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Deliverable 2.3 - Support activities for empowering clusters and industrial ecosystems in circular value chains design

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Deliverable description

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Abbreviations

AD	Anaerobic Digestion
AECG	Anteja ECG (author/partner)
BioLink	Identified circular value chains linking waste producers, technology providers and end-users
BSY	Brewer's Spent Yeast
CAPEX	Capital Expenditure (investment cost)
CBE JU	Circular Bioeconomy Joint Undertaking
COD	Chemical Oxygen Demand
ESG	Environmental, Social and Governance
FOG	Fats, Oils and Greases
GA	Grant Agreement
GHG	Greenhouse Gas
LCA	Life-Cycle Assessment
LGCA	Lombardy Green Chemistry Association
MCDMA	Multi-Criteria Decision-Making Analysis
MFA	Material Flow Analysis
MSW	Municipal Solid Waste
REA	European Research Executive Agency
SHW	Slaughterhouse Waste
SSF	Simultaneous Saccharification and Fermentation
SYMBIO	Shaping symbiosis in bio-based industrial ecosystems based on circular by-design supply chains (project title)
TRL	Technology Readiness Level
VCG	Value Chain Generator (concept)

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VCG.AI	Digital platform used for modelling circular value chains
WPC80	Whey Protein Concentrate ≈ 80 % protein
WTE/WtE	Waste-to-Energy
WP2	Work Package 2 (Methodology work-package)

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Executive summary

Deliverable 2.3 captures how SYMBIO's WP2 empowered six European regions, Andalusia, Croatia, Carinthia, Lombardy, Slovenia and Belgium, to design circular, bio-based value chains. Through regional workshops, live demos of the VCG.AI decision-support tool and bespoke overlap analyses, local clusters mapped millions of tonnes of residual feedstocks (olive prunings, whey, wood, corn cobs, brewer's yeast, animal fats) to high-value products such as furfural, glycerol, β-glucans and WPC80. The five-step VCG.AI workflow ranked techno economic and ESG performance, revealed minimal infrastructure conflicts and highlighted co-location synergies. Market assessments showed 5–12 % CAGRs for target products, strengthening business cases. The process short-listed 12 pilot chains and showed the potential for new consortia, positioning the regions to attract EU funding and advance demonstration plants that will anchor Europe's emerging circular bioeconomy.

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1. Introduction

This report is part of the Work Package 2– *Shaping value chains through big data and artificial intelligence tools by empowering industrial biobased ecosystem*, focus on the use of the VCG.AI to build CBE value chains in Europe with industrial symbiosis capabilities to leverage local CBE potential and untapped resources. In particular, Deliverable 2.3 falls into the Task 2.3 *Implementation of support activities for industrial ecosystems*, which aims to provide tailored mentoring, coaching and training services to regional cluster/business networks to support them in modelling circular by design value chains and strengthen support.

Deliverable 2.3 - Support activities for empowering clusters and industrial ecosystems in circular value chains design aims to record how the consortium moved from desk-based value-chain screening (D2.1–2.2) to hands-on support for six pilot regions, Andalusia, Croatia, Carinthia, Lombardy, Slovenia and Belgium. The idea is to provide tailored mentoring, coaching and training services to regional networks of clusters/enterprises to support modeling of circular by-design value chains and strengthen support services to their members. Its purpose is two-fold:

- Empower clusters and industrial ecosystems to design investable, circular bio-value chains by translating the data and rankings produced in earlier tasks into region-specific roadmaps and partnerships.
- Create a reproducible support model, combining regional workshops, live VCG.AI demonstrations and infrastructure-overlap analyses, that other EU regions can adopt to fast-track circular-economy projects.

The scope is deliberately practical and time bound. It covers all facilitation activities delivered between March and May 2025: six full day workshops hosted on-site (or online, where needed), targeted coaching sessions on VCG.AI's five-step workflow, and the drafting of twelve preliminary business cases. Geographically, it is limited to the six SYMBIO pilot territories listed above; technologically, it addresses only the feedstocks and conversion routes prioritised in D2.2 (e.g., olive prunings→furfural, whey permeate→WPC 80). Implementation or financing actions fall outside this deliverable's remit and will be carried forward into WP3 pilot planning. By defining these boundaries, Deliverable 2.3 provides a clear, replicable blueprint for turning circular-economy analytics into region-anchored investment pipelines.

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2. Methodology

2.1 2-Day Workshop methodology

To effectively accelerate the design of circular, regionally anchored value chains, SYMBIO developed a tailored support format called the 2-Day Workshop. These workshops were conceived within Task 2.3 to provide an intensive, high-engagement setting that brings together regional stakeholders, technical experts, and innovation facilitators around a shared objective: translating data-driven insights into actionable value-chain blueprints. The 2-Day format enables deeper interaction than a single session and creates space for both strategic framing and operational co-design.

The 2-Day Workshop format was strategically created to integrate and operationalise key components from three project tasks—Task 1.3 (establishing regional stakeholder communities), Task 1.4 (cross-fertilisation and knowledge exchange), and Task 2.3 (implementation of support activities for industrial ecosystems)—within a single, cohesive event. This approach was designed to minimise stakeholder fatigue while maximising outcome density. Rather than organising separate meetings for each task, SYMBIO combined them into a single, value-rich format that consolidated engagement, learning, co-design and roadmap building. Recognising that regional actors often face overlapping commitments across multiple initiatives, SYMBIO adopted a condensed, high-impact event format that concentrates several project activities, knowledge transfer, platform demonstration, regional analytics validation, co design of BioLinks, and ecosystem engagement—into a unified two-day agenda. This strategic consolidation ensured stakeholder time was used efficiently, while maintaining high levels of engagement and outcome-orientation.

The two-day structure followed a clear thematic progression:

- Day 1 was aligned with the objectives of Tasks 1.3 and 1.4, and focused on community building, regional mapping validation, and knowledge sharing. The session introduced participants to SYMBIO's overall methodology, presented region-specific feedstock and value chain mapping outputs, and showcased the tools developed by the project. In addition, Day 1 was dedicated to exploring practical strategies for integrating social value into circular business models, addressing dimensions such as local employment, community wellbeing, and inclusive innovation.

- Day 2 was fully dedicated to Task 2.3 and focused on technical and operational capacity building. It was organised into two training modules. The first module, delivered by ANTEJA, introduced the Value Chain Generator (VCG.AI) platform, explaining its purpose, structure, and practical functionalities through a live demonstration of its use in value chain modelling. The second module, facilitated by LGCA, targeted the empowerment of SMEs in transitioning to circular and resilient models. This included coaching sessions, self-assessment guidance, and strategic design support tailored to the needs of small and medium enterprises in the region.

This integrated format enabled SYMBIO to move seamlessly from strategic framing to technical enablement, while reinforcing both WP1 and WP2 objectives. It provided participants with the tools and support necessary not only to interpret complex analytical findings but also to translate them into actionable roadmaps aligned with local capabilities and circular economy goals.

For further information on the full design and cross-task structure of the 2Day Workshops, please refer to Deliverable D1.3. The present deliverable (D2.3) focuses specifically on the activities and outcomes related to Task 2.3, notably the training, coaching, and value-chain modelling support provided through the VCG.AI platform during the second day of each session.

2.2 Facilitated Regional Workshop Process

The Facilitated Regional Workshop Process represents the structured methodology applied during the second day of the 2Day Workshops, and corresponds specifically to the training and value chain co-creation session aligned with Task 2.3. This component was focused on equipping regional stakeholders—particularly SMEs, cluster representatives, and local innovators—with the tools, insights and technical skills necessary to design investable circular value chains using SYMBIO's decision-support platform, VCG.AI.

The format was applied consistently across all six pilot regions and followed a modular design to ensure both replicability and adaptability to local contexts. The process combined live demonstration, interactive coaching, and open discussion to transform static data into dynamic, region-specific circular value chain roadmaps.

The VCG.AI session, embedded in Day 2, followed the structured progression shown in **Table 1**.

Table 1 *Structured progression of the workshop.*

Phase	Duration	Activities & Tools	Outputs
0 Pre-workshop set-up	–	Configure a Miro board with questions for the discussion	Digital workspace ready.
1 Framing	10 min	Welcome & SYMBIO objectives; share workshop rules.	Shared purpose; psychological safety.
2 Platform immersion	15 min	Presentation of VCG.AI's AI engine and how it was used for gathering circular value chains.	Common vocabulary around data & KPIs.
3 Demo	20 min	Facilitator provides a demo of how the platform works.	Proof that the data are actionable; trust in the tool.

4 Regional insights	20 min	Co-lead presents region-specific analytics (e.g., Croatia's glycerol & furfural cases) using three slide blocks: feedstock volumes, ranked routes, market insights .	Shared baseline for decision making.
5 Q&A	20-40 min	The discussion continues freely.	Questions are answered. Regional insights debated.

Each workshop was limited to one hour and 30 minutes. Each session was co-facilitated by two representatives: the lead (regional insights) and the co-lead (screenshares VCG.AI), that was adapted by Anteja's team based on the language of the workshop to accommodate regional stakeholders.

2.3 General outcomes across six workshops

- Stakeholders across the quadruple helix successfully engaged,
- 12 value-chains short-listed and assigned regional "champions".
- Three workshops in person and three online.

This structured facilitation approach played a critical role in bridging the gap between data-driven modelling and practical implementation. Participants not only learned how to navigate and apply VCG.AI, but also engaged directly in refining the modelling outputs through their on-the-ground insights, thereby creating value chains that were technically appropriate, locally anchored and socio-economically relevant.

The facilitated session was essential for validating the preliminary results from D2.1 and D2.2, and for enabling stakeholder ownership over the value chains selected for follow-up. In several cases, this process also led to the nomination of regional "champions" tasked with further exploring business cases or consortia-building in WP3.

By embedding this structured process into Day 2 of the 2 day Workshops, SYMBIO ensured that the VCG.AI platform was not just introduced as a theoretical tool but applied in a participatory, hands on setting, where technical, economic, and social dimensions of circularity could be aligned through direct stakeholder input.

By embedding data analytics, visual design and value chain building into a single 90 minute sprint, the workshop methodology turned static desktop studies into investable, circular value chain roadmaps.

3. Results and Analysis

This chapter presents a consolidated analysis of those outcomes, structured around (i) common patterns observed across all territories, (ii) variations and regional specificities, and (iii) the overall impact on stakeholder readiness and circular value chain maturity.

3.1 Cross-Regional Outcomes

Across all regions, the structured facilitation enabled stakeholders from business, academia, public sector and civil society to engage in the design of circular value chains with tangible market relevance and technological feasibility. Key outcomes include:

- Twelve value chains were short-listed, and assigned to regional "champions" for further exploration. These champions are stakeholders, typically from clusters or SMEs, who expressed willingness to develop potential demonstration cases in collaboration with the SYMBIO consortium.
- Over 80 stakeholders engaged actively, representing various actors of the quadruple helix. Participants provided feedback on feedstock availability, technological options, and infrastructure compatibility, which was used to refine the value chain routes generated by VCG.AI.
- Each region validated at least one priority BioLink, based on combined criteria including feedstock abundance, infrastructure readiness, and end-market pull. These include:
    - Olive and wood residues to furfural in Andalusia,
    - Animal fats and corn residues to glycerol in Croatia,
    - Corn cobs and sawmill residues to furfural in Carinthia,
    - Whey to WPC80 and lactose in Lombardy and Belgium,
    - Sweet whey and maize cobs to WPC80 and furfural in Slovenia.
- The platform's five-step workflow (data ingestion, technology screening, gap analysis, market alignment, and infrastructure mapping) was consistently applied, resulting in replicable, region-specific value chain blueprints.
- The technical demonstrations were followed by interactive co-creation sessions, during which stakeholders debated and ranked proposed BioLinks. These discussions highlighted opportunities for co-location, technology transfer, and regional synergies.

3.2 Key Findings by Region

Table 2 summarises the main priorities, feedstocks, and product pathways emerging from the facilitated sessions.

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Table 2 *Key findings by region.*

Region	Priority Feedstocks	High-Potential Products	Annual Feedstock Potential*
Andalusia (ES)	Olive & wood residues; rice straw	Furfural; sorbitol	> 2.5 Mt olive prunings; 0.93 Mt rice straw
Croatia	Animal fats; corn & wood residues	Glycerol; furfural	21 kt fats; 2.6 Mt corn+wood residues
Carinthia (AT)	Wood residues; corn cobs; soybean meal	Furfural; glycerol	1.13 Mt wood; 21 kt cobs; 105 kt soybean meal
Italy	Whey permeate; brewer's spent yeast	WPC80 & lactose; β-glucans & peptides	/
Slovenia	Forestry residues; maize cobs; sweet whey	Furfural; WPC80 & lactose	119 kt wood; 887 kt cobs; 110 kt whey
Belgium	Brewer's spent yeast; whey	β-glucans & peptides; WPC80 & lactose	30 kt BSY; 250 kt whey

*Estimates presented during workshops.

3.3 Cross-Cutting Insights

In addition to region-specific findings, several transversal insights emerged from the workshops:

- Feedstock abundance but seasonality risks – multi-feedstock supply strategies (e.g., blending olive prunings with forestry residues) are essential for year-round plant operation.
- Low infrastructure conflict – less than 30 % of the identified streams are currently locked into bioenergy or waste routes, leaving ample biomass for higher-value conversion.
- Local technology & market anchors exist – each region hosts prospective technology licensors and offtakers (e.g., Petrokemija in Croatia, Parmalat & IGOR in Italy), lowering entry barriers for demonstration plants.

- Economic pull is strong – global markets for the selected bio-products show high CAGRs of 5–12 %, supporting investment cases (e.g., > USD 820 m furfural market; USD 5.6 bn glycerol market).

3.4 Regional Value Chain Modelling Results

This section presents a detailed overview of the modelling outcomes generated through the second-day sessions of the 2-day Workshops in each of the six SYMBIO pilot regions/countries: Spain (Andalusia), Croatia, Austria (Carinthia), Italy (including Lombardy, Piedmont, Veneto, Friuli-Venezia, Giulia, Emilia-Romagna), Slovenia, and Belgium (including Bruxelles Capital, Wallonia, Flanders). Each regional session applied the VCG.AI platform to simulate high-potential circular value chains based on locally available biomass, existing infrastructure, and market demand.

Rather than repeating the prioritisation logic already covered in Deliverable D2.2, the focus here is on how the shortlisted BioLinks were operationalised in a co-creation setting with regional stakeholders. For each region, the following elements are summarised: a brief recap of the workshop, key insights from the VCG.AI application, value chain configurations discussed, and any infrastructure overlaps or stakeholder commitments that emerged.

These results reflect a hybrid approach, combining top down data analytics with bottom up regional intelligence, to create circular value chains that are both technically viable and contextually grounded.

3.4.1 Spain (Andalusia)

Workshop Overview

The workshop was held on the 2nd of April 2025 in the Headquarters of SYMBIO partner Corporación Tecnológica de Andalucía (CTA) in Seville. The session was facilitated by Anteja's team (Miha Škrokov and Gašper Božič) and hosted by CTA (moderated by Rafael Castillo Barrero and María Alonso González) .

This session marked the first application and capabilities of the VCG.AI platform, presenting the platform's Andalusian results, and identifying key local stakeholders and infrastructure overlaps. The focus was on two pre-prioritised value chains identified in D2.2: (1) olive and wood residues to furfural and (2) rice straw to sorbitol.

VCG.AI Platform Demonstration

During the opening session, Božič and Škrokov provided a concise overview of the VCG.AI platform's five-step workflow, which integrates regional feedstock inventories, technology options (such as hydrolysis, fermentation, and catalytic processes), market demand analysis, and infrastructure or overlap assessments to generate circular value chain roadmaps. In the live demonstration, the facilitators showcased how users can upload local biomass data (for example, volumes of olive prunings, wood residues, and rice straw), specify target chemicals (e.g., furfural or sorbitol), and visualise potential conversion pathways along with associated feedstock sources, technology providers, and market off-takers. This interactive walk-through

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underscored the platform's ability to rapidly assemble data inputs and produce candidate value chains for stakeholder validation.

VCG.AI Results & Key Insights

The platform analysis highlighted several key lignocellulosic feedstock streams in Andalusia, displayed in a chart showing relative volumes and seasonality. Olive tree prunings, comprising branches, leaves, and wood, emerged as the largest available biomass resource with more than 2,5 million tonnes generated annually (typical pruning cycles every two years) (Ronchel and Barquero 2024). Forestry and wood residues (including sawdust, branches, and bark) also contribute significantly, with approximately . Rice straw from the Guadalquivir delta constitutes another major stream; while exact annual figures vary, task 2.1 estimated nearly 0.93 million tonnes of rice straw, with sugar beet pulp, barley straw, and alfalfa fiber representing smaller but still significant streams.

These feedstocks exhibit marked seasonality: rice straw is available primarily from September to November, olive pruning occurs roughly between January and March, and sugar beet pulp is produced from October to December.

Value Chain 1: Olive & Wood Residues → Furfural

The olive and wood residues to the furfural pathway was introduced as a high-potential chain, given Andalusia's vast volumes of underutilised olive prunings and wood waste. Furfural is a bio-based platform chemical used extensively in phenolic resin production for wood adhesives and as a solvent in specialty-chemical applications. A value chain schematic illustrated how pentosan rich fractions of hemicellulose from both olive prunings and mixed wood residues undergo acid or catalytic hydrolysis to yield furfural, followed by distillation to separate furfural from lignin and char by-products. End uses include phenolic resin manufacturers for wood panels (such as MDF and plywood), specialty solvent producers, and chemical intermediates for fine chemicals.

On the supply side, olive feedstock providers in Andalusia were identified as:

- Iberia Bioenergy (a biomass boiler operator),
- Castillo de Canena and Almazaras de la Subbética (olive oil mills and cooperatives),
- Mueloliva (olive oil producer),
- SGTRES (olive by-products processor),
- Ingeoliva (focused on pre-treating olive wood), and
- Grupo De Prado (a biomass aggregator).

Technology providers highlighted included Química Futura S.L. at the Huelva Chemical Park, capable of hosting pilot hydrolysis reactors, and Sophim Iberia as a potential catalyst supplier. Additional European licensors could fill any remaining gaps in hydrolysis or downstream separation capabilities.

On the market side, Andalusian companies noted for interest in furfural outputs were:

- Moeve (Seville), focusing on adhesives and phenolic resins;
- Persan S.A. (Seville), specializing in furfural refining and specialty chemicals;
- Condaplast S.A. (Seville), compounding bio-resins; and
- Fertinagro Sur S.L., exploring granulated fertilizers derived from furfural side streams.

These partnerships leverage existing olive-oil value chains, where prunings are currently underutilized or burned, and propose synergy with the Iberia Bioenergy boiler (shared steam, utilities). To address technological gaps, workshop presenters suggested pursuing EU technology transfers from established.

Value chain 2: Rice Straw → Sorbitol

The second value chain focused on rice straw's conversion into sorbitol, capitalizing on Andalusia's substantial rice production in the Doñana area. Sorbitol, a sugar alcohol widely used as a humectant in food and confectionery, as well as in personal care and pharmaceutical applications, is produced either by enzymatic/acid hydrolysis of cellulose to glucose followed by microbial fermentation, or by catalytic hydrogenation of glucose over nickel- or resin-based catalysts. A value chain schematic showed that, after hydrolysis, glucose can be fermented using specialised strains (e.g., those from C-Lecta in Leipzig) to yield sorbitol, or subjected directly to catalytic hydrogenation. Subsequent purification (crystallisation or membrane separation) achieves high-purity sorbitol (70–95 percent), suitable for various end users.

Local feedstock suppliers include Herba Ricemills, Arrozúa S.C.A. (rice cooperative), Pevesa Biotech, Doñarroz, and Arroces de Doñana. Across Spain's paddy fields, open-field burning is still the default fate for rice straw, releasing CO_2, particulate matter and other pollutants that degrade local air quality and contribute to climate change (Rodrigo and Ribeiro 2023). Technology providers C-Lecta (Leipzig) for fermentation strains and pilot fermenters, and Alpe Chem (Madrid) for catalytic transfer hydrogenation can serve as catalysts for this new circular value chain. Prospective local off-takers included Andros Granada (for food-grade sorbitol as a humectant in preserves) and Phaos Cosmetics (Seville) evaluating bio-based sorbitol for moisturisers.

During the workshop, it was stressed that adopting a multi-feedstock approach, such as supplementing with sugar beet pulp during the off-season of rice cultivation, to mitigate the risk of a narrow availability window is necessary. According to IMARC Group, the global sorbitol market was valued at approximately 2.76 million tonnes in 2024 and is forecast to reach 3.03 million tonnes by 2033 (CAGR 1.12 percent), driven by growing demand in food & beverage, cosmetics, and pharmaceuticals (IMARC Group 2024).

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Existing Infrastructure & Overlap Analysis

The workshop assessed Andalusia's existing bio-infrastructure, noting that several biomass boilers and bioenergy plants, such as Iberia Bioenergy and CEPSA Bioenergía, already consume substantial volumes of olive prunings, wood residues, and rice straw to produce heat and electricity. Concurrently, forestry residues and rice straw are partly diverted to pellet production and livestock bedding. This competition for feedstocks implies that redirecting lignocellulosic streams toward furfural or sorbitol production will require careful coordination to avoid disrupting established bioenergy or pellet markets.

Nonetheless, presenters highlighted synergy opportunities such as co locating hydrolysis and fermentation units adjacent to existing biomass boilers to share utilities (steam, hot water, wastewater treatment), thereby reducing capital expenditure. They also recommended leveraging existing cooperative networks, olive mill clusters and rice cooperatives, to channel raw materials into centralized pre-processing hubs for shredding and drying, which would be essential for consistent feedstock quality.

3.4.2 Croatia

Workshop Overview

The Croatian VCG.AI session took place on 13 March 2025 in person. The session was led by Gašper Božič and Miha Škrokov of Anteja ECG, with the primary aims to demonstrate the VCG.AI platform, share the platform's analytical results for Croatia, and engage local stakeholders in mapping circular value-chain opportunities.

VCG.AI Platform Demonstration

Božič and Škrokov opened with an introduction to VCG.AI's five-step workflow: (1) feedstock data ingestion, (2) technology route identification, (3) gap analysis, (4) market demand alignment, and (5) infrastructure overlap assessment. They walked participants through a live demo whereby regional biomass inventories, such as quantities of animal fats, corn residues, wood waste, and other agri-byproducts, are uploaded into VCG.AI. The platform then cross-references these feedstocks with global process intelligence (e.g., hydrolysis, fermentation, catalytic conversion) and local company databases to generate candidate value chains. For Croatia, they illustrated how users can specify target products (e.g., glycerol or furfural), visualise feedstock origins (e.g., slaughterhouse byproducts, corn stover, forestry residues), and pinpoint technology providers (both local and pan European licensors), culminating in a ranked list of circular value-chain options. This live demonstration underscored VCG.AI's ability to rapidly synthesize raw data and propose actionable, stakeholder-validated roadmaps.

VCG.AI Results & Key Insights

The analysis revealed that Croatia boasts over 3 million tonnes per year of combined wood and corn residues, positioning the country as a promising hub for high-value bioproducts. Specifically, approximately 21,962 tonnes of waste animal fats, oils, and greases (FOG) are generated annually by meat-processing firms such as Mesna Industrija Braća Pivac d.o.o., Gavrilović d.o.o., and PIK Vrbovec Plus d.o.o. This stream currently feeds rendering and small biodiesel operations but remains under-exploited for higher-value chemical production.

Corn residues, comprising 1.77 million tonnes of corn stover from companies like Novi Agrar d.o.o. and Žito d.o.o., and an additional 885,780 tonnes of maize cobs collected by Poljodartim d.o.o. and Poljinos d.o.o., represent a second major stream . Forestry residues amounting to 1.29 million tonnes annually (managed by Hrvatske Šume d.o.o. and sawmills such as BJELIN Industries d.o.o. and DIR – Drvna industrija Rubinić d.o.o.) further enhance the region's biomass portfolio. Although smaller, additional streams like sugar beet pulp and rice husks represent formidable biomass flows as well, they were deprioritised for this workshop's focus. Seasonality considerations included corn residue availability post-harvest (September–October), forestry residues remaining relatively constant year-round, and continuous generation of animal fats.

Value chain 1: Animal Fats & Corn Residues → Glycerol

The conversion of animal fats and corn residues into glycerol emerged as a prime circular value-chain opportunity due to substantial feedstock volumes and strong local market pull. Glycerol, a versatile polyol, is widely used as a humectant and sweetener in food and beverages, an emollient in cosmetics and personal care products, an excipient in pharmaceuticals, and as a chemical intermediate for epichlorohydrin, propylene glycol, and nitroglycerin. As of 2024, the global glycerol market was valued at approximately USD 5.6 billion, with a projected CAGR of 11.9 percent from 2025 to 2034; Europe accounted for roughly 30 percent of global refined glycerol trade in 2024, reflecting strong regulatory support for bio-based glycerol under EU standards (Glycerol Market Report 2025).

On the feedstock side, the workshop identified that some 21,962 tonnes of waste animal fats can be sourced from slaughterhouses and meat processors, including Mesna Industrija Braća Pivac d.o.o., PIK Vrbovec Plus d.o.o., Gavrilović d.o.o., Vindija d.d., KOKA d.o.o., PPK Valpovo, Stočarstvo Raic, El Taurus d.o.o., and Hospira Zagreb d.o.o. Concurrently, 1.77 million tonnes of corn stover, collected by agribusinesses such as Novi Agrar d.o.o., Žito d.o.o., Zadrugar d.d., and Kamenko Plus d.o.o., can augment glycerol yields via fermentation of stover-derived sugars. Additional feedstock can be found in the form of crude glycerol (5,600 tonnes per year) via transesterification for biodiesel at facilities like Agroproteinka d.d. (Krapina) and INA d.d. (Sisak). This crude glycerol (20–60 percent purity) requires further refinement to meet food and pharmaceutical grade (≥ 99.5 percent purity) but can be included as an entry feedstock.

Technologically, animal fat processing involves enzymatic hydrolysis (using lipases) of triglycerides to free fatty acids and glycerol, followed by downstream purification through acid neutralisation, vacuum distillation, and ion-exchange. Agroproteinka d.d. can supply lipase catalysts and associated downstream purification expertise regionally. Corn stover processing follows mechanical size reduction, steam explosion, and enzymatic hydrolysis (cellulases, hemicellulases) to free glucose and xylose. Microbial fermentation (e.g., Klebsiella pneumoniae) converts a portion of these sugars into additional glycerol, with residual lignin pelletised for boiler fuel. Blending triglyceride-derived glycerol with stover-derived glycerol in a unified purification line optimises throughput and economy of scale.

Local market offtakers include pharmaceutical and nutraceutical firms such as Pliva Hrvatska d.o.o., Belupo d.d., Krka-Farma d.o.o., JGL d.d., Genera d.d., and Hospira Zagreb d.o.o., which could require high-purity glycerol for syrups, ointments, and excipients. In cosmetics and personal care, Belupo and Krka-

Farma could utilise glycerol in lotions, soaps, and dental products, while food and beverage companies such as Vindija d.d., Podravka d.d., and Zvečevo d.d. could incorporate glycerol into bakery and confectionery items. Industrial and chemical intermediates producers like Saponia d.d. and Scott Bader d.o.o. could use technical-grade glycerol in detergents and specialty polymers, and Genera markets glycerol for nitroglycerin production.

Value chain 2: Corn & Wood Residues → Furfural

The corn and wood residues to the furfural chain was prioritised given Croatia's large lignocellulosic base and potential interest in bio-based furfural. Furfural, derived from pentose sugars (mainly xylose) in hemicellulose, is used to produce phenolic resin modifiers for wood panels, specialty solvents, and chemicals such as furoic acid and tetrahydrofuran (THF).

In Croatia, feedstocks include approximately 1.29 Mt/yr of forestry residues (branches, sawdust, bark) managed by Hrvatske Šume d.o.o. and sawmills such as BJELIN Industries d.o.o. and DIR – Drvna industrija Rubinić d.o.o.Most sawmill residues are now utilised for pellets or panel production, but a significant share, especially harvest residues, remains uncollected or is burned for energy (Cabiyo et al. 2021; Waste not, want not: Wood residues fo...). Additionally, 370 000 t/y of corn cobs and corn stover (supplied by Poljodartim d.o.o., Poljinos d.o.o., Žito d.o.d., Novi Agrar d.o.o., Zadrugar d.d., Kamenko Plus d.o.o. amongst others) are available but currently directed to low-value combustion or animal bedding.

The technology involves mechanical size reduction of wood chips and maize cobs, followed by dilute-acid hydrolysis to release xylose from hemicellulose. Xylose is then dehydrated under acid or catalytic conditions (e.g., aluminosilicate catalysts) at 180–200 °C to produce furfural at yields of approximately 50–60 percent of theoretical. Crude furfural, being unmixable with water, separates via gravity; subsequent distillation produces ≥ 99 percent purity. Co-products such as lignin/char can be pelletized for boiler fuel, while residual sugars in the aqueous phase can feed fermentation (e.g., ethanol or succinic acid).

Local offtakers include Drvna industrija Blato d.o.o. (wood-panel manufacturing), Krka d.d. and MOL Group (chemical divisions exploring sustainable intermediates), and Petrokemija d.d. (Kutina), which possesses existing acid-handling and distillation units that could be upgraded to handle crude furfural (Investment possibilities).

Existing Infrastructure & Overlap Analysis

VCG.AI's infrastructure assessment identified several facilities in Croatia that currently consume or process the same feedstocks targeted for glycerol and furfural production. For the glycerol chain, rendering plants KOKA d.o.o. (Varaždin), Natura Beef d.o.o. (Osijek), and Agroproteinka d.d. (Krapina), process category 3 animal by-products. To divert about 30 percent of animal fats toward high-purity glycerol, existing biodiesel production can be partially retained while dedicating a centralised purification line, potentially co-located at Agroproteinka d.d. or a new hub near Zagreb, for final refining.

According to a 2020 peer-reviewed overview of Croatia's biogas sector, the country's biogas production framework remains heavily centred on readily available feedstocks such as livestock manure and various agricultural or food-industry by-products. Lignocellulosic residues, including corn stover, play only a marginal role in current operations, as the infrastructural and logistical challenges associated with collecting and processing these materials have limited their integration into mainstream anaerobic digestion facilities (Petravić-Tominac et al. 2020). Securing sufficient stover (≥ 25 percent) for glycerol or furfural routes will require multi-year contracts with cooperatives such as Novi Agrar d.o.o. and Žito d.o.o.

Despite the existence of an estimated theoretical “technical potential” of approximately 376.000 tonnes/yr of corn cobs and corn stover across Croatia, most farmers opt to leave roughly two-thirds of this residue on their fields to preserve and enhance soil health (Kovačić et al. 2017) . Consequently, only a small fraction of the nation’s total available stover is ever considered for off-farm applications, as prioritizing long-term agronomic sustainability outweighs the short-term benefits of removing biomass for energy production.

In the furfural chain, co-locating a furfural pilot plant at Petrokemija d.d. (Kutina) could leverage existing steam, acid storage, and distillation capacity, potentially reducing capital expenditures. Pelletised lignin from furfural dehydration can feed private boilers, creating an integrated energy loop.

Other infrastructures like municipal composters (Zagreb’s Kompolo Centar, Osijek’s CERO) and waste-to-energy incinerators (Stereo Otok d.o.o.) - do not process large-scale lignocellulosic or fat streams, minimising overlap there. However, fragmented logistics for corn residues, often sold to AD or left in fields, necessitate forming cooperatives to aggregate ≥ 50 t loads to achieve transport economies. Similarly, animal fat is typically transported in 2–5 t tankers to rendering plants; establishing shared storage at a centralised purification hub near Zagreb or Krapina would streamline feedstock flow.

3.4.3 Austria (Carinthia)

Workshop Overview

On 15 May 2025, the SYMBIO project partners convened in Carinthia to present and discuss the application of the VCG.AI platform for uncovering circular bioeconomy solutions in the region. The workshop began with an introduction by Gašper Božič (VCG.AI) outlining the role of artificial intelligence in accelerating circular and bio-based product development. This was followed by a demonstration of the VCG.AI platform, showcasing how the tool integrates millions of patents, scientific publications, and company data to identify region-specific feedstocks, viable conversion technologies, and potential market applications for bio-based products. Miha Škrokov (AECG) then presented the curated results for Carinthia, focusing on two prioritised value chains: Corn Cobs & Wood Residues to Furfural and Soybean Meal to Glycerol. The session concluded with an interactive discussion on regional bioeconomy implementation, where local stakeholders explored collaboration opportunities.

VCG.AI Platform Demonstration

During the demonstration, Božič and Škrokov led participants through VCG.AI’s four core modules: (1) continuous patent and publication monitoring to identify emerging technologies; (2) geo-referenced plant mapping showing existing pilot, demonstration, and industrial-scale bio-facilities; (3) feedstock sourcing using predictive models to estimate regional biomass quantities; and (4) demand-side mapping that links potential end-users to identified bio-products . First, they showcased how VCG.AI tracks technology readiness levels (TRLs) for processes such as acid hydrolysis, catalytic dehydration, and enzymatic

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fermentation, enabling users to filter viable routes by maturity. Next, the geo-referenced map highlighted Carinthia's proximity to prominent technology providers (e.g., Andritz AG, Kanzler Verfahrenstechnik GmbH, BDI-Bioenergy International, Rieckermann GmbH), which support biomass pretreatment and conversion equipment.

VCG.AI Results & Key Insights

VCG.AI's region-specific analysis for Carinthia revealed that approximately 1,134,462 tonnes of wood residues are generated annually by local sawmills like HASSLACHER NORICA TIMBER, Johann Offner Holzindustrie, Holz Granitzer, Winterholz Sägewerk, and Reiter Bioholz, while corn production yields roughly 21,180 tonnes of cobs and stalks per year, primarily from AGRANA Stärke GmbH and Wech-Geflügel Gesellschaft GmbH (SYMBIO Project, 2024). Additionally, soybean processors (SOM Soja Ölmühle, BAG Ölmühle BetriebsgmbH) produce nearly 104,723 tonnes of soybean meal annually, a by-product from oil extraction used for animal feed and potentially higher-value routes (SYMBIO Project, 2024). Based on a combined ranking of feedstock volume, technology readiness, and local market pull, VCG.AI prioritised two value chains.

Value chain 1: Corn Cobs & Wood Residues to Furfural

Furfural, a renewable platform molecule derived from pentose sugars (primarily xylose), is used to produce solvents, resins, adhesives, and specialty fuels. Carinthia's combined biomass of roughly 1.15 million tonnes per year (wood residues + corn cobs) can be processed via acid hydrolysis or catalytic dehydration. Local technology partners include Andritz AG and Kanzler Verfahrenstechnik GmbH for hydrolysis reactors, and BDI-Bioenergy International and Rieckermann GmbH for catalytic systems. Market applications focus on specialty chemical distributors (Univar Solutions Austria, Brenntag Österreich, Foseco, ASK Chemicals, Akdeniz Chemson) and downstream resin formulators in Central Europe. According to IMARC's 2024 analysis, the global furfural market was valued at approximately USD 820 million and projected to grow at ~5.5% CAGR through 2033, driven by demand in phenolic resins and green chemistry initiatives (Furfural Market Report by Process (Qu...).

Value chain 2: Soybean Meal to Glycerol

Glycerol is a versatile polyol widely used in personal care, pharmaceuticals, food, and as a chemical intermediate. Carinthia's 104,723 tonnes of soybean meal can feed enzymatic or chemical conversion routes to produce refined glycerol . Local refining partners, Green Oleo (IT), Akdeniz Chemson (AT), and Treibacher Industrie (AT), could potentially process crude glycerol to food or pharmaceutical grade. Market off-takers include Mondi Frantschach (food packaging), Hermes Pharma (dermatological preparations), and DonauChem GmbH and Elox GmbH (bio-based solvent producers).

Existing Infrastructure & Overlap Analysis

VCG.AI overlaid these value chains onto Carinthia's existing bioeconomy infrastructure to assess potential feedstock competition or complementarity. Anaerobic digestion plants in Europe typically use livestock manure and energy crops like corn silage as main feedstocks. Woody residues are not commonly used due to their high lignin content and slow degradation, making them unsuitable for standard wet digestion biogas plants (Feedstocks). Carinthia's biodiesel plants (Biodiesel Kärnten, Bio-Oil Group) currently

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process waste cooking oils and animal fats (Startseite - Biodiesel Kärnten 2018; Our biodiesel and biomethane producti...). While this co-product flow indicates existing refining capacity, it does not directly compete with soybean meal for glycerol production; instead, it offers infrastructure, such as distillation and purification lines, that can be adapted to upgrade glycerol from soybean sources. Carinthia's soybean meal stream, approximately 104,723 tonnes per year primarily from SOM Soja Ölmühle and BAG Ölmühle BetriebsgmbH, is entirely separate from existing waste-to-energy and biogas infrastructures, ensuring minimal competition for this feedstock. None of the region's biogas plants (Hermann Martin Michael; Bioenergie Gadner; Markus Müller; Andreas Marko; Hans Peter Krenn; Manfred Armin Payer; Johann Hofer; Wasserverband Ossiacher See) processes protein-rich soybean meal, as they focus primarily on manure, silage, and catering residues for anaerobic digestion.

Finally, fragmented logistics for corn residue collection necessitate cooperative agreements among grain cooperatives (AGRANA Stärke, Wech-Geflügel) and local haulers to aggregate ≤ 50 t loads for cost-effective transport to a central furfural pilot site, Consequently, soybean meal can be routed exclusively into glycerol production via transesterification or enzymatic conversion without impinging on existing biodiesel or biogas capacities. By leveraging local refining partners (e.g., Akdeniz Chemson, Treibacher Industrie) for downstream purification, a Carinthian glycerol facility can thus capitalise on a secure feedstock base and tap into growing EU demand for high-purity glycerol in food, pharmaceutical, and personal-care markets.

With approximately 1.13 million tonnes of sawmill residues and 21,180 tonnes of corn cobs annually, Carinthia possesses a robust lignocellulosic feedstock profile for furfural production that is largely unclaimed by existing energy infrastructures. The region's biogas facilities, such as Bioenergie Gadner and the Markus Müller plant, primarily consume high-moisture substrates (manure, silage, organic waste) and do not accept woody residues or dry maize cobs, resulting in only low to moderate feedstock overlap (Kompost und Biogas Verband). Meanwhile, Kärntner Restmüllverwertungs GmbH (KRV Arnoldstein) focuses on mixed municipal and industrial waste streams, not segregated lignocellulosic biomass. Consequently, diverting sawmill byproducts (e.g., wood chips, sawdust, bark) and underutilised corn cobs into an acid-hydrolysis or catalytic dehydration route toward furfural faces minimal competition. By situating a furfural pilot, Carinthia can efficiently valorise this under-exploited biomass and meet Europe's growing demand for renewable furfural-based resins and solvents.

3.4.4. Italy

The Italian workshop of the SYMBIO project was conducted on 3 April 2025 at the headquarters of the lead partner Lombardy Green Chemistry Association in Milan, Italy. focusing on evaluating regional capacity for circular bioeconomy value chains through VCG.AI's data-driven platform. The agenda mirrored other pilot regions: (1) a brief introduction to SYMBIO's objectives; (2) a demonstration of the VCG.AI platform's capabilities; (3) presentation of VCG.AI's results for Italy; (4) interactive sessions to discuss implementing circular value chains in the Italian context. The presentation was led in Italian to adapt to the local context.

Notably, the Italian analysis under SYMBIO extended across five regions: Lombardy, Piedmont, Veneto, Friuli-Venezia Giulia, and Emilia-Romagna.

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Value chain 1: Whey Permeate → Proteins & Lactose

Northern Italy's dairy cluster, including Parmalat, IGOR, In.Al.Pi., and Caseificio Longo, produce large amounts of whey permeate as a by-product of cheese and yogurt manufacturing. VCG.AI ranked ultrafiltration and chromatographic separation as a proven, TRL 9 route for converting whey permeate into high-value whey protein concentrate (WPC80) and pharmaceutical-grade lactose. The process begins with sequential microfiltration/ultrafiltration to isolate WPC80 (~80 wt % protein), followed by ion-exchange chromatography to extract lactose monohydrate (≥ 99 wt % purity). GEA (Bologna) and Tetra Pak (Via Rasiglia) supply turnkey membrane systems to multiple Parmalat and IGOR plants.

Local market offtakers are well established: Puratos could source WPC80 for bakery and confectionery applications, while GSK, Baxter, and Pfizer contract pharmaceutical-grade lactose for tablet excipients and injectable formulations. Ferrero and Mondelez could incorporate WPC80 into sports nutrition products, and Nestlé and Danone include lactose in infant formula. According to IMARC Group, the global WPC market was valued at USD 5,5 Billion in 2024 (CAGR 3,41 % to 2033) (IMARC Group, 2024). Existing infrastructure overlap is negligible: regional biogas plants do not accept high-lactose streams due to low chemical oxygen demand (COD) efficiency, and Waste-to-Energy/incineration facilities focus on mixed MSW rather than liquid dairy by-products. Consequently, diverting larger amounts of whey permeate to protein and lactose recovery represents a significant value uplift without competing pressures.

Brewery Spent Yeast → β-glucans and active peptides

Brewer's spent yeast (BSY) is widely under-utilised across European breweries, often sold as low-value wet animal feed or fed to biogas digesters (Jaeger et al. 2020); yet it represents over 10 percent of total brewery by-products and is rich in proteins, cell-wall polysaccharides, and biologically active compounds.

VCG.AI identified mechanical separation followed by targeted ingredient extraction, leveraging enzymatic and physical fractionation, to unlock high-value fractions: β-glucans and active peptides. In this route, BSY from partners such as Baladin, Birrificio Angelo Poretti, Birrificio Italiano, Birrificio del Ducato, Menabrea, Birrificio Lambrate, and Toccalmatto, is first de-watered and subjected to cell-wall disruption (e.g., high-pressure homogenisation), followed by sequence-specific enzymatic hydrolysis to produce peptides and cell-wall fragments enriched in β-glucans. GEA Group and Biorigin could supply the mechanical separators and extraction equipment needed to maintain industrial-scale throughput, while final purification is achieved via membrane technologies (e.g., ultrafiltration for peptides) and ethanol precipitation (for β-glucans) to achieve > 90 percent purity.

The global beta-glucan market was valued at around USD 677 million in 2024 and is projected to grow significantly, reflecting increasing demand across industries (Polaris Market Research 2024). Active peptides address pharmaceutical, nutraceutical, and specialty ingredients markets. Leading industry examples, such as Leiber GmbH's expansion in Germany, which reached €116 million revenue in 2019 by upcycling BSY, underscore the economic viability of the approach. By partnering with ingredient offtakers (e.g., Puratos, IFF Benelux, Corbion, Kemin, L'Oréal, Henkel), Italian brewers can realise a CAPEX-optimised greenfield facility for BSY valorization, securing access to high-growth markets and significantly raising the circularity and profitability of their operations.

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Existing Infrastructure & Overlap Analysis

The existing network of biogas facilities in Northern Italy, including Agrisolar, Azienda Agricola Caramana, Manaresi Tamara, Selvabella, Società Agricola Cazzani, and Vittoria Bioenergia, primarily digest high-chemical-oxygen-demand substrates such as livestock manure, corn silage, and catering waste. Because whey permeate has a relatively low methane potential (Rico et al. 2014), few of whey streams are ever sent to these anaerobic digesters; the remainder is typically discharged to wastewater treatment or used as low-value animal feed (Azkarahman et al. 2025). As a result, virtually all of the whey permeate can be redirected into ultrafiltration and chromatographic separation processes.

Brewer's spent yeast (BSY) generated by Northern Italy's breweries can amount to significant quantities. BSY's high nitrogen content and low net methane yield make it an unattractive substrate; therefore, almost no BSY ever enters anaerobic digesters (Zupančič et al. 2017). This leaves virtually 100 percent of BSY free for valorisation via mechanical disruption and enzymatic hydrolysis, producing β-glucans and bioactive peptides for food, feed, pharmaceutical, and cosmetic applications, without any overlap with existing waste or bioenergy processes.

3.4.5 Slovenia

Workshop Overview

On 16 April 2025, partners from Anteja ECG convened the SYMBIO workshop in an online form. The event opened with an introduction to SYMBIO's objectives, developing circular, bio-based business models via AI-driven analysis, followed by a demonstration of the VCG.AI platform. Miha Škrokov then presented Slovenia-specific results, and local SMEs discussed strategies for accelerating sustainability through industrial symbiosis.

VCG.AI Platform Demonstration

Gašper Božič led a live walkthrough of VCG.AI's capabilities, showing how the platform integrates millions of patents, publications, market reports and company records to map feedstocks to high-value products. First, regional biomass data (e.g., forestry residues, corn by-products, dairy side-streams) were uploaded and geo-referenced. Next, VCG.AI's technology landscape module filtered viable processes by technology readiness levels (TRLs) and economic indicators. Finally, ranked value-chain options were generated, complete with local technology providers, prospective off-takers and overlap analyses, allowing participants to interactively explore and prioritise routes.

VCG.AI Results & Key Insights

In the Deliverable 1.3. of the Symbio project, we identified 119 000 t/yr of forestry residues and 887 000 t/yr of maize cobs and stover available across Slovenia. Six potential value chains were screened, with two prioritised for immediate follow-up:

- Forestry Residues & Maize Cobs → Furfural

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- Sweet Whey & Permeates → Whey Protein Concentrate (WPC80) & Pharmaceutical-Grade Lactose

Value chain 1: Forestry Residues & Maize Cobs → Furfural

Slovenia's forestry sector, state forests (SiDG) and sawmills such as Anles, Beles and Brin, produces roughly 119 000 t/yr of wood residues, while grain farms supply 887 000 t/yr of corn by-products. VCG.AI ranked dilute-acid hydrolysis, followed by catalytic dehydration as the most mature route (TRL 8-9), yielding furfural at ~50 % of theoretical. Technology licensors like Lenzing Group (Austria) and EU catalysis specialists can provide process equipment and catalysts. Purified furfural (≥ 99 wt %) targets applications in adhesives, resins and green solvents, where Europe's furfural market was valued at USD 820 million in 2023 (5,5 % CAGR) (Verma and Pulidindi 2024). Local off-takers potentially include Melamin d.d., Belinka Perkemija and Silvaprodukt.

Value chain 2: Sweet Whey & Permeates → WPC80 & Pharmaceutical-Grade Lactose

Major dairy processors in Slovenia, Ljubljanske mlekarne, Mlekarne Celeia, Pomurske mlekarne generated 110 000 t/yr of sweet and acid whey in 2021, of which approximately a good portion is under utilised or sent to biogas (Justin et al. 2022). VCG.AI highlighted ultrafiltration (to produce WPC80 at ~ 80 wt % protein) and chromatographic separation (to recover lactose ≥ 99 wt %) as TRL 9 processes already proven at industrial scale. These technologies could be supplied by GEA and Tetra Pak with enzymes from Chr. Hansen, and could convert 100 000 t of whey into roughly 1200 t of WPC80 and 5000 t of lactose annually (Pires et al. 2021). WPC80 addresses markets in nutrition, confectionery and cosmetics, while pharma-grade lactose serves pharmaceutical excipient demand.

Existing Infrastructure & Overlap Analysis

We reviewed Slovenia's bioprocessing and waste infrastructure, rendering plants, composting facilities, waste-to-energy (WTE) and biogas, to assess feedstock lock-in:

- Rendering/Animal By-Product Processing: Perutnina Ptuj and KOTO d.o.o. handle animal fats but do not process lignocellulosic residues or liquid whey; no overlap with furfural or whey valorization.

- Composting Facilities: eleven municipal composters (e.g., CERO Gajke, RCERO Celje) accept mixed organic waste; they rarely take segregated whey or dry wood residues, so competition is minimal.

Overall, both value chains face negligible to low competition from existing bioenergy and waste infrastructures, indicating that nearly all 119 000 t of forestry residues, 887 000 t of maize cobs, and 110 000 t of whey permeate can be redirected toward high-value chemical production without lock-in constraints.

3.4.6 Belgium

Workshop Overview

On 3 April 2025, VCG.AI convened the second SYMBIO workshop for Belgium. The workshop's aim was to leverage VCG.AI's AI-driven insights to identify technically feasible and economically viable circular value chains for under-utilised Belgian by-products.

Notably, the Belgium analysis under SYMBIO extended across three regions: Bruxelles Capital, Wallonia, Flanders.

VCG.AI Platform Demonstration

Gašper Božič led an interactive demonstration of VCG.AI's proprietary platform, showing how it ingests regional feedstock inventories, overlays global technology-readiness data, and maps process routes to high-value products. Live, the team uploaded Belgium-specific data on brewer's spent yeast and whey streams, then filtered by Technology Readiness Level and market potential to generate ranked value-chain options. The platform automatically identified local technology licensors (e.g., GEA, Tetra Pak, Chr. Hansen), prospective off-takers, and potential feedstock conflicts with existing infrastructure, enabling participants to refine and prioritize pathways in real time.

VCG.AI Results & Key Insights

VCG.AI's analysis highlighted two priority value chains for Belgium:

- Brewer's Spent Yeast → β-Glucans & Active Peptides
- Whey & Dairy Permeates → Whey Protein Concentrate (WPC80) & Pharmaceutical-Grade Lactose

Value chain 1: Brewer's Spent Yeast → β-Glucans & Active Peptides

Western European breweries produce roughly 30 000 t/yr of brewer's spent yeast per year, which is rich in cell wall polysaccharides and proteins but is typically used for low-value animal feed or biogas (Bambridge-Sutton 2023; LIFE 3.0 - LIFE project public page). VCG.AI identified a proven industrial route (TRL 8–9) involving mechanical cell-wall disruption (e.g., high-pressure homogenization), followed by enzymatic hydrolysis to fractionate β-glucans and peptides. GEA Group could supply separation equipment, Biorigin could provide pilot-scale extraction units, and Chr. Hansen could supply specialised enzymes. The process yields high-purity β-glucans (> 90 %) and active peptides (> 90 %), targeting food, feed, pharmaceutical, and cosmetic markets. The global beta-glucan market was valued at around USD 677 million in 2024 and is projected to grow significantly, reflecting increasing demand across industries (Polaris Market Research 2024).

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Value chain 2: Whey & Dairy Permeates → WPC80 & Pharmaceutical-Grade Lactose

Belgium's dairy sector generates approximately 250 000 t/yr of whey (Overview of Belgium's Dairy Market 2023). VCG.AI recommended ultrafiltration to produce WPC80 (~80 % protein) and chromatographic separation to isolate lactose monohydrate (> 99 % purity). GEA Group and Tetra Pak could supply membrane modules. From 250 000 t of whey, one can expect roughly 3 000 t of WPC80 and 12 500 t of lactose annually (Pires et al. 2021). WPC80 serves markets in nutrition, confectionery, and cosmetics, while pharmaceutical-grade lactose addresses tablet excipient demand.

Existing Infrastructure & Overlap Analysis

An assessment of Belgium's bioeconomy infrastructure shows minimal competition for both value chains:

- Biofuel & Biorefinery Facilities (Alco Biofuel, Cargill Bioro, Tereos, BioWanze) process ethanol and biodiesel feedstocks (cereals, oils) and do not accept yeast or whey.
- Waste-to-Energy & Incineration Plants (Bioenerga WtE, Biosteam Ostend, INDAVER, ISVAG, IVM, Ipalle, Harelbeke) handle mixed MSW and industrial waste, not liquid dairy streams or wet yeast slurries.
- Specialised Conversion (Biorigin) partners on yeast valorisation and thus serves as a collaborator rather than competitor for brewer's spent yeast.
- Wood & Biomass Processing (TORRCoal, Stora Enso) focus on lignocellulosic materials; no overlap with dairy or yeast.
- Insect-Based Bioconversion (M-Food, NUSECT) and Magisterial Processing Plants handle animal or plant biomass, not liquid or slurry by-products.

Biogas plants (e.g., Sebigas, Europlant) occasionally accept limited food waste but not high-nitrogen yeast or low-COD whey, so overlap is negligible (< 10 % feedstock diversion).

4. Conclusions

Deliverable 2.3 has demonstrated that targeted support activities can rapidly translate data driven insights into investable, regionally anchored circular bio-value chains. Through six facilitated workshops, spanning Andalusia, Croatia, Carinthia, Northern Italy, Slovenia and Belgium, SYMBIO's partners successfully guided over 80 stakeholders from industry, academia, government and civil society through a structured, two day process that combined community building, live VCG.AI demonstrations and co-creative valuechain design. This approach yielded twelve high-potential BioLinks, each championed by local clusters or SMEs, and underpinned by robust techno economic and ESG analyses.

Across all regions, the VCG.AI platform's five step workflow (feedstock ingestion, technology screening, gap analysis, market alignment and infrastructure mapping) proved both replicable and adaptable, enabling consistent benchmarking of routes such as lignocellulosic residues to furfural, whey permeate to WPC80 and lactose, and brewer's spent yeast to β-glucans. Critical cross cutting insights, from abundant yet seasonal feedstock streams to minimal lock-in with existing bioenergy uses, and strong market growth (5–12 % CAGRs for key products), collectively strengthen the business cases for circular biorefineries in each territory. Moreover, infrastructure overlap analyses highlighted co-location and utility sharing synergies, pointing to near term opportunities for pilot plant development with reduced CAPEX.

Importantly, the workshops fostered stakeholder ownership. By assigning "regional champions" to each value chain, SYMBIO has laid the groundwork for sustained consortium building and targeted pilot planning in further efforts of the project. These champions, drawn from olive oil cooperatives in Andalusia, meat processors and agribusinesses in Croatia, sawmill operators in Carinthia, dairy clusters in Italy and Slovenia, and breweries in Belgium, are now equipped with both the analytical roadmaps and the local networks needed to advance demonstration projects.

Finally, the structured support model piloted here offers a clear blueprint for other European regions seeking to accelerate their own circular bioeconomy transitions. By integrating strategic framing, participatory tool immersion and region specific coaching into a concise 90 minute VCG.AI sprint, SYMBIO has shown how to turn static desktop studies into actionable investment pipelines. As the project moves into WP3, these outcomes position the six pilot territories to attract EU funding, scale demonstration plants and ultimately contribute to the emergence of a vibrant, circular-by-design industrial ecosystem across the Union.

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