information in the form of research papers or technical reports, which could provide comprehensive insights into the capabilities and adaptability of these technologies.

Language Barriers and Data Quality in Regional Bio-Based Ecosystems Research

The main challenges for data harmonisation included ensuring consistency across data collected from six regions, which may involve potentially language barriers between the research team and partner regions. This could lead to misunderstandings in terminology and nuance in translations, ultimately affecting clarity and the completeness of data collection.

Firstly, **terminology misunderstandings** can occur during data collection process. Partners may inaccurately translate categories, actor descriptions, or activity details, resulting in inconsistencies that are difficult to detect later. Additionally, subtle nuances lost in translation can lead to further complications.

Data quality also poses significant challenges. Incomplete or inaccurate data from partners can hinder the harmonisation process. Missing information about actors or activities complicates accurate categorisation and can create an incomplete picture of the ecosystem. Similarly, inaccurate information could lead to misclassifications during harmonisation.

To address these issues, a **workshop** will be conducted **with regional stakeholders** to validate the collected data and identify broader systemic enablers and barriers within the bio-based innovation ecosystem across all regions. This comprehensive approach aims to provide a solid and harmonised foundation for mapping bio-based industries innovation ecosystems within the SYMBIO project partner regions.

Final implications of data collection limitations

The scarcity of detailed data on both biomass conversion rates and emerging technologies introduces a degree of uncertainty into the study. For biomass data, the assumptions made in selecting conversion rates could lead to variability in secondary biomass estimates, potentially affecting the evaluation of biomass

potential in each region. Similarly, the limited availability of information on emerging technologies could result in an incomplete assessment of the technological landscape, potentially overlooking innovative solutions or overestimating the adaptability of current technologies.

These limitations highlight the need for continued research and data collection improvements in the fields of biomass utilization and technological innovation. Enhanced data transparency from technology providers, further studies into biomass conversion processes, and more specialized training for data collectors will be essential for refining future analyses. Despite these challenges, the study provides valuable insights into the current state of biomass utilization technologies, and the limitations identified underscore areas where future research can enhance the robustness of future bioeconomy studies.

6. Trigger dynamics for industrial symbiosis

Across the SYMBIO's pilot regions examined, common triggers facilitating industrial symbiosis and bio-based innovation include policy alignment across multiple governance levels, collaborative networks, technological infrastructure, and strong industrial bases. These factors provide essential structural support to foster industrial symbiosis and bio-based innovation. However, the mapping exercise also identified gaps within the ecosystems, which will be further explored with stakeholders to propose adequate measures for improving the conditions for bio-based industrial symbiosis. The general enabling factors for industrial symbiosis identified across the various countries of the pilot regions considered are:

- **Governmental and EU policy alignment.** In all regions, strong policy frameworks, such as EU Circular Economy Action Plans, Smart Specialization Strategies, and bioeconomy roadmaps (e.g., Slovenia's Bioeconomy Strategy of Podravje) are significant triggers. These policies not only align local objectives with broader European priorities but also facilitate funding and cross-border collaboration through programs like Horizon Europe and CBE JU.
- **Collaborative Networks and Clusters.** Innovation clusters and regional hubs are key triggers in all regions. For example, Italy's Consorzio Italbiotec and LGCA, the Carinthian Green Tech Valley Cluster, the Sustainable Business Network in Slovenia, and Croatia's CroBioHub demonstrate how collaboration across industries fosters industrial symbiosis. This synergy between businesses, academia, and public authorities drives the exchange of resources, ideas, and innovations.
- **Technological and Digital Infrastructure.** The integration of smart technologies and digital platforms for waste and resource exchange is a key enabler of industrial symbiosis. Regions like Carinthia, with its Digital Innovation Hubs and Technology Parks, or Belgium's Bio Base Europe Pilot Plant, highlight how digital and technological tools facilitate efficient symbiotic exchanges.
- **Resource-rich industrial and Agricultural Sectors.** All regions have established industries or agricultural sectors (e.g., agriculture in Croatia, forestry in Slovenia, manufacturing in Northern Italy) that provide a strong base for industrial symbiosis. The availability of organic waste, biomass, and other raw materials enables symbiotic exchanges between sectors.

A more specific vision of the key triggers for industrial symbiosis for each country will be provided afterwards.

6.1 Italy

The regions of Northern Italy—**Lombardy**, **Piedmont**, **Veneto**, **Friuli-Venezia Giulia**, and **Emilia-Romagna**—offer a dynamic environment for industrial symbiosis, supported by a strong industrial base, a robust policy framework, and innovative support systems. The main drivers for industrial symbiosis and bio-based innovation in Northern Italy are outlined below:

- **Strong industrial ecosystem synergies.** Lombardy, Emilia-Romagna, and Veneto are home to powerful industrial hubs, including sectors such as agriculture, automotive, chemicals, food processing, and textiles. Industrial symbiosis thrives on exchanges of by-products and waste materials, making these regions ideal for synergistic collaborations. Additionally, Northern Italy features well-developed waste management systems, which facilitate the reuse of industrial by-products, facilitate energy recovery, and promote material exchanges, all of which drive the implementation of industrial symbiosis. In the bio-based sector, organizations like the Lombardy Green Chemistry Cluster (LGCA) and Assobiotec play a significant role in fostering cross-industry collaboration and resource sharing among different industries. The bio-based sector in Northern

Italy benefits from projects and programs such as RuralBioUp and CDP Venture Capital, which offer mentorship, funding, and collaboration opportunities. Innovation hubs like Emilia-Romagna High Technology Network provide valuable resources for bio-based startups and could strengthen the industrial symbiosis network by offering shared R&D spaces.

- **Policy framework.** Italy's National Strategy for the Circular Economy and National Bioeconomy Strategy (BIT II) offer a cohesive policy environment supporting industrial symbiosis, particularly by aligning with EU circular economy mandates. These strategies include funding opportunities through Horizon Europe and the European Regional Development Fund (**IRMO**). However, existing legislation and policy instruments need to be reviewed to remove regulatory and bureaucratic obstacles that complicate compliance and hinder the implementation of symbiosis practices.
- **Research and innovation support.** Key organizations like Consorzio Italbiotec and the National Research Council (CNR) provide technical expertise, innovation resources, and guidance to both industrial symbiosis initiatives and bio-based projects. Platforms such as Torino City Lab and IP4FVG Digital Innovation Hub facilitate experimentation, by integrating digital tools with symbiosis efforts to optimize resource exchanges. Despite a solid research foundation in Italy, improved collaboration between research institutions and businesses is needed to effectively translate research into industrial applications. Regional initiatives should align more closely with industry needs to promote real-world symbiosis. Additionally, the complex funding landscape and long administrative procedures discourage many small and medium-sized enterprises (SMEs) with limited time and resources from investing in symbiosis networks. Regional programs should make extra effort to support smaller enterprises in this area.

6.2 Austria

Industrial symbiosis in Austria, in particular in **Carinthia**, is emerging as a strategic approach to fostering circular economy initiatives. The region is working towards enhancing resource efficiency by promoting collaboration among industries to reuse by-products, waste, and energy. The main drivers for industrial symbiosis and bio-based innovation in Carinthia are outlined below:

- **Environmental and circular economy policies.** Carinthia's bio-based industry operates within a broader framework of international, European, and national policies promoting sustainable development and circular economy principles. These policies encourage the reuse of materials, energy, and waste between industries, a key driver for industrial symbiosis. At the regional level, the Carinthian Economic Development Fund (KWF) has developed a strategy to support innovation and growth, including potential benefits for bio-based businesses. However, a more targeted approach specifically tailored to the needs of this sector could be beneficial.
- **Business and innovation support.** Carinthia's bio-based businesses have access to a range of funding opportunities at the national, regional, and international levels. Despite the efforts of the delivery actors (government, research institutions, businesses), coordinating symbiotic partnerships can be challenging, because of that complex landscape. At the national level, the Austrian Energy and Climate Fund, the Austrian Research Promotion Agency (FFG), and the Ministry of Climate Action offer funding programs that could potentially benefit bio-based businesses. Additionally, the R&D tax credit and grants program provides incentives for innovation. At the regional level, the Carinthian Economic Development Fund (KWF) and the Chamber of

Commerce offer funding and support services. The Just Transition Fund, available through the KWF, can also be a valuable resource for regions transitioning to a low-carbon economy. However, Carinthia currently lacks dedicated funding programs specifically for bio-based enterprises.

- **Cross-industry collaboration.** Regional institutions, such as Energieforum Kärnten and Chamber of Commerce Carinthia, provide valuable resources and connections and foster networks that facilitate collaboration between industries. These networks play a crucial role in triggering industrial symbiosis by helping businesses identify waste streams that can be reused by other companies.
- **R&D and knowledge transfer.** Carinthia's bio-based research landscape is characterized by a strong presence in national and international projects, with collaborations across universities, research institutions, and businesses. The region benefits from EU projects like BIOTRANSFORM and FUTURAL, strengthening collaboration among local research institutions and businesses that can accelerate innovation and alignment of the research with regional priorities. Additionally, enhancing communication and knowledge transfer between researchers and industry can bridge the gap between theoretical knowledge and practical application. Strong research institutions, like FH Kärnten, University of Klagenfurt, and Joanneum Research, provide a solid foundation for bio-based research in Carinthia. Identifying and addressing specific research gaps within the region is crucial to ensure that research efforts align with the pressing needs of the bio-based industry.

6.3 Belgium

In Belgium, industrial symbiosis has developed through various regional initiatives, with each region—**Brussels Capital, Flanders, and Wallonia**—implementing distinct but complementary strategies to drive sustainability, resource efficiency, and industrial collaboration. The main drivers for industrial symbiosis and bio-based innovation in Belgium and its regions are outlined below:

- **Policy and regulatory drivers (EU & national).** Bio-based businesses in Belgium, supported by both EU and national frameworks, are key to triggering industrial symbiosis. Policies like the EU Bioeconomy Strategy and Flemish Materials Programme encourage sustainable resource use, which is central to IS efforts. The alignment of bio-based circular economy principles with industrial symbiosis enhances synergies, especially when focusing on bio-based waste valorisation.
- **Bio-based innovation and support networks.** Organizations like Bio Base Europe Pilot Plant and Flanders Biobased Valley act as catalysts for industrial symbiosis by offering research, development, and scaling services that enable businesses to share bio-based resources and waste streams. This collaborative ecosystem fosters symbiotic relationships in sectors such as agriculture, chemicals, and biotechnology.
- **Support landscape and delivery actors' complexity.** Belgium offers extensive funding options, including from EU Structural Funds and national programs; however, navigating the complex funding landscape remains a challenge for bio-based businesses. Improving access to information on bio-based innovation funding and simplifying the application process will enable more firms to participate in industrial symbiosis projects. Coordination among the various bio-based delivery actors and industrial symbiosis platforms is essential but often hindered by competing priorities

and fragmented mandates. Enhanced coordination between bio-based industry players, civil society, and government would improve synergies.

Below is a specific analysis of the triggers and challenges for industrial symbiosis and bio-based innovation identified for each specific region in the Belgian country, as summarised in **Table 7**.

Table 7 *Summary of Triggers and Challenges for industrial symbiosis and bio-based innovation in Belgium country by region.*

Region	Key Triggers	Challenges/Barriers
BRUSSELS CAPITAL	BeCircular policy legacy, urban synergies, small industries collaboration.	Limited space, complex regulatory environment.
FLANDERS	Circular Flanders, chemical sector symbiosis, digital matchmaking.	High costs for small firms, data sharing challenges.
WALLONIA	Circular Wallonia, eco-innovation, industrial ecology hubs.	Legacy of deindustrialization, infrastructure gaps.

6.3.1 Brussels Capital Region

- **Urban circular economy.** Bio-based urban synergies are a natural extension of industrial symbiosis in Brussels, where they contribute to the recycling of urban waste, especially in the construction and agri-food sectors. Initiatives like BeCircular drive innovation by funding collaborative bio-based projects that reduce material and energy consumption. However, the dense urban environment poses challenges, as the limited space for large industrial activities restricts the scale of bio-based industrial symbiosis initiatives. Increasing the availability of shared innovation spaces and connecting small bio-based firms with urban industries could address this constraint.
- **Cross-industry collaboration.** Given its smaller industrial base, Brussels focuses on cross-industry collaborations. Bio-based innovation projects can stimulate urban industrial symbiosis, where bio-based businesses exchange by-products like organic waste for energy production or materials recovery.

6.3.2 Flanders

- **Sector-specific bio-based symbiosis.** Flanders' strong chemical industry and focus on bio-based innovations in sectors like biotech and bioplastics are key triggers for symbiosis. For instance, Blue Gate Antwerp is an industrial symbiosis hub where bio-based businesses and industries share resources like waste energy and by-products for sustainable production. However, in bio-based sectors such as biotech, the issue of confidentiality complicates the sharing of waste streams and by-products. Promoting data sharing protocols that protect intellectual property while enabling resource exchange could foster wider participation.
- **R&D support.** Flanders benefits from a well-established bio-based research and development network, including organisation such as Bio Base Europe and the Flanders Biobased Valley. These entities provide shared facilities that reduce barriers for bio-based startups, facilitating synergies and symbiosis between established industries and emerging bio-based players.

6.3.3 Wallonia

- **Circular Wallonia Strategy.** The region's ongoing transition from heavy industry poses a challenge for integrating bio-based businesses into industrial symbiosis networks. However, repurposing former industrial sites into bio-based innovation hubs (e.g., for biorefineries) could accelerate the transition. Compared to Flanders, Wallonia lacks the infrastructure needed for large-scale symbiosis. Investing in infrastructure that facilitates the transportation and processing of bio-based waste streams could expand opportunities for symbiosis. In 2021, Wallonia launched its Circular Wallonia strategy, with the explicit goal of fostering industrial symbiosis, encouraging collaboration among sectors such as construction, energy, and waste management to close material loops and optimize resource usage.
- **Eco-innovation in biorefineries and agriculture.** Wallonia's focus on biorefineries and agricultural waste valorisation naturally aligns with the bio-based industrial symbiosis. Initiatives like the ValBiom platform facilitate the exchange of agricultural by-products among sectors like energy, bioplastics, and agribusiness, creating synergies that enhance the bio-based circular economy.

6.4 Spain

In Spain, in particular, in **Andalusia**, industrial symbiosis is a growing focus as part of broader initiatives toward sustainability and circular economy strategies. The main drivers for industrial symbiosis and bio-based innovation in Andalusia and its regions are outlined below:

- **Regulatory push and policy initiatives.** The Andalusian Circular Bioeconomy Strategy (ACBS) promotes resource efficiency and bio-based sector growth, aligning with EU circular economy directives. This strategy inherently supports the formation of industrial symbiosis networks as businesses seek to meet regulatory requirements and capitalize on government incentives for sustainability. However, administrative bottlenecks and institutional support gaps pose challenges to swift implementation, which also impacts the scaling of industrial symbiosis across bio-based industries. Ensuring that the principles of Regional Innovation Strategies for Smart Specialization (RIS3) are well understood and applied can enhance inter-sector coordination.
- **Bio-based business and innovation support.** Andalusia's ecosystem for bio-based innovation support plays a significant role in fostering industrial symbiosis. The Andalusian Circular Bioeconomy Strategy will have the financial resources needed to provide financial aid to businesses involved in symbiosis projects through grants and subsidies, promoting the use of local resources and encouraging innovation in resource management. The presence of accelerators, incubators, and venture-building initiatives facilitates the creation of bio-based businesses that naturally engage in symbiosis by using organic by-products and creating circular supply chains. Collaboration among the diverse support initiatives could be improved to avoid duplication, which could also help streamline industrial symbiosis partnerships. Identifying gaps—such as the need for mid-stage support—ensures that businesses grow and engage in long-term symbiotic exchanges.
- **Promotion of bio-based symbiosis.** Promotional activities, such as international fairs (e.g., BioSpain, Smart Agrifood Summit), are essential in creating visibility and networking opportunities for bio-based businesses in Andalusia. These platforms not only boost the biobased industry's

exposure but also enable new industrial symbiosis projects by connecting companies across sectors (agriculture, energy, and waste management). Recognition programs, like the Andalusia Environment Awards, create incentives for bio-based companies to integrate symbiotic models into their processes, highlighting innovation in circular bioeconomy solutions. The Biodistritos initiative, focusing on sustainable local food systems, promotes cooperation among bio-based and traditional businesses, facilitating symbiotic relationships at a regional level.

- **Diverse delivery actors in bio-based circular economy.** Sector-specific platforms (like HortObserTIC and OLEOVALORIZA) provide a strong framework for symbiosis, enabling agriculture, food processing, and waste management to exchange by-products and resources. Public-private partnerships, such as the Andalucía Agrotech Digital Innovation Hub (DIH), create collaborative spaces for resource sharing and the thriving of industrial symbiosis within a biobased context. These actors address complex challenges by bringing together expertise across various fields.
- **Research infrastructure and innovation.** Bio-based industries often face technological challenges related to converting raw biomass into usable resources, which can limit participation in symbiotic exchanges. Investment in R&D and technology transfer is crucial for overcoming these barriers. Research institutions, such as IFAPA and the Agrifood Campus of International Excellence, are critical in developing bio-based technologies that enable industrial symbiosis, particularly in the agriculture and bioenergy sectors. Collaborative research projects, like ICT-BIOCHAIN, provide real-life models for symbiotic exchanges. Although there is no single bioeconomy-focused centre in Andalusia, fostering collaboration between existing research centres can amplify innovation and industrial symbiosis efforts, particularly around agricultural by-products and biomass valorisation. Additionally, market uncertainties regarding the competitiveness of bio-based products can limit demand and the potential for industrial symbiosis. Expanding the market through branding initiatives, like "Gusto del Sur", can help make bio-based goods more attractive and facilitate symbiosis with other industries.
- **Educational and skills gaps.** While Andalusia has some promising educational initiatives (e.g., master's degrees in Circular Bioeconomy and IFAPA training programs), there is a need to expand specific bio-based symbiosis-focused education. Introducing programs that equip businesses with the skills needed to manage biowaste exchanges, renewable energy production, and cross-industry collaboration would help foster a symbiotic culture. The lack of tailored business development programs for bio-based industries is a barrier to growth. Establishing mentorship and training at different stages of business development enhances participation in the bio-based circular economy.

6.5 Croatia

Croatia is increasingly focusing on industrial symbiosis as part of its circular economy goals. While there are promising green technology initiatives, the infrastructure for large-scale production of bio-based chemicals from biomass remains underdeveloped. There are gaps in capabilities and investments are needed to transform emerging bio-based technologies into viable alternatives to traditional chemical production methods. The main drivers for industrial symbiosis and bio-based innovation in Croatia are outlined below:

- **EU and national policies.** Croatia's alignment with the EU Green Deal and the Circular Economy Action Plan is a significant trigger for promoting industrial symbiosis. National strategies, including the National Strategy for Sustainable Development and Croatia's Smart Specialization Strategy, prioritize bio-based innovation and circular economy practices. These policies create a favourable environment for businesses to adopt industrial symbiosis by fostering collaboration among key stakeholders, including government agencies, businesses, and research institutions.
- **Access to EU and national funding programs.** Funding programs, particularly from EU Structural Funds and national initiatives, provide incentives for businesses to adopt resource-efficient and symbiotic practices. Programs such as the Operational Program Competitiveness and Cohesion (OPCC), and national platforms like HAMAG-BICRO, offer financial support for projects promoting innovation and competitiveness, thereby driving industrial symbiosis. However, businesses face difficulties navigating the complex application processes of these funding programs, which limits access to resources for symbiotic projects. Additionally, Croatia lacks specific regional programs tailored to bio-based industrial symbiosis, resulting in fragmented support for businesses needing guidance and resources for collaborative efforts.
- **Innovation and research collaboration.** Croatia's bio-based research landscape is characterized by a strong network of research institutions, collaborative projects, and knowledge transfer initiatives. However, further development is needed to enhance the impact of research and accelerate commercialization. Research institutions like the Ruđer Bošković Institute and the Croatian Forest Research Institute play a crucial role in conducting research relevant to bio-based industries. The University of Zagreb's Departments of Chemical Engineering and Technology and the University of Split's Biotechnical Department also contribute to this field. Strengthening collaboration between these research organisations and businesses can facilitate knowledge transfer and accelerate innovation. Partnerships with international research institutions can also provide access to new technologies and expertise. Collaborative projects could be promoted by the Innovation Council on Food and Bioeconomics or initiatives like the CroBiohub or Biomass Croatia. Additionally, EU-funded research projects offer Croatian institutions opportunities to participate in international collaborations and secure funding.
- **Support from industry associations.** Organizations, like the Croatian Chamber of Economy, CROBIOM (Biomass Association), and the Green Energy Cooperative, actively promote industrial symbiosis by organizing workshops, and events, and providing platforms for knowledge sharing. These networks help businesses discover collaborative opportunities and enhance resource efficiency.

6.6 Slovenia

Slovenia is advancing its efforts in industrial symbiosis, driven by its circular economy goals. The country's research institutions and existing industries have strong potential to adopt biomass-based production. The key challenge lies in bridging the gap between research and industrial applications, which will require scaling up technologies, investing in infrastructure, and fostering stronger collaboration between industry and academia. The main drivers for industrial symbiosis and bio-based innovation in Slovenia are outlined below:

- **Policy and strategic alignment with EU Circular Economy goals.** Slovenia's policies align with the EU Circular Economy Action Plan and Green Deal, promoting circular economy principles that naturally encourage industrial symbiosis. The Smart Specialization Strategy and the Bioeconomy Strategy of the Podravje Region highlight these sectors as priorities for growth and innovation. Slovenia's Roadmap for Circular Economy supports this by creating a favourable regulatory environment. However, the country lacks dedicated regional programs specifically for industrial symbiosis or bio-based industries. While national policies support the broader circular economy, insufficiently targeted initiatives or specialized funding at the national level for bio-based innovation limit the impact of symbiosis-driven industries.
- **Emerging funding opportunities.** Access to EU funds through programs like the Circular Bio-based Europe Joint Undertaking (CBE JU), alongside national programs, like Eko Sklad - Slovenian Environmental Public Fund, and private investment from entities, like LoginEKO, provide financial incentives for companies investing in circular economy projects, including industrial symbiosis.
- **Growing eco-innovation and bio-based industry networks.** Professional networks, such as Chambers of Commerce and EIT Climate-KIC, and industry clusters are supporting the growth of eco-innovation. These platforms stimulate the cross-sectoral synergies essential for industrial symbiosis and foster knowledge exchange among key stakeholders in bio-based sectors. However, collaboration between government agencies, research institutions, and industries remains fragmented, limiting the scalability of industrial symbiosis practices and hindering knowledge sharing across sectors. Establishing public-private partnerships could address this gap by aligning research with industry needs.
- **Research and innovation infrastructure.** Research institutions like the University of Maribor and the University of Ljubljana, along with collaborative programs such as Circular Change, foster symbiosis-related innovation. However, Slovenia's bio-based research landscape is limited, with existing research organizations primarily focused on agriculture, pulp and paper, and renewable energy. Although these institutions have the potential to contribute to bio-based innovation, their specific focus areas may restrict their impact. There is a pressing need for more comprehensive and interdisciplinary research initiatives.

7. Reference

1. Baldassarre, B.; Schepers, M.; Bocken, N.; Cuppen, E.; Korevaar, G.; Calabretta, G. Industrial Symbiosis: Towards a Design Process for Eco-Industrial Clusters by Integrating Circular Economy and Industrial Ecology Perspectives. *J. Clean. Prod.* **2019**, *216*, 446–460, doi:10.1016/j.jclepro.2019.01.091.
2. Bijon, N.; Wassenaar, T.; Junqua, G.; Dechesne, M. Towards a Sustainable Bioeconomy through Industrial Symbiosis: Current Situation and Perspectives. *Sustain.* **2022**, *14*, 1–24, doi:10.3390/su14031605.
3. Communication 2011/571: Roadmap to a Resource Efficient Europe Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0571.
4. What Industrial Symbiosis Means Available online: https://www.sfridoo.com/en/industrial-symbiosis/.
5. Gatto, F.; Re, I. Circular Bioeconomy Business Models to Overcome the Valley of Death. A Systematic Statistical Analysis of Studies and Projects in Emerging Bio-Based Technologies and Trends Linked to the Sme Instrument Support. *Sustain.* **2021**, *13*, 1–37, doi:10.3390/su13041899.
6. Italian National Institute of Statistics (ISTAT) Available online: http://dati.istat.it/Index.aspx?QueryId=33654.
7. Malt Extract Process Available online: https://barmalt.com/malt-extract-process/.
8. Value calculated using the specific conversion rate.The information regarding the applied conversion rate is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.
9. Lovarelli, D.; Garcia, L.R.; Sánchez-Girón, V.; Bacenetti, J. Barley Production in Spain and Italy: Environmental Comparison between Different Cultivation Practices. *Sci. Total Environ.* **2020**, *707*, 135982, doi:10.1016/j.scitotenv.2019.135982.
10. The Soybean Market - Italy Available online: https://www.businesscoot.com/en/study/the-soybean-market-italy.
11. Soybean Production in Italy: Agronomy, Economics, and Policy Available online: https://true-project.webarchive.hutton.ac.uk/download/version/1552572744/module/11580062177/name/TRUE CLIN2 Poster Centofanti.pdf?t=1552572744.
12. Total Cultivated Area for the Production of Soy in Italy from 2014 to 2023 Available online: https://www.statista.com/statistics/716486/cultivated-area-for-soy-in-italy/.
13. Soy and Palm Oil Available online: https://www.danishcrown.com/global/sustainability/important-issues/soy-and-palm-oil/.
14. Soybean Meal - They're Not All the Same Available online: https://dairy.osu.edu/newsletter/buckeye-dairy-news/volume-9-issue-4/soybean-meal-theyre-not-all-same.
15. Value calculated using the specific conversion rate.The information regarding the applied conversion rate is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.
16. Organic Rice Production Systems in Italy: A Preliminary Environmental Assessmet Available online: https://www.academia.edu/92497317/Organic_rice_production_systems_in_Italy_a_preliminary_environmental_assessmet_Risicoltura_biologica_in_nord_Italia_prime_valutazioni_ambientali.
17. Governa, F.; Sacco, L. The History of Rice Cultivation in Northern Italy: A Focus on Lombardy and Piedmont. *J. Agric. Hist.* **2004**, *78*, 163–185.
18. Piyathissa, S.D.S.; Kahandage, P.D.; Namgay; Zhang, H.; Noguchi, R.; Ahamed, T. Introducing a Novel Rice Husk Combustion Technology for Maximizing Energy and Amorphous Silica Production Using a Prototype Hybrid Rice Husk Burner to Minimize Environmental Impacts and Health Risk. *Energies* **2023**, *16*, doi:10.3390/en16031120.
19. Value calculated using the specific conversion rate.The information regarding the applied conversion rate is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.
20. Fumonisins in Italina Maize: Analysis and Consideration Available online: http://www.micotossine.it/public/pag_192.pdf.
21. Facts and Figures on Organiz Farming in Italy 2020 Available online: https://www.sinab.it/sites/default/files/Facts and figures 2020 EN.pdf.
22. Local Benchmark Sites of Emilia-Romagna Soils Available online: https://ambiente.regione.emilia-romagna.it/en/geologia/soil/benchmark-local-sites-of-emilia-romagna-soils.
23. Region, E.; Romagna, E.-; Reggiano, P.; Directive, N.; Romagna, E.-; Climate, T. Programming for the Green Economy: RDP Measures Based on a LIFE+ Study of Best Practice in Reducing GHG Emissions from Agriculture. **2014**, 1–3.
24. Straw Produced by 1 Hectare of Wheat Available online: https://areasosta.com/faq/quanta-paglia-produce-un-ettaro-di-grano.
25. Value calculated using the specific conversion rate.The information regarding the applied conversion rate is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

26. Italy Alfaalfa Market Size 2024-2033 Available online: https://reportsglobe.com/product/italy-alfalfa-market/.

27. Alfalfa Value Chain at a Regional Scale (Province of Bologna, Italy) Available online: https://www.pgro.org/alfalfa-value-chain-at-a-regional-scale/.

28. Viccaro, M.; Cozzi, M.; Rocchi, B.; Romano, S. Conservation Agriculture to Promote Inland Biofuel Production in Italy: An Economic Assessment of Rapeseed Straight Vegetable Oil as a Self-Supply Agricultural Biofuel. *J. Clean. Prod.* **2019**, *217*, 153–161, doi:10.1016/j.jclepro.2019.01.251.

29. Forleo, M.B.; Palmieri, N.; Suardi, A.; D., .Domenico COALOA The Eco-Efficiency of Rapeseed and Sunflower Cultivation in Italy. Joining Environmental and Economic Assessment. *J. Clean. Prod.* **2017**, *172*, doi:10.1016/j.jclepro.2017.11.094.

30. Industriali, I.-I.S. per le C. Rapeseed in Italy Available online: https://www.gcirc.org/fileadmin/documents/Bulletins/B17/GCIRCBUL17_08.pdf.

31. Palmieri, N.; Forleo, M.B.; Suardi, A.; Coaloa, D.; Pari, L. Rapeseed for Energy Production: Environmental Impacts and Cultivation Methods. *Biomass and Bioenergy* **2014**, *69*, 1–11, doi:10.1016/j.biombioe.2014.07.001.

32. Arthey, T. Challenges and Perspectives in Global Rapeseed Production Available online: www.agribenchmark.org/cash-crop.

33. Development, R. Bioeconomy Case Study Low-Carbon Transition in the EU Sugarbeet Sector – Bioeconomy as a New Business Model. **2019**, *2015*.

34. Conversion Factors between Cubic Metres and Green Tonnes Available online: https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2018/sources/timber-2/conversion-factors/.

35. *The Role of Wood Residues in the Transition to Sustainable Bioenergy*; 2023; ISBN 9789251375037.

36. Camia, A.; Robert, N.; Jonsson, R.; Pilli, R.; Garcia-Condado, S.; Lopez-Lozano, R.; van der Velde, M. *Biomass Production, Supply, Uses and Flows in the European Union-JRC Science for Policy Report*; 2018; ISBN 9789279772368.

37. Municipal Waste in Italy: Production, Collection and Management Available online: https://www.isprambiente.gov.it/en/ispra-events/municipal-waste-in-italy-production-collection-management-and-energy-recovery.

38. Sommererhebung 2023, AgrarMarkt Austria Available online: https://www.ama.at/getattachment/d6c3bf7f-48c8-4132-8380-aaf165bb9c36/Sommererhebung_2023.pdf.

39. Panoutsou, C.; Singh, A. Roadmap for Lignocellulosic Biomass and Relevant Policies for a Bio-Based Economy in What Types of Lignocellulosic Biomass Are Included in the Analysis ? Lignocellulosic Biomass in This Analysis Includes : ? Forest Biomass from Primary Forestry Production.

40. Austrian National Statistics Office Available online: https://www.statistik.at/.

41. Agriculture and Horticulture in Numbers Available online: https://www.climatechangepost.com/countries/austria/agriculture-and-horticulture/.

42. An Opportunity Provided by Climate Change: Soy Production to Increase in Europe in the Future Available online: https://phys.org/news/2023-01-opportunity-climate-soy-production-europe.html.

43. Value calculated using the specific conversion rate.The information regarding the applied conversion rate is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

44. Sustainable Thinking in Carinthian Agriculture and Forestry Available online: https://carinthia.com/en/business-technology/agriculture-and-forestry/.

45. Value calculated using the specific conversion rate.The information regarding the applied conversion rate is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

46. FORESTRY IN CARINTHIA Available online: https://www.fao.org/4/y9351e/Y9351E05.htm.

47. KÄRNTEN - Geography and History Available online: https://circabc.europa.eu/webdav/CircaBC/ESTAT/regportraits/Information/at21_geo.htm.

48. Statistical Office of the European Union - Eurostat Eurostat Database Available online: https://ec.europa.eu/eurostat/data/database (accessed on 30 May 2024).

49. EUROSTAT Database Available online: https://ec.europa.eu/eurostat/data/database.

50. Corn Stover Available online: https://www.agmrc.org/commodities-products/biomass/corn-stover.

51. Wheat in Belgium Available online: https://oec.world/en/profile/bilateral-product/wheat/reporter/bel.

52. Trejo, A. Sustainability Assessment of Wheat Production in the Netherlands - A Comparison between Organic and Conventional Production. **2015**, 37.

53. How to Identify Farm Crops on a Country Walk Available online: https://www.discoveringbelgium.com/identify-farm-crops/.

54. Chapter XI - FODDER OATS IN EUROPE Available online: https://www.fao.org/4/y5765e/y5765e0f.htm.

55. Agricultural Production - Crops Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural_production_-_crops.

56. Caracterización Sector Agrario y Pesquero de Andalucía 2023 Available online: https://www.juntadeandalucia.es/sites/default/files/2024-04/Caracterización Sector Agrario y Pesquero de Andalucía 2023 _0.pdf.

57. Beet Planting Will Increase More than 20% in Spain Due to Good Sugar Prices Available online: https://www.tridge.com/news/beet-planting-will-increase-more-than-20-in--ijxymj.

58. SUGAR BEET Cultivation Available online: https://regaber.com/en/remolacha-azucarera/.

59. Krzysiak, Z. Profitability of Sugar Beet Production in 2023/2024 Campaign on Example of Lublin Voivodeship. *Eng. Rural Dev.* **2024**, *23*, 540–549, doi:10.22616/ERDev.2024.23.TF101.

60. Sugar Beet Harvest in Europe Down Available online: https://www.cbs.nl/en-gb/news/2019/24/sugar-beet-harvest-in-europe-down.

61. SUPERFICIE FORESTAL Andalucia Available online: https://www.mapa.gob.es/estadistica/pags/anuario/2019/CAPITULOS_TOTALES/AE19-C06.pdf.

62. Medio Ambiente En Andalucia Available online: https://www.juntadeandalucia.es/medioambiente/portal/documents/20151/130955021/informe-medio-ambiente-andalucia-2023.pdf/bace344d-38c7-a0c1-1f64-de6ece3ff74f?t=1703165024975.

63. Evaluación de Biomasa Potencial En España a Nivel Provincial Available online: https://www.agroalnext.es/descargas/evaluacion-de-biomasa-potencial-en-espana-a-nivel-provincial/.

64. Croatian Bureau of Statistics Available online: https://podaci.dzs.hr/2023/hr/58457.

65. Statistik.At Available online: https://www.statistik.at/en/statistics/agriculture-and-forestry/crop-production-and-farming/arable-land-permanent-grassland.

66. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

67. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

68. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

69. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

70. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

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75. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

76. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

77. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

78. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy

of the SYMBIO project results.79. Hirter Bier Available online: https://www.hirterbier.at.

80. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

81. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

82. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.83. Emulco NV Available online: https://emulco.com.

84. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

85. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.86. Ajinomoto OmniChem NV Available online: https://www.ajinomoto-omnichem.com.

87. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

88. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

89. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

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102. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

103. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

104. The specific information regarding technology owners is considered sensitive when defining the Industrial Exploitation Strategy of the SYMBIO project results.

105. Chertow, M.R. Industrial Symbiosis: Literature and Taxonomy. *Annu. Rev. Energy Environ.* **2000**, *25*, 313–337, doi:10.1146/annurev.energy.25.1.313.

106. Vladimirova, D.; Miller, K.; Evans, S. Scaling European Resources With Industrial Symbiosis. **2018**.

107. Konietzko, J.; Bocken, N.; Hultink, E.J. Circular Ecosystem Innovation: An Initial Set of Principles. *J. Clean. Prod.* **2020**, *253*, 119942, doi:10.1016/j.jclepro.2019.119942.

108. World Business Council for Sustainable Development Collaboration, Innovation, Transformation: Ideas and Inspiration to Accelerate Sustainable Growth - A Value Chain Approach About This Document. **2011**.

109. Consorzio Italbiotec Available online: Consorzio Italbiotec.

110. Assobiotec Available online: Assobiotec - English version (federchimica.it).

111. ENEA , Italian National Agency for New Technologies, Energy and Sustainable Economic Development Available online: https://www.enea.it/it/ .

112. Lombardy Green Chemistry Association (LGCA) Available online: https://www.chimicaverdelombardia.it/en/.

113. RuralBioUp Project Available online: https://www.ruralbioup.eu/.

114. ForestEcoValue Project Available online: https://www.alpine-space.eu/project/forest-ecovalue/.

115. TEC4I FVG - Human Technology Hub Available online: https://tec4ifvg.it/.

116. IP4FVG Digital Innovation Hub Available online: https://www.ip4fvg.it/.

117. BeIT Available online: https://madeinitaly.gov.it/en/.

118. The Italian Bioeconomy Strategy (BIT) Available online: https://scar-europe.org/images/SCAR_EVENTS/Greece_24_05_2018/2-5_Annalisa_Zessa.pdf.

119. Bioeconomy Trade Fair Available online: https://confindustria.lombardia.it/cluster/report-9-lombardy-technology-clusters.pdf.

120. Ecomondo Fair Available online: https://unb.ecomondo.com/visit-2024/?utm_source=google_ads&utm_medium=sem&utm_campaign=T3&gad_source=1&gclid=Cj0KCQjw6oi4BhD1ARIsAL6pox1fJz_L4A-jyoOC6YkR0TrU72newwn02dQX96tDhDnFrSeGg8alDnUaAiUSEALw_wcB.

121. Bioeconomy Dialogues Available online: https://www.sviluppospostenibile.regione.lombardia.it/it/b/854/bioeconomy-dialogues?g= g-7551 g-7552 g-7555 g-7558.

122. Terra Next Accelerator Available online: https://www.terranextaccelerator.com/.

123. Cluster SPRING Available online: https://www.clusterspring.it/en/about-us#:~:text=SPRING%2C acronym of Sustainable Processes,to by Directorial Decree no.

124. National Research Council (CNR) Available online: https://www.cnr.it/ .

125. Superior Institute for Environmental Research and Protection (ISPRA) Available online: https://www.isprambiente.gov.it/en .

126. Federated Innovation @Mind Available online: https://www.federatedinnovation-mind.com/.

127. Council for Agricultural Research and Analysis of Agricultural Economics (CREA) Available online: https://www.crea.gov.it/en/about-crea.

128. Italian Institute of Technology (IIT) Available online: https://www.iit.it.

129. Italian Technological Clusters Available online: https://www.mur.gov.it/it/aree-tematiche/ricerca/iniziative-speciali-e-grandi-ricerche/cluster-tecnologici-nazionali .

130. BIOCIRCLE Master Available online: https://masterbiocirce.com/.

131. University of Milano-Bicocca Available online: https://en.unimib.it/.

132. University of Eastern Piedmont Available online: https://www.uniupo.it/en.

133. University of Bologna Available online: https://www.unibo.it/en.

134. AMOCEAB - Adrion Master's on Circular Economy and Bioeconomy.

135. University of Trieste Available online: https://portale.units.it/en.

136. University of Padua Available online: https://www.unipd.it/.

137. Ca' Foscari University of Venice Available online: https://www.unive.it/.

138. University of Verona Available online: https://www.univr.it/it/.

139. Consorzio Legno Alta Lombardia Available online: http://www.consorziosegherie.it/.

140. C-Green Available online: https://www.cgreen.it/en/home-en/.

141. Agrifood Agency Available online: https://www.agrifoodfvg.it/en/16166/the-agency.

142. Funding Support | Business Development Support Available online: https://carinthia.com/en/investments-start-ups/funding-and-support-programmes/.

143. Build! Gründerzentrum - the Centre for Innovative Startups Available online: https://build.or.at/en/.

144. Biobase Platform Available online: https://biobase.at/.

145. Stadtwerk Klagenfurt Available online: https://www.stw.at/.

146. InvestCEC - Replicable Model for Local Circular Economy Projects Available online: https://investcec.eu/.

147. Sustainability Coalition Available online: https://www.ktn.gv.at/Service/News?nid=35767.

148. Carinthian Economic Development Fund Available online: https://kwf.at/ueber-den-kwf/strategie-des-kwf/#:~:text=Unsere Strategie ist so angelegt,Saisonalität im Bausektor und in.

149. Just Transition Fund (JTF) - Topics A-Z Available online: https://www.ktn.gv.at/Themen-AZ/Details?thema=3&detail=1325.

150. Fraunhofer Institute of Austria Available online: https://www.fraunhofer.at/.

151. Wood K+ Network Available online: https://wood-kplus.at/de/partner/foerderprojekte.

152. University of Klagenfurt Available online: https://www.aau.at/en/.

153. University of Applied Sciences Kärnten Available online: https://www.fh-kaernten.at/en/.

154. Öli – Fett Weg. Mit Energie Available online: https://www.oeli.at/.

155. B2BE Facilitator - Business to Bioeconomy Available online: https://www.b2be-facilitator.be/nl/.

156. Flanders Biobased Valley Available online: https://profile.clustercollaboration.eu/profile/cluster-organisation/6965d2e7-06c1-4e6d-821f-037083622d78.

157. Valbiom Available online: https://www.valbiom.be/.

158. EU Green Week 2024 - European Union (Europa.Eu) Available online: https://green-week.event.europa.eu/index_en.

159. Belgian Science Policy Available online: https://www.belspo.be/belspo/organisation/about_intro_en.stm.

160. About | Bio-Based Industries Consortium (BIC) Available online: https://biconsortium.eu/about.

161. VIB.BE - Ecosystem Available online: https://vib.be/en/business/ecosystem.

162. Bioeconomy in Flanders. The Vision and Strategy of the Government of Flanders for a Sustainable and Competitive Bioeconomy in 2030 Available online: https://www.vlaanderen.be/publicaties/bioeconomy-in-flanders-the-vision-and-strategy-of-the-government-of-flanders-for-a-sustainable-and-competitive-bioeconomy-in-2030.

163. Walloon Waste and Resources Plan (PWD-R) Available online: https://sol.environnement.wallonie.be/pwd-r.html.

164. Be Circular, Be Brussels Available online: https://www.circulareconomy.brussels/.

165. Let Us Introduce Ourselves | Flanders Innovation & Entrepreneurship Available online: https://www.vlaio.be/en/about-us/let-us-introduce-ourselves.

166. Vrije Universiteit Brussel Available online: https://www.vub.be/nl.

167. Université Libre de Bruxelles Available online: https://www.ulb.be/.

168. Ghent University Available online: https://www.ugent.be/en.

169. Business Innovation Centre of Croatia (BICRO) Available online: https://hamagbicro.hr/o-nama/osnivanje/.

170. Startup Factory Zagreb (ZICER) Available online: https://www.zicer.hr/startup-factory/?lang=en.

171. Croatian Biomass Association (CROBIOM) Available online: https://www.drvnipelet.hr/.

172. Croatian Strategic Plan Form the Common Agricultural Policy Available online: https://ruralnirazvoj.hr/intervencije/.

173. Ruđer Bošković Institute Available online: https://www.irb.hr/eng.

174. Croatian Forest Research Institute Available online: https://www.sumins.hr/en/.

175. Renewable Energy Sources in Agriculture / Graduate Studies (MS) / University of Zagreb Faculty of Agriculture (Unizg.Hr) Available online: https://www.agr.unizg.hr/en/1283/Renewable+Energy+Sources+in+Agriculture.

176. LUI - University of Ljubliana Incubator Available online: https://www.lui.si/english/.
177. Center Rog Available online: https://center-rog.si/en/.
178. Technologies and Business Models for the Circular Economy (TBMCE) 2024 Available online: https://tbmce.um.si/.
179. Strategic Research and Innovation Partnership – Networks for the Transition into Circular Economy (SRIP – Circular Economy) Available online: https://srip-circular-economy.eu/srip-circular-economy/about-us/.
180. CER Available online: http://www.cer-slo.si/.
181. Slovenia's Smart Specialisation Strategy Available online: https://evropskasredstva.si/en/slovenias-cohesion-policy-programme-2021-2027/slovenias-smart-specialisation-strategy/#:~:text=Slovenia%27s Smart Specialisation Strategy (S4,comprehensive and tailored policy mix.
182. Slovenia: Systems Innovation for the Transition to a Circular, Regenerative and Low-Carbon Economy - Climate-KIC Available online: https://www.climate-kic.org/circularslovenia-2-2/.
183. Circular Bioeconomy Strategy of Podravje Region Available online: https://circulareconomy.europa.eu/platform/sites/default/files/2024-03/CCRI_Regional-strategy_Circular-Bioeconomy-Podravje-2023_eng.pdf.
184. Kmetjiski Inštitut Slovenje Available online: https://www.kis.si/en/.
185. Inštitut Za Celulozo in Papir Available online: https://icp-lj.si/?lang=en.
186. Innorenew Centre of Excellence Available online: https://innorenew.eu/.
187. Studies at FKBV – Faculty of Agriculture and Biosystems Sciences Available online: https://www.fkbv.um.si/?page_id=32.
188. University of Ljubliana Available online: https://www.uni-lj.si/en/university.

Annex 1 – Bio-based Industries Innovation Ecosystem Mapping Template

Mapping your Bio-based Industries Innovation Ecosystem

The idea is to make a list of actors and initiatives relevant to bio-based industries and innovation in your region. This is an initial mapping that will be further validated with stakeholders to identify broader systemic enablers and barriers for the ecosystem.

1. Bio-based business and innovation support (in some cases digital)

What business support programmes exist in your region? Please list the names of the programmes and indicate what support is available. Consider:

- Mentoring, advice from innovation experts
- Export & IP programmes
- Business support programmes for start-ups and emerging enterprises
- Innovation spaces, labs

2. Promotion

What design promotion activities take place in your region? For example:

- Promotional campaigns
- Trade fairs, exhibitions, promotional events
- Trade missions
- Bio-based, circular labels
- Award schemes for bio-based products

3. Delivery actors

What organisations, associations, networks and clusters related to bio-based industries and innovation exist in your region? What government departments are involved in shaping the ecosystem? Consider:

- Government departments, e.g. Departments of Environment, Social Welfare, Regional Development, Business, Agriculture, Rural Affairs Waste Management etc
- Regional innovation/development agencies
- Intellectual Property Agencies
- Professional networks for bio-based and circular industries
- Incubators and clusters

4. Policy

What policies or strategies exist in your region that relate to bio-based industries and innovation? Are they included in regional development plans and/or smart specialisation strategies? Consider:

- EU, national & regional legislation and action plans around bio-based and circular
- International frameworks for social value (SDGs)
- National-level SDGs or regional development plans
- Regional-level development plans or social value plans

5. Funding

What financing mechanism such as subsidies, grants, vouchers, tax credits exist in your region? Please indicate what activities are eligible. Consider various sources of funding:

- EU structural funding;
- National funding programmes;
- National innovation grants;
- Research funding;
- Private investment;
- Charitable investment;
- Tax credit schemes.

6. Research

Please list any related research and technology transfer institutions and initiatives such as:

- Research & technology organisations;
- Knowledge transfer/exchange programmes;
- Product development support through design - design research bridging the gap between research and market;
- Collaborative projects.

7. Education

Please list educational institutions and initiatives in your region such as:

- Further & higher education institutions;
- Industry - based training programmes
- New business development programmes in bio-based/circular industries

8. Users

Please list any major businesses across the value chains in bio-based and circular industries, (agriculture, biomaterial processors, product development, retailers, users, waste management. valorisation actors). This could also include community organisations such as community growing initiatives of renewable energy clusters.

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Annex 2 – Comprehensive Bio-based Industries Innovation Ecosystem Mapping for each pilot region

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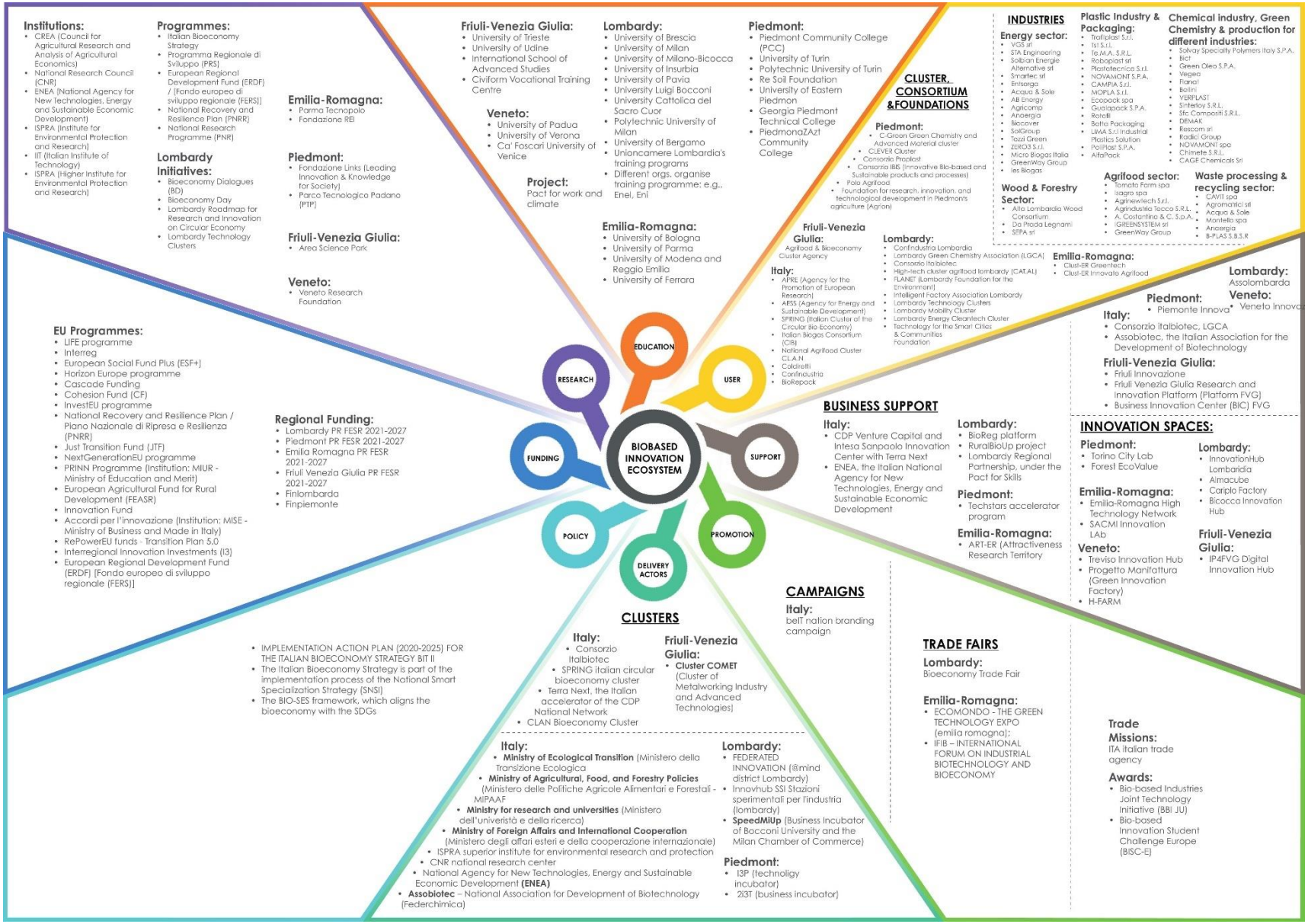

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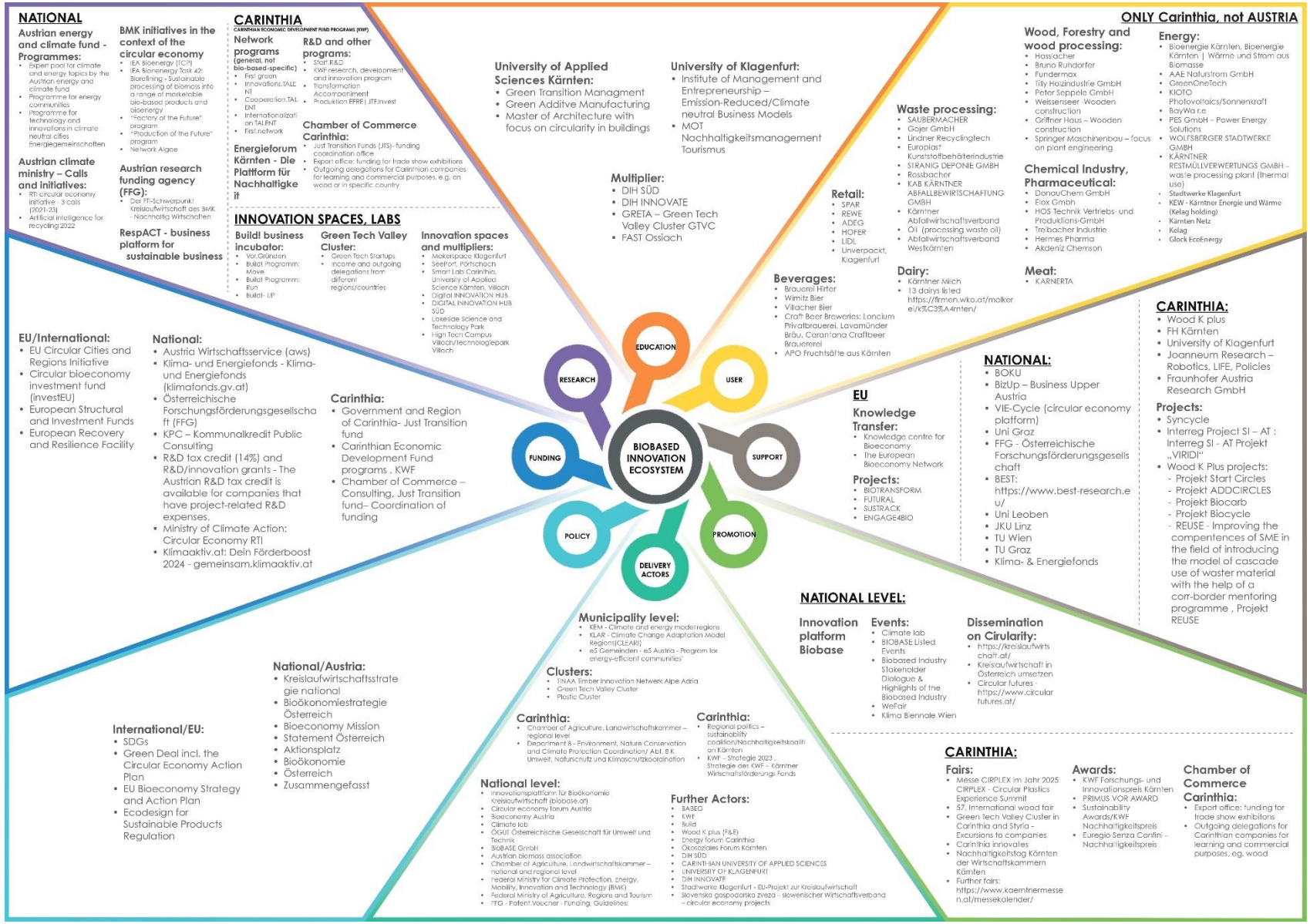

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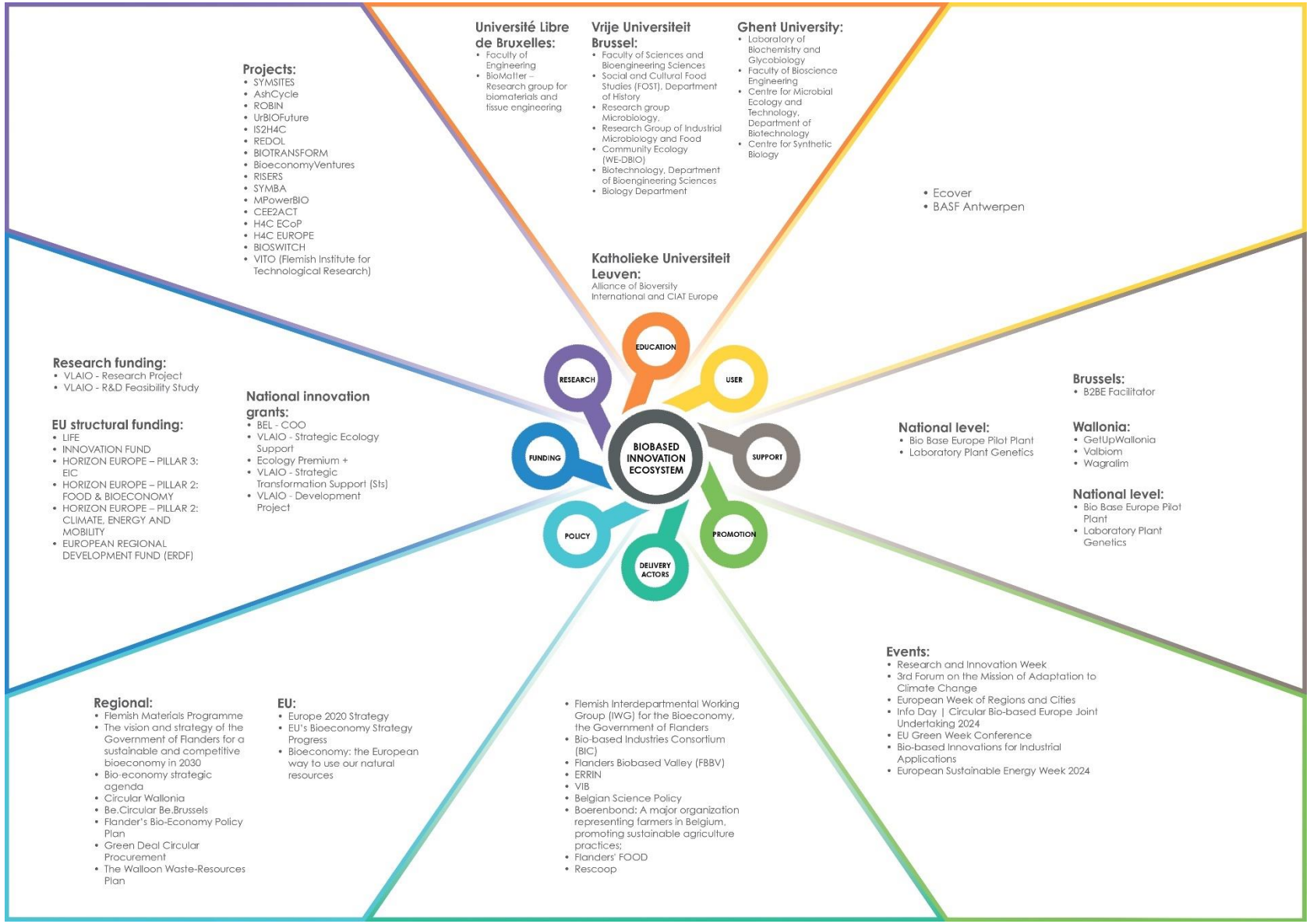

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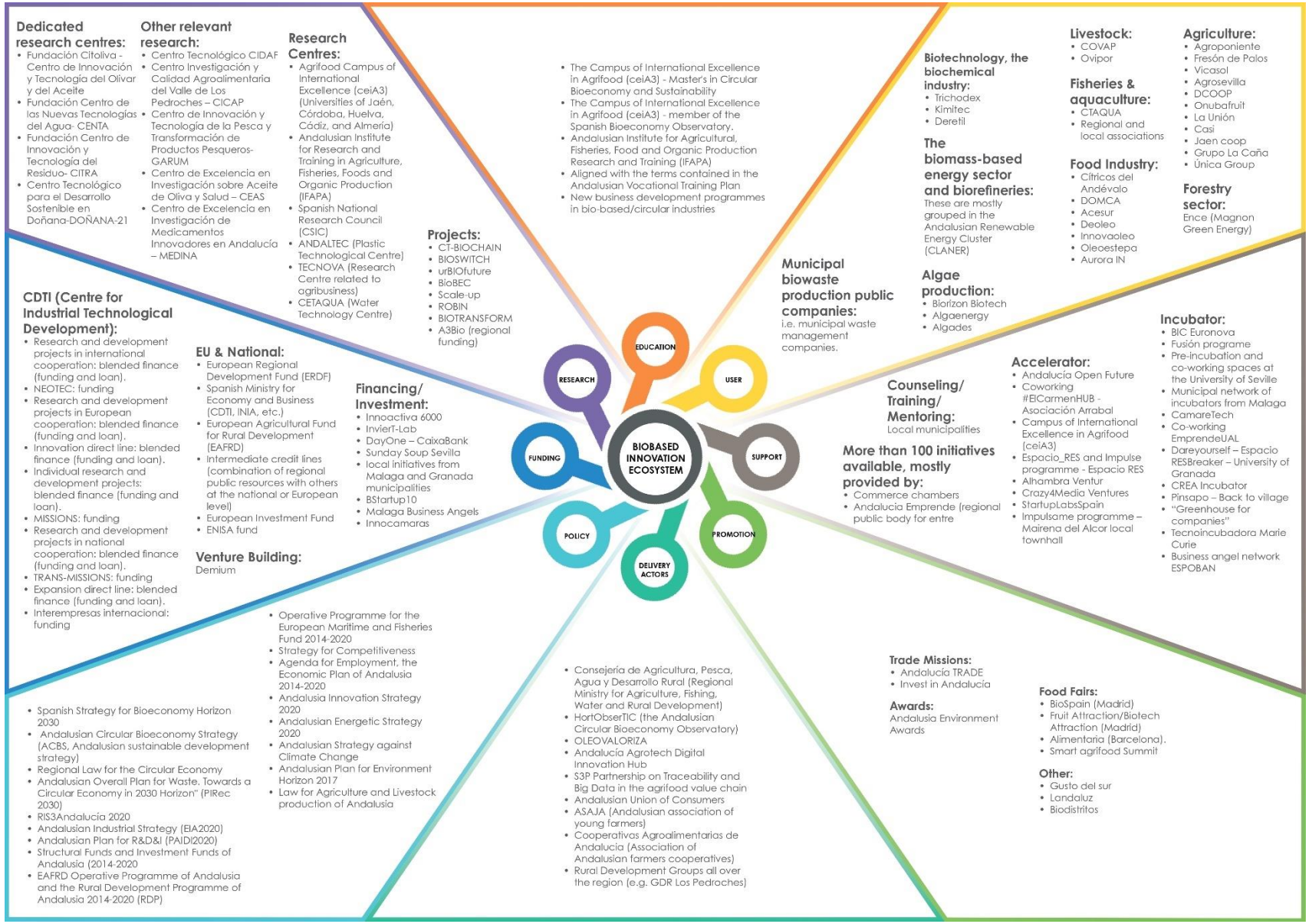

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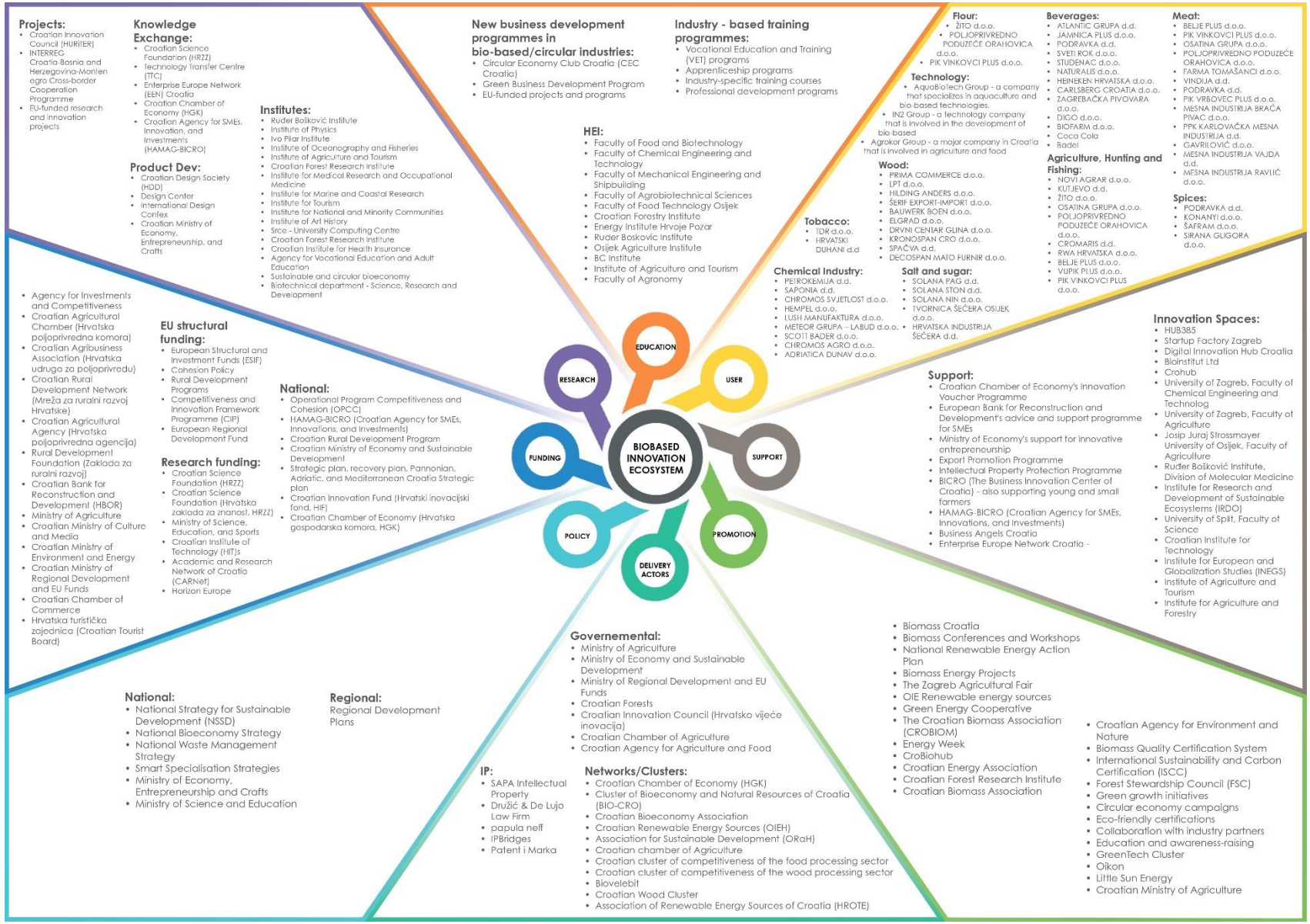

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