Interreg CENTRAL EUROPE
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TeBiCE

BOOK OF GOOD EXAMPLES: BIOCIRCULAR SOLUTIONS FOR SMEs

Driving Sustainable Growth in the Primary and Agro-Food Sectors

CONTENT

INTRODUCTION

The shift towards a sustainable, circular, and bio-based economy is no longer a choice—it is an urgent necessity. In the face of climate change, resource depletion, and increasing socio-economic pressures, small and medium-sized enterprises (SMEs) in the agriculture and agro-food sectors inevitably need to transform their operations to remain competitive and resilient.

The Interreg TeBiCE project (Territorial biorefineries for circular economy) champions this transformation by promoting biocircularity — an innovative fusion of bioeconomy and circular economy principles. By leveraging local resources, minimizing waste, and regenerating ecosystems, biocircular solutions offer a pathway to sustainable value creation and inclusive rural-urban development.

This Book of Good Examples showcases a curated selection of real-world practices and pilot actions that exemplify how SMEs can successfully transition to biocircular business models. These case studies span diverse territories and production systems, providing practical and adaptable models that address common barriers in value chains—such as inefficiencies, environmental impacts, and limited market access.

By highlighting these exemplary initiatives, the book aims to:

- Inspire and empower SMEs to adopt biocircular practices that boost competitiveness, reduce environmental footprints, and create long-term value.
- Facilitate interregional learning and knowledge transfer by sharing lessons learned, success factors, and replicable models across different socio-economic contexts.
- Support policymakers and ecosystem actors in co-creating enabling frameworks, financial incentives, and governance structures that accelerate biocircular transitions.

This publication is not just a catalogue of best practices—it is a call to action. It underscores the power of territorial innovation, stakeholder engagement, and integrated strategies that align with wider EU goals, including the Green Transition and Long-Term Vision for Rural Areas.

This book contributes to building a resilient, green, and inclusive future for Europe's rural and peri-urban regions. The journey to sustainability begins with grounded, evidence-based actions—many of which are already delivering positive change on the ground.

We invite you to explore these examples, adapt them to your local context, and become a catalyst for biocircular transformation.

"Biocircularity is not just a slogan—it is a systemic approach that links nature, economy, and society. If we want to leave behind linear thinking, we need to think in circles and cycles rooted in biology."

- Christian Patermann, Advisor to the EU Bioeconomy Strategy, known as the "father of the European bioeconomy"

🕮 Source: Bioeconomy Policy Dialogue, 2020

UNLOCKING SUSTAINABLE GROWTH

The imperative for sustainable transformation is clear: markets, consumers, and regulatory frameworks are converging around the demand for greener, smarter, and more responsible business models. For small and medium-sized enterprises (SMEs), particularly in the primary production and agro-food sectors, this shift presents a powerful opportunity—not a constraint.

Biocircularity, the fusion of bioeconomy and circular economy principles, offers SMEs a strategic pathway to resilience and relevance in the 21st-century economy. It encourages the use of renewable biological resources, promotes zero-waste approaches, and fosters innovation throughout the value chain—from soil to shelf.

This is not merely about regulatory compliance or corporate responsibility—it is about unlocking new sources of value. SMEs that embed sustainability into their core operations are more likely to:

- Enhance resource efficiency, reducing dependency on external inputs and volatile global markets.
- Access new markets and customers, including sustainability-conscious consumers, public procurement schemes, and green finance.
- Increase resilience to shocks, including climate-related disruptions, supply chain instability, and policy changes.
- Strengthen stakeholder relationships, from producers and processors to municipalities, researchers, and investors.

Leading businesses are already recognizing that sustainability is becoming the benchmark for innovation, competitiveness, and growth. The early adopters of biocircular practices are not only positioning themselves ahead of tightening environmental regulations—they are also becoming leaders in product quality, brand trust, and regional value creation.

Through this shift, rural and peri-urban SMEs can become pioneers of territorial transformation, playing a key role in revitalizing local economies, preserving ecosystems, and fostering social cohesion. Biocircularity enables regions to move from linear, extractive models to regenerative systems that close loops, regenerate soils, and circulate value locally.

As demonstrated by the pilot actions and good practices documented in this volume, the transition is already underway. Those who act now—by rethinking materials, redesigning processes, and building partnerships—will shape the future of agro-food systems.

In short, sustainability is no longer a niche strategy. It is the new mainstream—and for SMEs, it is the key to unlocking enduring prosperity.

“Biomass quality and availability are key factors to unlock the deployment of a truly circular and sustainable bio-based economy in Europe, which is of strategic importance, especially today, to decrease our dependency on and to accelerate the replacement of non-renewable fossil products, materials and nutrients with new and innovative biobased ones.”

- Virginia Puzzolo, Head of Programme Unit at the Circular Bio-based Europe Joint Undertaking (CBE JU)

🕮 Source: ETA-Florence Renewable Energies, 24th Newsletter, 2023.

BIOCIRCULARITY: A WIN-WIN PATH TO SUSTAINABLE PROSPERITY

In a world increasingly challenged by climate change, biodiversity loss, and the unsustainable exploitation of finite resources, the need for transformative business models has never been greater. Biocircularity, the strategic integration of bioeconomy and circular economy principles, emerges as a compelling solution that aligns environmental responsibility with economic opportunity.

For small and medium-sized enterprises (SMEs), especially those in the agri-food and primary sectors, adopting biocircular practices isn't just about "doing the right thing." It's a smart, future-focused business move that offers multiple advantages:

- Competitive Edge

  Differentiate your business in a crowded marketplace by delivering products and services that reflect sustainability and innovation. Eco-conscious consumers and B2B buyers increasingly prioritize ethical sourcing, low environmental impact, and regenerative practices.

  Biocircularity builds trust, enhances brand value, and positions your SME as a leader, not a follower.

- Cost Savings

  Circular resource use means doing more with less. By minimizing waste, repurposing agricultural and industrial by-products, and optimizing inputs such as water, energy, and raw materials, SMEs can significantly lower production costs. What was once considered "waste" becomes a new input, creating value while improving the bottom line.

- Future-Proofing

  Environmental regulations are tightening across Europe and globally. From carbon pricing and emissions limits to extended producer responsibility and circular economy directives, the policy landscape is evolving fast. By aligning early with these frameworks, SMEs avoid compliance risks and position themselves as partners in public sustainability goals.

- Market Expansion

  The demand for bio-based products—such as compostable packaging, plant-based ingredients, and renewable construction materials—is growing rapidly. Biocircular enterprises can tap into emerging markets across sectors including food, cosmetics, bioplastics, textiles, and energy. Public procurement is also increasingly favouring sustainable, local suppliers.

- Resilience

  Global supply chains are vulnerable to disruption—from pandemics and political instability to climate impacts and raw material shortages. Biocircular approaches enhance resilience by localizing inputs, diversifying supply sources, and building regenerative systems that rely less on extractive, volatile global networks.

- Positive Legacy

  Beyond immediate profits, biocircularity allows businesses to leave a lasting, positive mark. By contributing to the Sustainable Development Goals (SDGs), the European Green Deal, and regional climate and innovation strategies, SMEs can help build healthier ecosystems and stronger communities—while securing their own long-term viability and social license to operate.

In short, biocircularity is not a burden. It's a business accelerator. It aligns economic incentives with planetary boundaries and positions SMEs as critical actors in building resilient, vibrant, and sustainable regional economies.

"A sustainable bioeconomy is central to tackling urgent global challenges like climate change, food security and land degradation. Combined with circularity, it can drive systemic change across value chains."

- European Commission – Bioeconomy Strategy

📖 Source: EU Bioeconomy Strategy Update, 2018

CASE STUDIES

Showcasing Biocircular Innovation Across Regions

This chapter presents a curated collection of 10 pilot actions implemented across 8 TeBiCE regions from 6 countries (Austria, Germany, Italy, Poland, Slovakia, Slovenia), capturing real-world applications of biocircular principles in the agri-food and bioeconomy sectors.

Each case study fiche follows a standard template to ensure comparability and clarity. These fiches document not just what was done, but why it mattered—highlighting context-specific challenges, innovative solutions, measurable impacts, and key insights for future replication.

Whether you're a policymaker, SME, researcher, or community stakeholder, these concise case snapshots are designed to:

- Inspire new ideas by showing what biocircularity looks like in action.
- Inform future strategies by sharing lessons learned from the ground.
- Enable cross-regional learning and transferability of proven solutions.

Use these case studies as a toolbox for practical innovation and a testament to how small steps, rooted in place-based action, can drive systemic change.

A. Hemp Stem Material into Biocomposites

Region

Agricultural rural region of southern Slovakia. Figure 1 provides an indicative map of hemp growers (yellow) and hemp growers including processing (red) - excluding stems

Figure 1: Slovak region

Short Description

In the partner agro-farm Persefone Ltd. (formerly Izo Partners Ltd.), hemp is cultivated primarily for seed. Following harvest, stalks are dried and processed at the Hemp Cooperative's decorticator, where mechanical separation of fibres from the woody core (hemp shives) takes place. These separated materials form the base for further recovery and production, creating sustainable biocomposite products for construction and furniture industries.

Sector

Mixed (Combination of production and processing)

Challenges Addressed

Key constraints and bottlenecks in the value chain:

- Limited motivation among growers to include hemp in crop rotations as a high-value industrial crop, beyond its soil regeneration benefits, as a remediation plant and green manure crop.

- Lack of local processing facilities for stalks leading to high logistic costs and energy consumption.
- Absence of short value chains connecting local production, processing and production innovation.

Market, regulatory, environmental, or social challenges:

- The hemp sector in Slovakia is developing slowly due to conservative attitudes among stakeholders.
- Insufficient systemic support for SME transformation towards the circular bioeconomy.

Solution Implemented

Innovation and approach adopted:

The strategy was to identify pioneering growers and launch pilot processing projects demonstrating the added value of hemp stalk utilization. The initiative promotes short value chains that retain value within the region, engage local human and financial capital, and generate tangible environmental benefits through circular bioeconomy practices.

Technology, methodology, or partnerships used:

Deployment of mobile processing units (mobile decorticators), training in high value-added product manufacturing and mapping and fostering cooperation between SMEs and public-private partners, including municipalities with social enterprises or local construction projects.

Rationale:

Short value chains keep economic benefits local while reducing transportation emissions, thus creating substantial positive enviro-impacts. They also foster community engagement and create sustainable employment opportunities.

Implementation Steps

Key actions taken:

Finding and engaging hemp seed growers willing to process the stalk on a pilot basis. Within the HempCluster, development and production of hemp flint boards for construction and furniture use. Repairs and innovation of the second-hand decorticator and proof of concept, development of a new more compact mobile version, production of which is currently underway.

Timeline:

Phase	Actions Taken
Planning 2020-2021	Definition of goals in the Hemp Cluster Strategic plan 2020-2025: development of a mobile decorticator and recyclable/compostable hemp

	shiveboards. Funding secured through member inputs and partial R&D grant.
Implementatio n 2022-2024	Development and testing of solutions with partners/growers. Modification of existing second-hand decorticators and creation of proof-of-concept mobile versions.
Evaluation 2024-2025	Collection and assessment of feedback from growers and users. Refinement of processes and technology based on pilot results.

Results and impact

Economic and technical outcomes:

The processing facilities enable farmers to recover value from the entire plant. Raw hemp stalks sell for approx. 150 €/tonne, while processed shives and fibres achieve 400-600 €/tonne. A shared mobile decorticator among multiple growers in a regio-cycle supports efficient seasonal use of the equipment and accelerates return on collective investment.

Environmental and social benefits:

- The circular bioeconomy model reduces waste and promotes sustainable soil use.
- Encourages local job creation and the use of renewable, biodegradable materials in construction.

SME Testimonials:

“Hemp straw enriches the soil as green fertilizer, but by processing it into materials for production, the added value per hectare increases significantly.”

– *Peter, Izo Partners Ltd.*

“Shives from our decorticator are suitable for moulded boards or polymer building compounds such as hemcrete or hemplime.”

– *Fero, Kuruc Co. Ltd.*

Lessons Learned

Challenges faced during implementation:

Technical conflicts evolved between design engineers and experienced cluster members. Additionally, rising material and component prices coupled with extended delivery times.

Management responses:

Use of adaptive design, local fabrication, and creativity to overcome resource limitations.

Key takeaways for future implementation:

Localized processing of hemp stems within regional cycles (regiocycles) makes strong both economic and ecological sense. Cooperative models between SMEs enable short value chains and foster community-level circular economy ecosystems. SMEs entering into a cooperative relationship should consider expanding the short value chain to include further production from the materials obtained.

Scalability and Replicability

Potential for broader application:

This model can be adapted to other regions and contexts, both within and outside Europe, where hemp or similar technical crops can form the foundation of local bio-based economies. Beyond the hemp sector, the concept of short value chains can also serve as a guiding principle for high added-value production in other industries, such as forestry, agro-waste valorization, or renewable construction materials. By fostering the synergy of local human and financial capital, this approach enhances regional sustainability, competitiveness, and community resilience.

Adaptation for SMEs at different development stages:

For start-ups and growth enterprises: equipment sharing, collaborative product development, cost-efficient scaling and coordinated more significant market coverage.

For established firms: good complement for portfolio expansion, product diversification, and closer integration of growers into the eco-industrial production processes.

Supporting resources needed for scaling:

Community-based funding complemented by innovation grants to purchase machinery. Public-private partnerships with municipalities for shared processing facility hubs. Policy frameworks initiating and supporting pilot circular bioeconomy projects with emphasis on short value chains development.

Contact Information

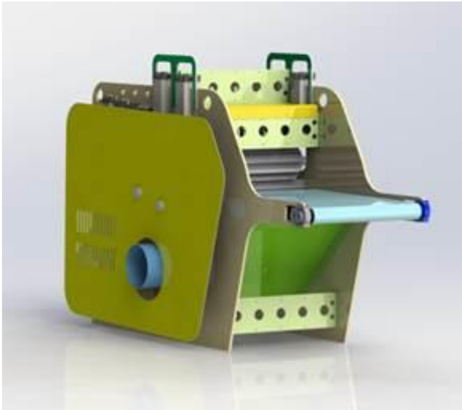
Lead Organization: Hemp Cooperative / Konopne druzstvo

Key Contact Person: Dusan Knezovic - CEO

Email: knezovic@hempcluster.eu

Additional Resources:

Refurbished Charle & Co. decorticator



Mobile decorticator prototype

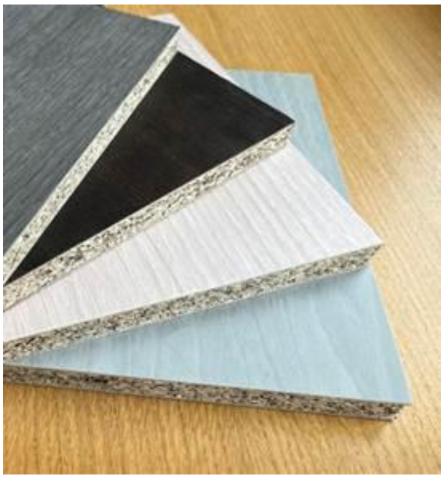
Dewed and undewed hemp stem,

fiber, shives and microparticles powder

Hemp shives

Hemcrete/hemplime blocks

Hempboard 100% compostable



Hempboard

100% recyclable Wood-coated hempboards

Figure 2: examples from HEMP process

B. From Vineyard to Value: A Circular Economy Case Study on Prosecco By-Products in Valdobbiadene

Region

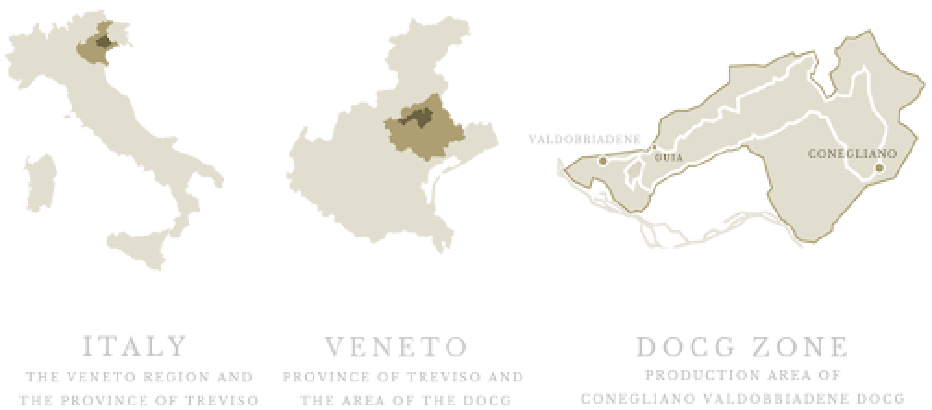


Figure 3: Veneto region - Conegliano Valdobbiadene

The Veneto region, located in northeastern Italy, is one of the country's most economically dynamic and culturally rich areas. Renowned for its industrial districts, agricultural excellence and world-famous cities like Venice and Verona, Veneto plays a key role in both traditional and innovative sectors.

Within this region, the municipality of Valdobbiadene — located in the province of Treviso — is internationally recognized as a symbol of high-quality Prosecco production. The term "Valdobbiadene" more broadly refers to the hilly area at the heart of the Prosecco Superiore DOCG zone, stretching between Conegliano and Valdobbiadene, which is also a UNESCO World Heritage site. This area combines a deep-rooted winemaking tradition with increasing efforts toward sustainability and circular economy practices.

Short Description

As part of the TeBiCE project, Adami S.r.l.—a long-standing Prosecco Superiore DOCG winery based in the province of Treviso—was selected for a pilot action aimed at assessing and valorising by-products from the Prosecco production process. Through direct site visits and interviews, detailed data were collected on the generation and current management of pomace, lees, stems and tartaric residues from fermentation processes. While most by-products are already valorised through secondary channels, winery fermentation residues emerged as a potential key material, currently qualified as waste. In particular the potential of wine lees was evaluated as they contain valuable compounds such as:

- Lipids (e.g., sterols, glycolipids) for dietary supplements
- Polyphenols with antioxidant and therapeutic properties
- Proteins and peptides for nutraceuticals
- Polysaccharides and mannoproteins for wine stabilization and cosmetics
- Glutathione, a natural antioxidant with potential to reduce SO_2 use in winemaking

Finally, the study highlighted their potential for transformation into bio-stimulants or ingredients for nutraceutical applications, laying the groundwork for future technological development within a circular economy framework.

This mapping lays the groundwork for future pilot activities aimed at developing high-value applications for winery by-products, contributing to sustainability and innovation in the wine sector

Sector

Mixed (Combination of production and processing)

Challenges Addressed

Key constraints and bottlenecks in the value chain

- Logistics and Seasonality: very short production window (12 days/year) limits consistent supply to downstream processors.
- Moisture and Perishability: high water content in pomace and lees makes storage and transport difficult without immediate treatment.
- By-product Composition: presence of pesticide residues and persistent contaminants (e.g., PFAS) in some by-products raises safety and environmental concerns.
- Economic Viability: low unit value and insufficient volumes (e.g., stems < 0.02 €/kg) hinder the economic feasibility of investing in valorisation technologies.

Market, regulatory, environmental, or social challenges

- Regulatory Aspects:

Strict compliance required for food, cosmetic and feed applications (e.g. EU Novel Food Regulation, REACH).

Legal obligation to send lees and marc to distilleries (Italian Ministerial Decree No. 185138/2023).

- Market Access: high competition and limited consumer awareness for functional ingredients from wine by-products, especially outside niche bio-based sectors.
- Environmental and Social Concerns:

Potential environmental impact from contaminants.

Social acceptance and awareness of upcycled products remain limited.

Solution Implemented

Description of the approach, innovation, or model adopted

To address the challenges of by-product valorisation in the Prosecco DOCG supply chain, the project adopted a data-driven and scalable pilot model. The core of the approach was grounded in a rigorous scientific assessment of the current by-product management practices, with the aim of fully understanding their technical characteristics, economic implications and environmental footprint. Rather than limiting itself to a purely technological exploration of new solutions, the study was designed to provide a comparative framework in which alternative valorisation pathways could be critically evaluated against traditional disposal or low-value reuse practices.

The model combined quantitative data collection (e.g., mass balance reconstruction, cost estimates, emissions baselines) with qualitative insights from stakeholders, allowing for a systemic understanding of where value could be created or recovered along the supply chain. In this way, the project aimed not only to test innovations, but to guide decision-making through evidence-based evaluation, ensuring that any proposed transition was both feasible and impactful in the specific context of DOCG wine production.

Methodology

This involved:

- Direct engagement with Adami S.r.l. through interviews and site visits.
- Reconstruction of the production mass balance to quantify by-product volumes.
- Mapping of current uses and identification of valorisation gaps.
- Selection of priority streams (e.g. second fermentation lees) for further technological development.
- Integration of findings into a broader model applicable to DOCG and DOC producers.

- Engagement of specialised companies such as Coccitech S.r.l. (agri-biotech and oenological innovation) and SAM Moldoi (nutraceuticals from alpine botanicals) to assess the feasibility of extracting high-value compounds from selected residues.
- Design and preliminary execution of laboratory-scale tests to evaluate bioactive compound recovery, with a focus on applications in the biostimulant and nutraceutical sectors.
- Preliminary evaluation of regulatory and market implications for potential product classes derived from the identified by-product streams.

Technology

- Extraction technologies: autoclaving, sonication, enzymatic hydrolysis, supercritical fluids.
- Analytical methods for characterising bioactive compounds (e.g., polyphenols, mannoproteins, glutathione).

Partnerships

- Collaboration with biostimulant producers for testing reuse of lees.
- Engagement with academic institutions (e.g., University of Bordeaux) for extraction research.
- Coordination with regional and national regulatory bodies for legal compliance.

Why this solution?

The solution adopted in the Adami S.r.l. the pilot addressed key challenges such as seasonality, perishability, and regulatory constraints, through a practical, scalable model based on real production data. It prioritized high-value reuse of by-products, aligned with circular economy goals, and involved active stakeholder engagement to ensure feasibility. Designed for replicability, the model also supports cross-border application in similar wine-producing regions.

In particular, the project focused on targeting high value-added sectors such as biostimulants, nutraceuticals and phytopharmaceuticals as potential end-use markets for the recovered by-products. These sectors offer significant economic return potential, where the value of the transformed products can justify the investment required to develop a dedicated supply chain. Moreover, they allow for the recovery of biologically active compounds and molecules that can be used both in soil regeneration and human nutrition, further increasing the environmental and societal value of the proposed valorisation strategies.

Implementation Steps

Key actions taken

- T1 [October 24 – March 25] Reconstruction of production mass balances to quantify by-product generation.
- T2 [January 25 – April 25] Mapping of current uses and valorisation gaps for each by-product stream & Selection of second fermentation lees as a priority stream for further experimentation.
- T3 [January 25 – December 25] Preliminary regulatory analysis to assess legal constraints and compliance needs.
- T4 [May 25 – September 25] Recovery of by-products from Adami and initiation of lab tests with companies in the biostimulant sector.
- T5 [September 25 – December 25] Test results evaluation, comparison with baseline scenario and solution optimization
- T6 [January 26 – tbd] Development of a scalable and replicable model applicable to other

Results and impact

Measurable benefits

- Resource Efficiency: valorisation of up to 90 tons/year of lees and 48 tons/year of pomace/stems at Adami Srl alone. T6 [January 26 – tbd] Development of a scalable and replicable model applicable to other
- Cost Reduction: potential savings from avoided disposal costs for second fermentation lees (currently classified as special waste).
- Sustainability: reduction in waste sent to distillation or landfill; potential for bio-based product substitution (e.g., biostimulants, cosmetics).
- Circular Economy Impact: integration of winery by-products into new value chains (e.g., biostimulants, nutraceuticals).
- Scalability: model applicable to ~800 tons/year of DOC-level by-products across the Veneto-Friuli region.

Key Performance Indicators (KPIs)

By-product Type	Adami Srl Production	Estimated DOCG Total	Estimated DOC Total
Grape Marc and Stems	48 tons	140–150 tons	~800 tons

Fermentation Lees	400–500 kg	~16.000 kg	~90.000 kg
Second Fermentation Lees	~100 kg	~3.500 kg	~20.000 kg
Tartaric By-products	20–30 kg	~1.000 kg	~6.000 kg

Lessons Learned

Challenges faced during implementation

In addition to the intrinsic challenges posed by the nature of wine production by-products—such as seasonal variability, perishability, and instability—one of the most significant difficulties encountered was the translation of traditional agricultural practices into measurable, quantitative data and standardized parameters. These elements are essential for building models and references that can be extended to the broader DOCG supply chain, yet they are often missing, informal, or highly context-dependent.

How they were managed

To overcome this barrier, it was crucial to establish direct engagement with producers, not only through interviews but by observing firsthand the practices involved in by-product generation and handling. Site visits and open dialogue with production staff enabled the collection of otherwise unavailable technical details and helped reconstruct operational streams. Additionally, the team worked to systematize scattered information into structured datasets that could support replicable modelling and scenario analysis.

Key takeaways for future implementation

Future projects aiming to replicate this model should recognize that data availability and standardization are not guaranteed in traditional agri-food contexts. It is therefore essential to invest time in on-site engagement and participatory data collection and to treat producers not merely as data sources but as active partners in the co-construction of knowledge. This relational approach is fundamental to ensure the accuracy, usability and scalability of any Circular Economy strategy within the primary production sector.

Scalability and Replicability

Potential for broader application

- Other Sparkling Wine Regions: especially in Slovenia, France (Champagne), and Spain (Cava) where similar production processes and by-products exist.

- Still Wine Producers: adaptable with minor modifications to lees and pomace handling.
- Fruit Juice & Brewing Industries: similar by-products (e.g., pulp, fermentation residues) can be valorised using comparable technologies.
- Agro-industrial Waste Streams: sectors like olive oil, tomato processing, or dairy could benefit from extraction and fermentation technologies.

Adaptation for SMEs at different development stages

The pilot model developed in this project is inherently flexible and can be adapted to the specific needs and capacities of SMEs at different stages of development:

Startups can benefit by using the model as a framework for identifying untapped value in production residues and as a basis for building innovative, circular business models.

Growing businesses may leverage the approach to diversify their product lines or explore new high-value markets—such as biostimulants or nutraceuticals—through partnerships and pilot production.

Established firms, with more structured operations and capital resources, can integrate valorisation pathways into existing sustainability strategies, using the model to quantify returns on investment, reduce environmental impact and strengthen market positioning through traceable circular practices.

Supporting resources needed for scaling

To enable broader adoption and replication, several enabling conditions are required. First, targeted funding mechanisms—including innovation grants, circular economy incentives and green transition financing—are essential to cover the upfront costs of R&D, equipment and process adaptation.

Second, strategic partnerships with research centers, biotech firms, and regulatory experts can help bridge the knowledge and technical gaps SMEs may face when entering new sectors. Finally, policy support at regional and national levels—such as clearer by-prdocut & end-of-waste criteria, harmonised valorisation guidelines and tax incentives—can accelerate the transition by reducing uncertainty and creating a favourable ecosystem for investment and collaboration.

Risk and Mitigation Strategies

Potential risks encountered

The pilot faced several risks, both operational and systemic. Key concerns included the technical uncertainty around the efficiency and scalability of extraction processes for high-value compounds from by-products, and the regulatory complexity related to classifying and marketing new outputs Additionally, the lack of standardised data across producers and the fragmentation of the supply chain posed risks to replicability and stakeholder alignment. From a market perspective, uncertainty about demand, regulatory acceptance and certification pathways added further challenges.

Mitigation measures implemented

To address these risks, the project adopted mitigation strategies focusing on early-stage identification and categorisation of technical, economic and compliance-related risks. A phased technology-readiness-based approach was applied to prioritise low-complexity valorisation options for early validation, while higher-risk scenarios were deferred for later-stage exploration. Regulatory risks were managed through consultation with subject-matter experts and benchmarking against the D2.3.3 compliance matrix, which allowed the project team to map critical authorisation pathways and anticipate barriers to market entry. The active involvement of producers and technology partners further supported adaptive risk monitoring, ensuring early detection of bottlenecks and rapid adjustment of pilot activities.

c. Beyond the Core: Circular Economy Applications for Radicchio Leaves

Region

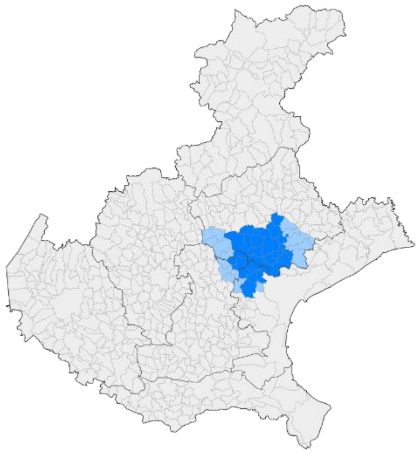


Figure 4: Veneto region - main Radicchio's production zone

Radicchio is a key horticultural product in northeastern Italy, particularly in the Veneto region, where its cultivation is deeply tied to local climate and soil conditions. Among the various types, Radicchio Rosso di Treviso IGP Tardivo (commonly known as radicchio tardivo) is considered the most prized variety due to its complex cultivation process and superior quality.

Radicchio tardivo is cultivated primarily in the provinces of Treviso, Padova and Venezia. The area lies between the Sile and Brenta rivers, benefiting from fertile, well-drained alluvial soils and a temperate climate with cold winters — essential for the development of the plant's unique characteristics.

Short Description

The radicchio valorisation pilot is a collaborative initiative led by Veneto Agricoltura, with the involvement of Tera Bona S.C.A.R.L. and Vortex. The project focuses on turning radicchio by-products, particularly leaf residues, into valuable resources for the food, pet food, cosmetic and nutraceutical sectors.

Through direct engagement with stakeholders and a detailed mass-flow analysis, the team mapped the radicchio supply chain and identified that 28% of the total 935 tons/year processed by Tera Bona becomes by-product. This is caused by the intrinsic characteristics of radicchio and its natural growth pattern, where the edible part develops internally and the outer leaves must be discarded during processing. While most of this material is currently composted, a small portion, mainly finishing leaves, was found suitable for upcycling.

The proposed valorisation process is divided into two phases:

- Primary processing (by Tera Bona and Vortex): involves washing, drying and milling the selected leaves into a fine powder.
- Secondary processing (by Vortex): includes extracting and enhancing bioactive compounds for use in high-value applications.

This pilot not only demonstrates the technical and economic feasibility of by-product valorisation but also provides a replicable model for other agri-food chains.

Radicchio tardivo holds Protected Geographical Indication (IGP) status, reflecting its historical and cultural value.

Sector

Mixed (Combination of production and processing)

Challenges Addressed

Key constraints and bottlenecks in the value chain

- Seasonality of production: the radicchio supply chain operates mainly from September to April, requiring adaptable processing and storage strategies.
- Logistical challenge of transporting processing residues back to the fields for composting: during winter months, when radicchio is harvested and processed, field conditions are often muddy, waterlogged or otherwise inaccessible due to cold and wet weather, making the return transport of organic by-products impractical or economically unfeasible. As a result, this limits circular practices such as soil amendment with organic residues or on-site composting and may contribute to increased costs or waste accumulation at processing facilities.
- High share of unexploited by-products: due to the fact that the edible part grow internally, approximately 28% of the processed radicchio (~262 tons/year), consisting of leaf and root residues, are considered by-products and are currently discarded or composted.
- Limited reuse of biomass: only a small fraction (finishing leaves, ~3%) is washed and suitable for upcycling, highlighting a lack of valorisation pathways.
- Technological gaps: existing drying and micronisation technologies were not tailored to radicchio biomass, necessitating the development of a low-temperature process to preserve nutritional and sensory properties.
- Fragmented data and traceability: mapping by-product flows required direct stakeholder engagement due to limited existing documentation.

Market, regulatory, environmental, or social challenges

- Regulatory compliance: valorisation for food, cosmetic, or agronomic use must adhere to national and regional regulations, which can be complex and resource-intensive.
- Economic barriers: disposal costs, although relatively low, represent a recurring burden and a missed opportunity for value creation.
- Market access and product classification: the classification of by-products and their transformation into marketable ingredients requires nutritional labelling and safety validation.
- Need for cross-sector collaboration: SMEs often lack the capacity to develop and test new technologies independently, making partnerships like the one with Vortex essential.

Solution Implemented

To address the challenges of by-product valorisation in the Radicchio supply chain, the project adopted a data-driven and scalable pilot model. The core of the approach was grounded in a rigorous scientific assessment of the current by-product management practices, with the aim of fully understanding their technical characteristics, economic implications and environmental footprint. Rather than limiting itself to a purely technological exploration of new solutions, the study was designed to provide a comparative framework in which alternative valorisation pathways could be critically evaluated against traditional disposal or low-value reuse practices.

The model combined quantitative data collection (e.g., mass balance reconstruction, cost estimates, emissions baselines) with qualitative insights from stakeholders, allowing for a systemic understanding of where value could be created or recovered along the supply chain. In this way, the project aimed not only to test innovations, but to guide decision-making through evidence-based evaluation, ensuring that any proposed transition was both feasible and impactful in the specific context of radicchio production.

Methodology

To address the challenges of underutilised by-products, seasonality and lack of valorisation infrastructure in the radicchio supply chain, the project implemented a replicable and field-tested model. This approach combine:

- Direct stakeholder engagement (e.g. interviews and site visits with Tera Bona) to reconstruct material flows and identify by-product typologies.
- Mass-flow analysis to quantify by-product generation (~28% of total input).
- Mapping of current uses and identification of valorisation gaps.
- Technological development of a tailored valorisation process for selected biomass fractions (finishing leaves and root portions).

- Solution partner engagement and pilot testing of a two-phase processing chain (drying/milling and extraction/functionalisation).

Technology

Vortex, selected technology provider, has developed a patented internal process that transforms agro-food by-products—from apple pomace to hazelnut residues—into innovative, high-value raw materials without regard to the original industrial production line. This proprietary pathway stabilizes highly moist substrates, preventing spoilage and enabling them to be standardized and processed into functional ingredients such as flours, pastes, fibers and bioactive extracts.

In order to understand how to properly functionalise the selected technology to radicchio by-products a six-phase experimental protocol was applied:

- Moisture content analysis
- Drying tests (time and temperature calibration)
- Nutritional and microbiological evaluation
- Process optimisation
- Nutritional labelling definition
- Extraction and characterisation of bioactive compounds

Partnerships

Tera Bona S.C.A.R.L.: provided access to real production data and biomass.

Vortex: developed and tested the technological process.

Veneto Agricoltura: coordinated the pilot and ensured alignment with regional innovation strategies.

Why This Solution?

This approach was chosen because it preserves the nutritional and sensory quality of the biomass, making it suitable for high-value applications in food, cosmetics and nutraceuticals. It is also adaptable to the seasonal nature of radicchio production and can be extended to other crops with different harvesting windows. The process was developed with regulatory compliance in mind, aligning with national and regional requirements which facilitates future commercialisation. Moreover, it supports circular economy principles by transforming agricultural waste into functional ingredients. Finally, the model is scalable and transferable, offering a practical solution for other horticultural supply chains seeking to reduce waste and increase resource efficiency.

Implementation Steps

Key actions taken

- T1 [October 24 – March 25]
  By-product mapping and target stream selection: material flows were reconstructed with Tera Bona, identifying ~28% of input as by-products.
- T2 [January 25 – April 25]
  Biomass selection: Mapping of current uses and valorisation gaps for each by-product stream & selection finishing leaves and root portions were chosen as the most suitable for valorisation.
- T3 [May 25 – September 25]
  Process Testing: a six-step protocol was applied: moisture analysis, drying calibration, quality checks, optimisation, labelling, and bioactive extraction.
- T4 [September 25 – December 25]
  Framework Creation: a replicable model was built, combining field data, supply chain analysis, and tech validation.
- T5 [January 26 – tbd]
  Scalability Planning: integration with other seasonal crops was considered to optimise equipment use.

Results and impact

Measurable benefits

- By-product recovery potential: out of ~935 tons/year of radicchio processed, ~262 tons/year (28%) are by-products. The project identified finishing leaves (~3%) as immediately suitable for valorisation, enabling a first step toward reducing waste.
- Cost reduction baseline: current disposal costs were quantified at €518.68/year, with a unit cost of 2.28 €/ton. This figure serves as a reference for evaluating future savings through valorisation.
- Resource efficiency: the drying and micronisation process allows for the reuse of biomass that was previously discarded, supporting circular economy goals and reducing environmental impact.

Key Performance Indicators (KPIs)

The following table summarizes quantitative flows, by radicchio type, across the main supply chain stages:

Radicchio Type	Harvesting (t)	Trimming (t)	Refinement (t)	Final Product (t)	Disposal Costs (€)
Round radicchio	113,00	156,50	-	815,00	165,17
Early radicchio (Treviso)	120,92	150,42	26,14	754,25	166,30
Late radicchio (Treviso)	25,06	125,32	50,13	250,64	92,17
Variegated radicchio	98,24	53,24	12,36	532,39	92,84
Verona radicchio	1,20	0,60	-	6,00	1,10
Rosa radicchio	1,20	0,60	-	6,00	1,10
Total	359,63	486,68	88,62	2.364,28	518,68

Lessons Learned

Challenges faced during implementation

In addition to the intrinsic challenges posed by the nature of radicchio processing by-products—such as high moisture content, rapid perishability and strong seasonal concentration—one of the most significant difficulties encountered was the translation of fragmented and artisanal post-harvest practices into measurable, quantitative data and standardized parameters. These aspects are essential for building scalable valorization models, yet they are often informal, vary significantly across farms, and are seldom documented in a way that supports technical reproducibility or system-wide integration.

How they were managed

To overcome this barrier, it was crucial to establish direct engagement with producers and processors, not only through structured interviews but through on-site observation of sorting, trimming, and by-product handling practices. Field visits conducted during the harvest season allowed for the real-time mapping of biomass flows, as well as the identification of specific by-product categories such as outer leaves and taproots. In parallel, a sampling campaign was carried out to characterize key physical and chemical properties—such as moisture content, fiber structure, and residual antioxidant load. These activities enabled the reconstruction of material flow baselines and supported the creation of structured datasets suitable for modeling scenarios, evaluating stabilization options, and assessing feasibility for upcycling into functional ingredients.

Key takeaways for future implementation

Future projects aiming to replicate this model should recognize that data availability and standardization are not guaranteed in traditional agri-food contexts. It is therefore essential to invest time in on-site engagement and participatory data collection and to treat producers not merely as data sources but as active partners in the co-construction of knowledge. This relational approach is fundamental to ensure the accuracy, usability and scalability of any Circular Economy strategy within primary production sector

Scalability and Replicability

Potential for broader application

The pilot established a replicable methodological framework for mapping and valorising by-products in the horticultural sector. While focused on radicchio, the approach is designed to be transferable to other vegetable supply chains, especially those with similar seasonal dynamics and by-product profiles. The drying and micronisation process can be adapted to other crops with non-overlapping harvest periods, allowing for year-round utilisation of equipment and infrastructure.

Adaptation for SMEs at different development stages:

- Startups can benefit from the validated process and framework to enter niche markets (e.g., functional ingredients, natural cosmetics) without needing to develop technology from scratch.
- Growing businesses can integrate the valorisation model to diversify product lines and reduce waste-related costs.
- Established firms can scale the process, optimise logistics, and explore cross-sector applications (e.g., pet food, nutraceuticals), leveraging existing infrastructure.

The collaboration between Tera Bona and Vortex demonstrates how partnerships between SMEs and technology providers can accelerate innovation and reduce barriers to entry.

To enable broader adoption and replication, several enabling conditions are required. First, targeted funding mechanisms—including innovation grants, circular economy incentives and green transition financing—are essential to cover the upfront costs of R&D, equipment and process adaptation. Second, strategic partnerships with research centers, biotech firms and regulatory experts can help bridge the knowledge and technical gaps SMEs may face when entering new sectors. Finally, policy support at regional and national levels—such as clearer by-product & end-of-waste criteria, harmonised valorisation guidelines and tax incentives—can accelerate the transition by reducing uncertainty and creating a favourable ecosystem for investment and collaboration.

Risk and Mitigation Strategies

Potential risks encountered

The pilot faced several risks, both operational and systemic. Key concerns included the technical uncertainty around the efficiency and scalability of extraction processes for high-value compounds from by-products, and the regulatory complexity related to classifying and marketing new outputs Additionally, the lack of standardised data across producers and the fragmentation of the supply chain posed risks to replicability and stakeholder alignment. From a market perspective, uncertainty about demand, regulatory acceptance and certification pathways added further challenges.

Mitigation measures implemented

To address these risks, the project adopted mitigation strategies focusing on early-stage identification and categorisation of technical, economic and compliance-related risks. A phased technology-readiness-based approach was applied to prioritise low-complexity valorisation options for early validation, while higher-risk scenarios were deferred for later-stage exploration. Regulatory risks were managed through consultation with subject-matter experts and benchmarking against the D2.3.3 compliance matrix, which allowed the project team to map critical authorisation pathways and anticipate barriers to market entry. The active involvement of producers and technology partners further supported adaptive risk monitoring, ensuring early detection of bottlenecks and rapid adjustment of pilot activities.

D. Utilisation of Agricultural and Food Residues for Yellow Mealworm Farming and Processing

Region

Figure 5: Warmia and Mazury voivodeship, north-eastern Poland

Short Description

Company CIRWINS Insects – has been operating since 2022 and focuses on products intended for animal feeding based on an alternative source of protein obtained from mealworm larvae (figure 6 and figure 7). The goal of the company is to focus on vertical insect rearing and make every effort to ensure optimal rearing conditions to produce live (figure 8) and dried larvae (figure 9) for the pet and husbandry feed market. The company uses simple feed materials obtained from local suppliers (e.g. cereal brands, oilseed cakes, second grade fruits and vegetables). In the next steps after the implementation, the company plans to develop the product offer towards, among others: insect paste, full-fat and defatted insect meal, mealworm oil, and fertilizer made from insect frass.

Figure 6: Farm building of CIRWINS company in Kamień Duży (Poland)

Figure 7: Insect rearing facility

Sector

Mixed (Combination of production and processing)

Challenges Addressed

- Efficient utilisation of feed materials from residues of agriculture and food industry.
- Setting up proper environmental conditions for efficient feed utilisation and growth of yellow mealworm larvae.
- Setting up proper conditions for efficient larvae drying.

Market, regulatory, environmental, or social challenges:

Insect farming and processing is a new branch of the agri-food sector not only in Poland but throughout the entire EU. Insect farming and their nutritional requirements have not been studied to the same extent as those of typical livestock. There is a lack of both nutritional recommendations (research) and suppliers of equipment or feed. Regulations concerning insect farming are based on those for typical livestock (e.g. veterinary regulations) and should be appropriately adapted to this group of animals. Moreover, to the inhabitants of Europe, insects are more often associated with pests and disease vectors than with a source of feed or food, so overcoming entomophobia also requires considerable effort.

Solution Implemented

In the first stage, an interview and an on-site visit to the yellow mealworm farm operated by CIRWINS were carried out by a team from the University of Warmia and Mazury in Olsztyn (UWM). The current rearing conditions were assessed, and an interview was conducted with the company's CEO regarding the needs and challenges at the present stage. Measurements were taken of insect rearing efficiency, feed substrate provision, and environmental conditions.

In the next stage, recommendations were introduced concerning the nutritional and environmental requirements of the insects. Feeding substrates that are efficient in yellow mealworm rearing were identified, along with guidelines on how they should be processed and provided (including a feeding schedule during larval development). At this stage, the recommendations were monitored and evaluated through documentation of the rearing process and visits by UWM staff.

The reared larvae could either be sold directly to the pet market as feed (e.g. for reptiles or ornamental birds) or processed through drying. To enable this, an appropriate microwave-drying technology was developed, tailored to the required characteristics of the dried larvae, including moisture content, water activity, and microbiological parameters. At this stage, UWM provided the expertise essential for the proper execution of the process and for interpreting the results obtained.

Why this solution?

This stepwise approach enabled the identification of the company's needs and challenges during its initial development phase. The sequentially planned actions allowed staff to implement recommendations while simultaneously acquiring knowledge of new and improved rearing technologies and insect processing.

Implementation Steps

Key actions taken:

The key actions encompassed stages from interviews and preliminary studies (December 2024), through the implementation of recommendations, to their current adoption and initial assessment (June 2025). The final evaluation of the implemented actions is planned for no earlier than the end of 2025.

Results and impact

Measurable benefits and Key Performance Indicators (KPIs): Improved rearing volumes by 75%, highest sales by 60% annually for at least 5 years (growing the market and carving substantial share for Cirwins' business.

SME Testimonials: "I believe the project helped us better understand all the intricacies of rearing yellow mealworms and thus improve both feeding needs of mealworms per tray, but also boost their production volumes by ca. 80-90% in 2025 vs 2024, which enabled us to place more products on the market and boost sales by ca. 80% vs. 2024. We also see further potential to keep such a high growth path over, at least, the next 24-48 months. Moreover, Improved efficiency of feeding mealworms and boosting their production volumes helped us drive down costs of heating needs, which resulted in improved bottom line. We are very positive about further use of our joint conclusions to further boost the company's growth." (Mateusz Mentlewicz, CEO, CIRWINS).

Figure 8: Live yellow mealworm larvae

Figure 9: Dried yellow mealworm larvae

Lessons Learned

Challenges faced during implementation: Implementing the recommendations needed substantial changes in work organisation and in insect rearing technology, encompassing both the breeding stock and the larvae production stock. The additional measurements required extra staff time and the adaptation of established habits and routines present at this stage of the company's development.

How they were managed: The introduction of the recommendations and the implementation of new measurements required work reorganisation, staff training, and awareness-raising discussions to explain the purpose of these changes.

Key takeaways for future implementation: The implemented changes led to a marked increase in productivity, more efficient feed utilisation, and a significant improvement in staff performance. At this stage, further measures should be undertaken to enhance the insect rearing process and to identify more feeds sourced from agricultural and food industry residues.

Scalability and Replicability

Potential for broader application:

This solution can be implemented in small-scale yellow mealworm processing facilities (1–10 tonnes of larvae per month), particularly in repurposed former poultry production buildings, which are abundant in Poland and where the technology is highly replicable. Following the introduction of rearing automation, a similar technological approach could be adopted at a significantly larger production scale.

Adaptation for SMEs at different development stages:

Employing a step-by-step method is especially appropriate for new companies without prior experience in large-scale insect production and processing. It allows them to expand their insect stocks and tailor and refine their methodologies to their specific requirements and the technologies being implemented on the further steps of development.

Supporting resources needed for scaling

Insect farmers can apply for various types of funding for equipment purchases and, in cooperation with research institutions, for research and development grants. Given the ongoing lack of knowledge regarding the nutritional requirements of insects, close collaboration with the scientific sector is essential. Furthermore, aligning agricultural policy and increasing support from the Ministry of Agriculture to a level comparable to that provided for traditional livestock farmers would be well received by this new and developing branch of industry in Europe.

Contact Information

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E. Agri-food Waste Bioconversion into Animal Feed, Fuel or Other Products

Region

Kujawsko-Pomorskie Voivodeship in Poland

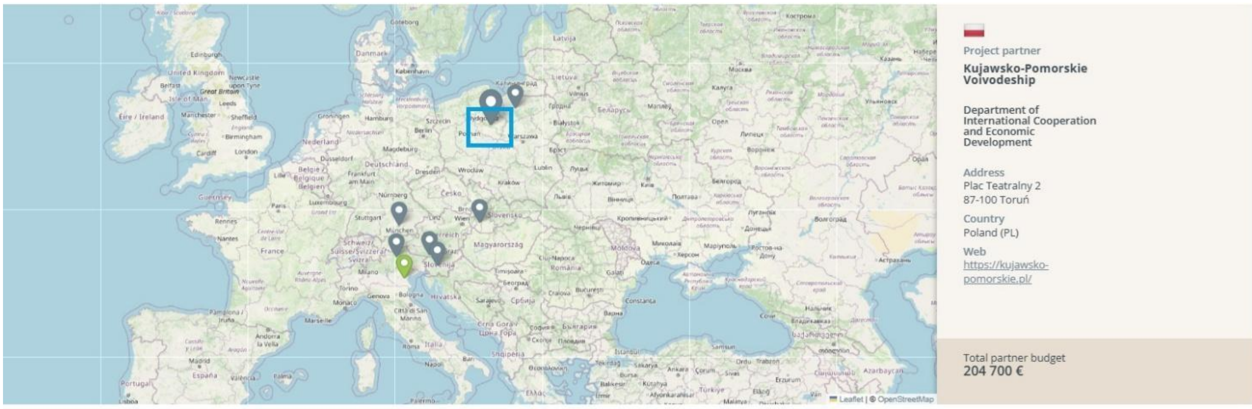

Figure 10: Kujawsko-Pomorskie (Poland) region is marked on the Europe map with a blue rectangle. Source of the map: https://www.interreg-central.eu/projects/tebice/

Short Description

In the proposed value chain, the partner will analyse the efficient use of agricultural residues to produce biogas, organic fertiliser and animal feed as end products.

Sector

☑ Processing (e.g., food production, manufacturing, etc.)

Challenges Addressed

Key constraints and bottlenecks in the value chain:

- the most effective sources of substances are expensive and therefore we are looking for cheaper and more accessible alternatives
- the value chain is short and on this basis it is possible to search for new solutions based on the search for biologically active substances

Market, regulatory, environmental, or social challenges:

- lack of broader knowledge and awareness in local society about the principles of the circular economy
- regulatory constraints hindering various aspects of the development and operation of biogas plants in the region and the country

Solution Implemented

Description of the approach, innovation, or model adopted: As part of the pilot activities, we are analysing the raw materials available in our region in terms of their efficiency (to the anaerobic digestion process), usefulness and the substances they contain that can be valorised. We conduct meetings and seminars for the broadest possible community in the region in order to promote and expand the knowledge and awareness of society

Technology, methodology, or partnerships used: In order to search available information, we use the tools available in the project (Value Chain Generator AI©), scientific publications, published and official statistical data as well as contacts with experts and other

Why this solution? We try to rely on official and trusted sources of information in order to propose reliable solutions

Implementation Steps

Key actions taken an timeline and timeframe: selected activities from the pilot schedule are presented in the table

1	Conducting promotional events such as seminars and conferences for the non-specialists, business and scientific community	May 2025
2	Mapping available raw materials so that the supply chain is optimized in terms of the principles of circular bioeconomy – preparation of a dedicated report	March 2025
3	Analyzing scientific and specialist literature to characterize the materials used in terms of their chemical composition, physicochemical and biological properties and the possibilities of developing the material for new value chains	April 2025
4	Conducting analysis and preparing a report based on searching for information and data in scientific and specialist literature regarding the optimization of technological solutions	June 2025

5	Conducting value chain optimization analyses based on available tools in the TeBICE project	August 2025

Results and impact

Measurable benefits: The main benefit will be the expansion of knowledge on the availability of raw materials in the region as well as the acquisition of knowledge on the content of substances in terms of new value chains.

SME Testimonials: "Currently, we encounter many limitations in obtaining new substrates that would have a positive impact on the development of the company"

Lessons Learned

Challenges faced during implementation: Databases contain an incomplete set of data and are selective

How they were managed: Narrowing the field of action and modifying goals

Key takeaways for future implementation: Consider the availability of databases and source data

Scalability and Replicability

Potential for broader application: Yes, pilot activities concern broadly understood biomass and the implementation of the planned activities concerns raw materials that can be valorised in other branches of interest

Adaptation for SMEs at different development stages: Companies can gain knowledge and access to sources of new materials, establish business contacts to expand distribution and optimize costs as well as reach a wider group of recipients with your products

Supporting resources needed for scaling: Cooperation at the level of legal regulations with the relevant legislators and close contact with potential recipients of valuation products would enable the development of activities undertaken in the pilot project.

Risk and Mitigation Strategies

Potential risks encountered: There is a low risk of not obtaining the data needed to implement the activities within the pilot.

Mitigation measures implemented: the risk is minimized by expanding access to new sources of databases and publications

Contact Information

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F. Upgrading a By-Product: Regional Collaboration for Food-Grade Pumpkin Seed Meal

Region

Austria – Regional Focus: Southeast Styria (Steiermark)

Pumpkin seed oil production is a regionally rooted tradition in Austria and extends beyond the borders of Styria. As illustrated in figure 11, pumpkin seed press cake—a by-product of oil pressing—is also produced in other federal states, including Lower Austria, Burgenland, and Upper Austria.

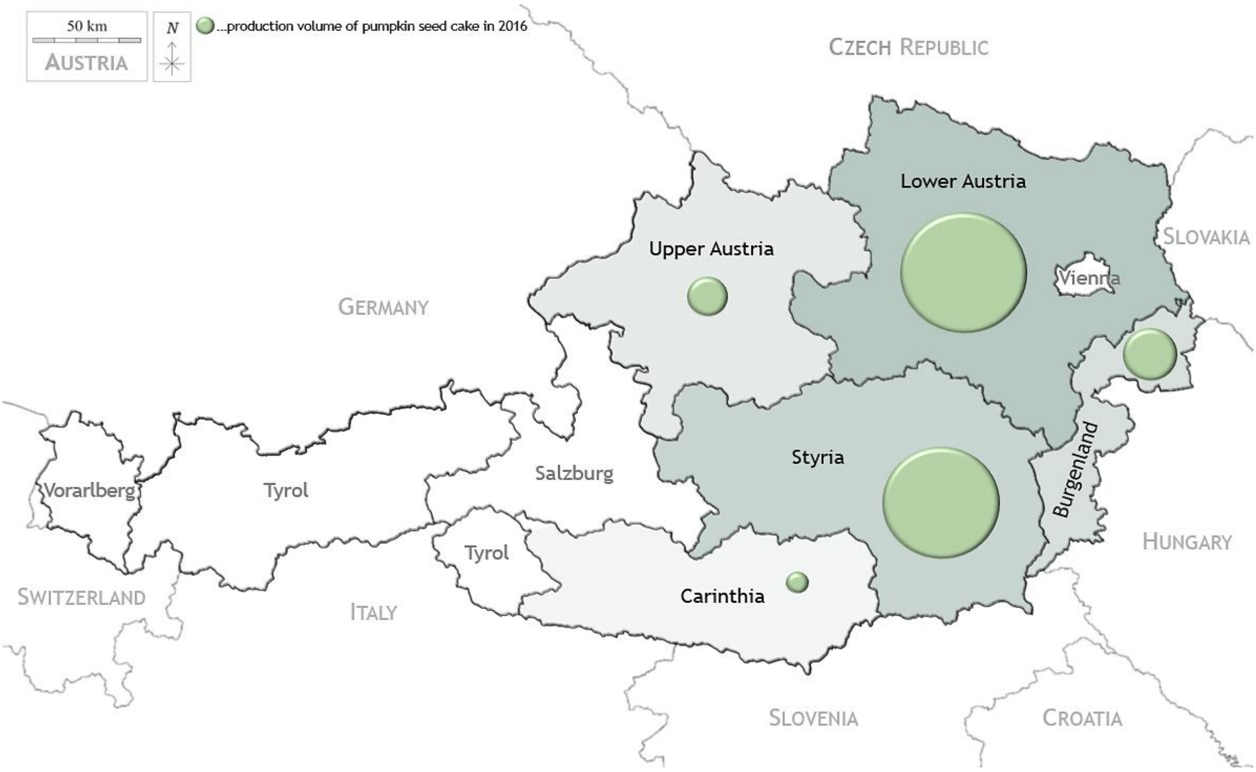

Figure 11: Pumpkin Seed Oil and Press Cake Production in Austria region

However, this case study focuses on Southeast Styria, where the highest concentration of Protected Geographical Indication (PGI)-certified pumpkin seed oil production is found. The pilot project partners involved in this case are all based in this region, where small and medium-sized oil mills generate significant volumes of pumpkin seed press cake as part of traditional oil pressing.

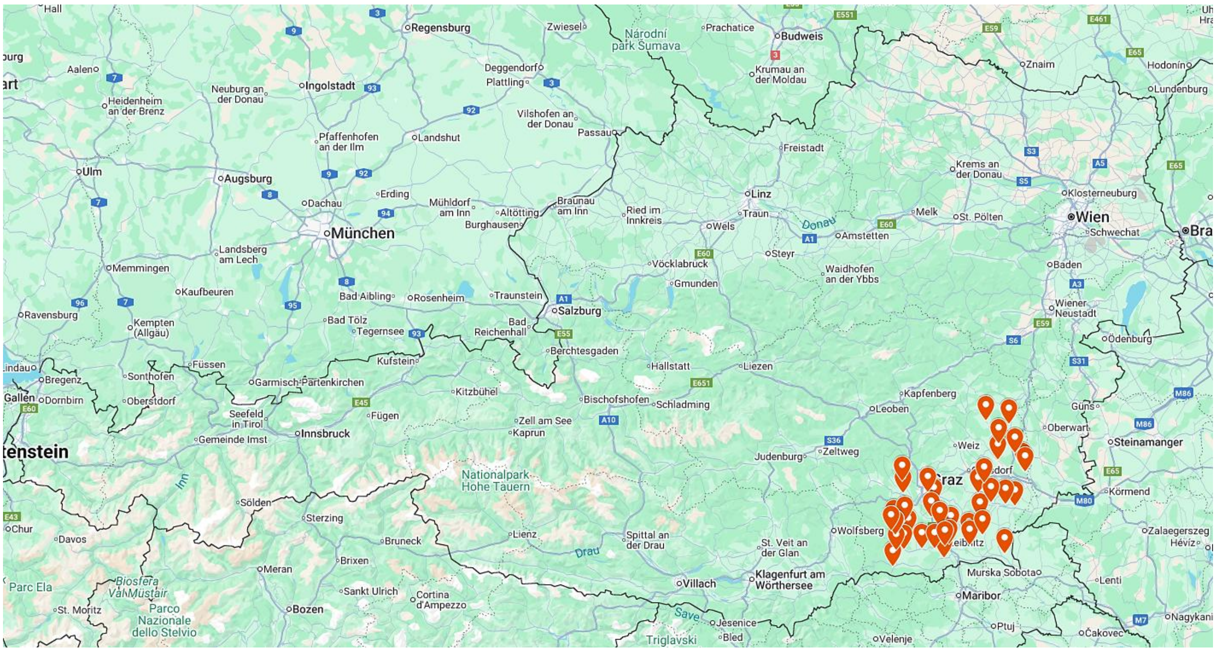

Figure 12: Pilot Area in Southeast Styria

As shown in figure 12, the participating oil mills are geographically clustered in this southeastern part of the province, which combines strong local networks, traditional know-how, and established processing infrastructure. This regional focus provided an ideal setting for testing cooperative approaches to the valorisation of press cake into high-quality pumpkin seed meal.

Short Description

This value chain begins with pumpkin seed cake, a by-product of traditional pumpkin seed oil production. Rather than being used solely as animal feed, the press cake is further processed into pumpkin seed meal – a relatively coarse but protein-rich food ingredient. The process may involve additional mechanical pressing to lower the fat content, followed by grinding and sieving to achieve a defined particle size.

The processing was carried out in collaboration with Kiendler GmbH, a relatively small oil mill in south-eastern Styria. The company's traditional roasting methods and gentle pressing result in a consistent raw material/by-product that supports further processing while maintaining the quality of the final product.

Sector

Mixed (Combination of production and processing)

Challenges Addressed

Key constraints and bottlenecks in the value chain

Lack of complete processing infrastructure at individual mills

Most small-scale oil mills do not have the full range of equipment needed to transform press cake into food-grade meals. While basic steps such as coarse crushing are possible, further processing stages such as fat reduction, fine sieving or packaging require shared infrastructure.

Fragmented raw material quantities and isolated operations

The annual amount of press cake available per mill is too low for efficient standalone processing. Without pooling and coordinated scheduling, minimum volumes required for continuous or economic processing cannot be reached.

Lack of coordination mechanisms for joint processing and logistics

Without a shared organisational structure, it is difficult for small oil mills to synchronise delivery, processing schedules, and responsibilities. This leads to inefficiencies, communication gaps and a high coordination burden for individual actors.

Market, regulatory, environmental, or social challenges:

Price uncertainty and lack of market transparency (economic barrier)

The wide variation in market prices for pumpkin seed meal – ranging from approximately €1 to €20 per kilogram – creates significant uncertainty for small oil mills. This lack of transparency makes it difficult to assess the economic potential of the product and discourages investment in new or related value chains.

Seasonal and climate-related supply fluctuations (environmental barrier)

The availability of pumpkin seed press cake depends on the annual oil pumpkin harvest, which can be affected by weather conditions and seasonal variability. Year-to-year fluctuations in yield and raw material quality make it difficult to ensure stable supply and processing schedules. This limits long-term planning and creates uncertainty for small producers, particularly when it comes to investments in equipment and facilities for meal production.

Coordination and trust challenges (social/organisational barrier)

Effective cooperation between multiple small oil mills requires clear agreements on quality standards, delivery schedules, quantities and revenue sharing. In the absence of a structured coordination mechanism, misunderstandings, inefficiencies and lack of trust can hinder smooth collaboration.

Transport and coordination costs (economic barrier)

Delivering press cake to a central processing facility involves additional efforts such as transport planning, packaging, scheduling and traceability. For small oil mills, these are economically relevant factors that can discourage participation in joint processing models.

Solution Implemented

Description of the approach, innovation, or model adopted:

To address the structural and organisational barriers in the value chain, a cooperative model was developed and selected as the most suitable solution. The aim was to enable small oil mills to jointly participate in the further processing and marketing of pumpkin seed press cake, without having to build up full-scale infrastructure individually.

The chosen approach is based on a shared value chain, in which participating mills contribute their processed product – pumpkin seed meal – to a central coordination unit. This unit, legally set up as a registered cooperative (eGen) under Austrian law, takes over downstream tasks such as packaging, logistics, marketing and sales. The eGen model ensures equal voting rights for all members and operates on behalf of the group, enabling professional market access, shared responsibility, and coordinated quality management – while allowing each mill to retain control over its own production steps.

Technology, methodology, or partnerships used:

Two variations of the cooperation model were developed to enable joint valorisation of pumpkin seed press cake among small oil mills. Both models rely on a shared organisational structure – a registered cooperative (eGen) – which handles downstream tasks such as packaging, logistics, marketing, and sales. The models differ primarily in where the processing takes place and how responsibilities are allocated:

In the first model (Figure 13), mills deliver unprocessed press cake to the eGen before any further processing. The eGen then organises contract processing, quality control, and packaging at a processing facility. This approach centralises key operations and is considered the preferred option in terms of efficiency, consistency, and branding.

Operational tasks of the eGen in this model include:

- Processing planning and contract assignments
- Quality management
- Logistics coordination
- Packaging
- Marketing and sales

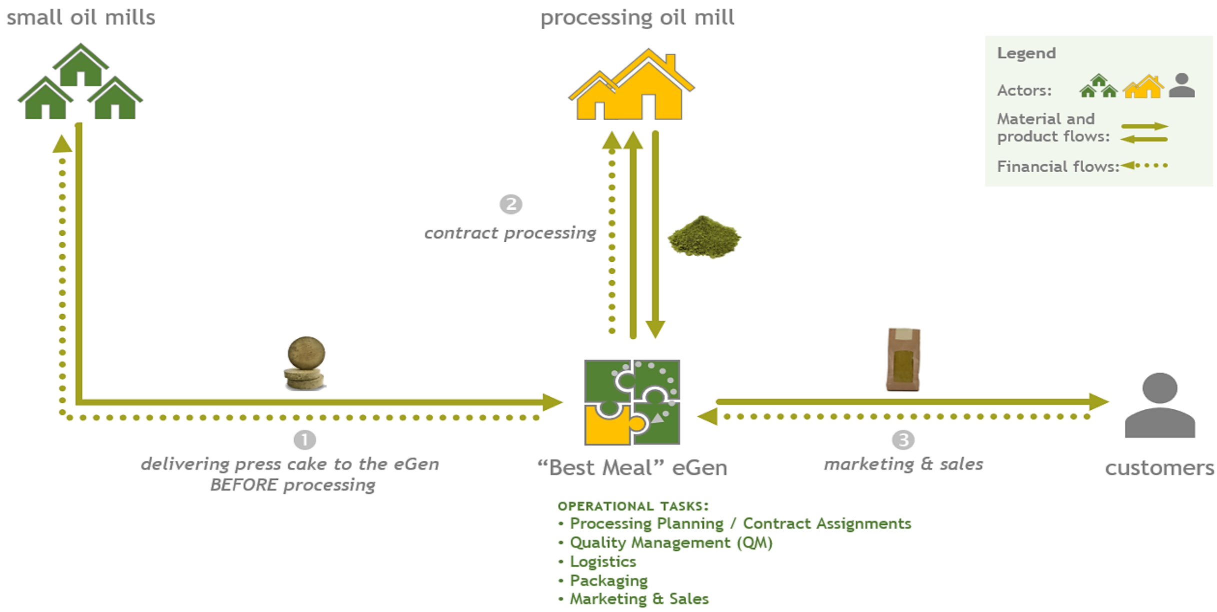

Figure 13: Cooperation Model 1

In the second model (Figure 14), each mill is responsible for contract processing on its own and only delivers the refined pumpkin seed meal to the eGen. The central entity takes over from there. This model requires less coordination effort and allows individual mills to retain control over processing.

Operational tasks of the eGen in this model are limited to:

- Logistics
- Packaging
- Marketing and sales

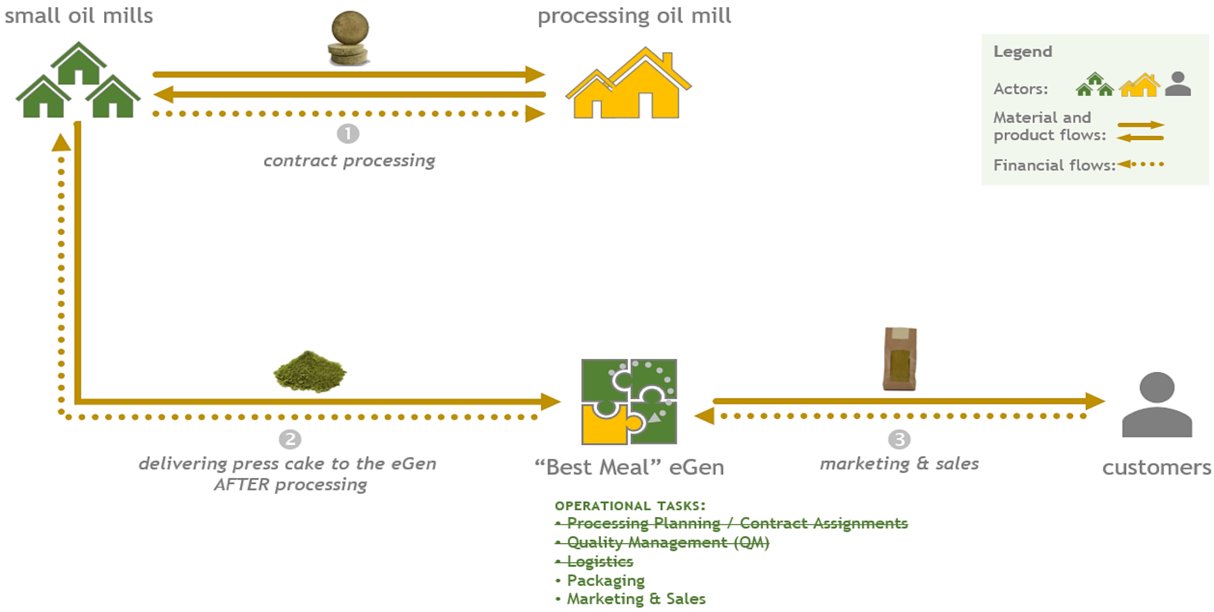

Figure 14: Cooperation Model 2

While Cooperation Model 1 is considered more effective in the long term, most small mills involved in the pilot project were – for practical reasons – only ready to commit to the decentralised approach of Cooperation Model 2 at this stage.

Why this solution?

These cooperative models were chosen because they offer a flexible and scalable framework for enabling small oil mills to participate in value-added processing. They allow for shared responsibility and coordinated tasks without requiring each mill to invest in full processing infrastructure. The use of a registered cooperative (eGen) ensures a clear governance structure, democratic decision-making, and equal representation of all participants.

Among the two variants, Cooperation Model 2 was selected as the starting point, as it aligns better with the current capacities and preferences of the participating mills. However, Cooperation Model 1 is considered a more robust long-term solution, as it offers greater efficiency, consistency, and professionalisation of the overall value chain. The two-model approach also allows for future transition and scaling. Once established, this form of cooperation has the potential to remain stable over time, even in the face of yield fluctuations or changes in membership, and it can be transferred to other regions and value chains within the agricultural sector.

Implementation Steps

Key actions taken:

The implementation process focused on setting up a cooperative processing structure for pumpkin seed press cake in south-eastern Styria. The approach involved identifying committed partners, collecting operational data, developing suitable cooperation models, and testing their applicability in practice. The processing was carried out in collaboration with Kiendler GmbH as the central processing facility, supported by four small oil mills who contributed press cake for further refinement into pumpkin seed meal.

Timeline:

Phase	Actions Taken
Initial Planning (Sep. – Oct. 2024)	Informal planning phase initiated in September 2024, including coordination within the project team and identification of implementation goals. In October, personal outreach was conducted to approach small oil mills in the region and assess initial willingness to participate in a pilot setup.
Partner & Data Collection (Feb. 2025)	A structured questionnaire was sent out to oil mills across Styria to collect data on processing capacity, infrastructure, raw material volumes and general interest in collaboration. The results formed the factual basis for model development.
Model Development (Apr. – May 2025)	Several cooperation models were drafted in close coordination with the participating oil mills, taking into account real processing constraints and preferences. The models were designed to fit the regional context and reflect different levels of coordination and investment.
Expert Input & Evaluation (Jun. – Jul. 2025)	The developed models were presented to selected technical and organisational experts in a series of structured online interviews. Feedback focused on feasibility, process design, legal form, and organisational requirements. Recommendations were integrated into the final implementation setup.
Implementation Preparation (Aug. – Sep. 2025)	Final selection of the preferred cooperation model. Internal responsibilities were clarified. Logistics and delivery schedules for the partner mills were coordinated. Kiendler GmbH prepared processing equipment and batch planning.
Start of Joint Processing (Oct. 2025)	Processing of the first test quantities began under real conditions. Press cake from four small mills was delivered and refined into pumpkin seed meal. The cooperative coordination structure was piloted using the example of model variant 2. Monitoring and adjustments are ongoing.

Results and impact

Measurable benefits:

Increased raw material utilisation

By processing approx. 100–150 t of pumpkin seed press cake annually (according to the central oil mill), a by-product that was mainly used as animal feed is upgraded into a food-grade product.

Higher value creation

Production of pumpkin seed meal with defined quality parameters (residual fat 6–8 % after additional defatting, particle size < 500 µm).

Efficiency gains through cooperation

Smaller mills benefit from the infrastructure and experience of the central mill, reducing investment risks.

Key Performance Indicators (KPIs):

Due to delays in the implementation of the cooperation model, no baseline data are available yet. The following KPIs are possible indicators with which results and impacts can be measured in the future.

Input processing capacity

- Volume of processed pumpkin seed press cake (t/year)

Product quality

- Residual fat content (%) after defatting
- Particle size (µm, homogenised < 500 µm)
- Protein content (%) in the meal

Market success

- Sales volume of pumpkin seed meal (t/year)
- Average sales price (€ per kg, food-grade)
- Number of acquired B2B customers

Cooperation & scaling

- Number of mills involved in the supply chain
- Amount of joint investments (€)
- Utilisation rate of installed equipment (%)

Sustainability & resource efficiency

- Share of press cake valorised into higher-value food (%)
- Reduction of material diverted to feed or waste (t/year)
- Energy consumption per tonne of processed meal (kWh/t)

Lessons Learned

Challenges faced during implementation:

- Differences in technical equipment across mills → no uniform starting point.
- Limited raw material volumes per mill → need for joint coordination.
- Uncertainty regarding market prices and sales opportunities.
- Partial reluctance towards centralised processing or marketing.

How they were managed:

- Instead of immediately establishing a formal organisation, a low-threshold enquiry ("yes, this could be of interest to me") was conducted to test acceptance.
- Various cooperation models (centralised, decentralised, hybrid) were kept open as options.
- The survey was complemented by interviews to better understand concerns and expectations.

Key takeaways for future implementation:

- Basic approval is an important first step but does not yet replace formal cooperation.
- The next phase must focus more strongly on concrete framework conditions (organisation, financing, marketing).
- A step-by-step approach (from initial interest → pilot trials → formal structure) is more promising than attempting an immediate "large-scale" model.

Scalability and Replicability

Potential for broader application:

The cooperation model developed and discussed in this pilot, based on decentralised raw material supply and centralised processing and marketing, is transferable to other regions with a dense network of small producers. It works particularly well when individual SMEs lack the scale, equipment, or capacity to enter food-grade product markets on their own.

Adaptation for SMEs at different development stages:

For smaller mills, the model offers a low-risk opportunity to participate in value-added production through shared infrastructure and coordinated sales. More advanced actors can serve as processing and packaging hubs, enabling others to access markets without major investments. The centralised branding and marketing structure enables even micro-enterprises to present themselves professionally and to offer products with consistent quality.

Supporting resources needed for scaling:

Successful replication depends on three key factors: (1) a reliable processing and packaging partner, (2) a lean but functional coordination structure, and (3) joint marketing under a shared label or product identity. Lean governance formats (e.g. cooperative agreements or coordination units) could be sufficient in the early phases. Public funding can strengthen implementation through support for coordination, branding development, and/or marketing infrastructure.

Risk and Mitigation Strategies

Potential risks encountered:

Raw material inconsistencies

- Different roasting levels, fat content, and moisture levels across suppliers created uncertainty in product standardisation.

Coordination difficulties

- Due to lack of prior cooperation, roles, timelines, and responsibilities were not always clearly understood by all actors.

Regulatory uncertainty for food-grade marketing

- For some participants, it was unclear which food safety standards applied to intermediate products (e.g. pumpkin seed meal vs. final food product).

Dependence on a single processing partner

- Centralised processing created a temporary bottleneck risk in case of machine downtime or scheduling conflicts.

Mitigation measures implemented:

- Product consistency was stabilised through process adaptation at the central mill (e.g. adjusting sieving parameters, pre-sorting batches) and informal feedback loops with each supplier.
- Coordination challenges were addressed via low-threshold communication tools (group chats, calls) and an open coordination culture. This aligns with the participatory coordination logic outlined in TeBiCE D2.3.3.
- Legal uncertainties were mitigated by limiting the initial pilot to B2B use and involving only certified food-grade processors. This phased approach corresponds to the risk mitigation strategy ‘RMS-4: Limit exposure in early stages’ in TeBiCE D2.3.1.
- Processing dependence was reduced by aligning batch planning with available capacity and preparing contingency options for future scaling (e.g. additional drying or sieving partners). This supports the redundancy logic in RMS-2: Shared operational buffers.

Contact Information

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Figure 15: Source: www.kiendler.com

G. Utilisation of Apple Residues for Pet Food Production

Region

The South Tyrol region in the north-eastern part of Italy is a leading producer of apples, which in turn generate a significant amount of apple residues.

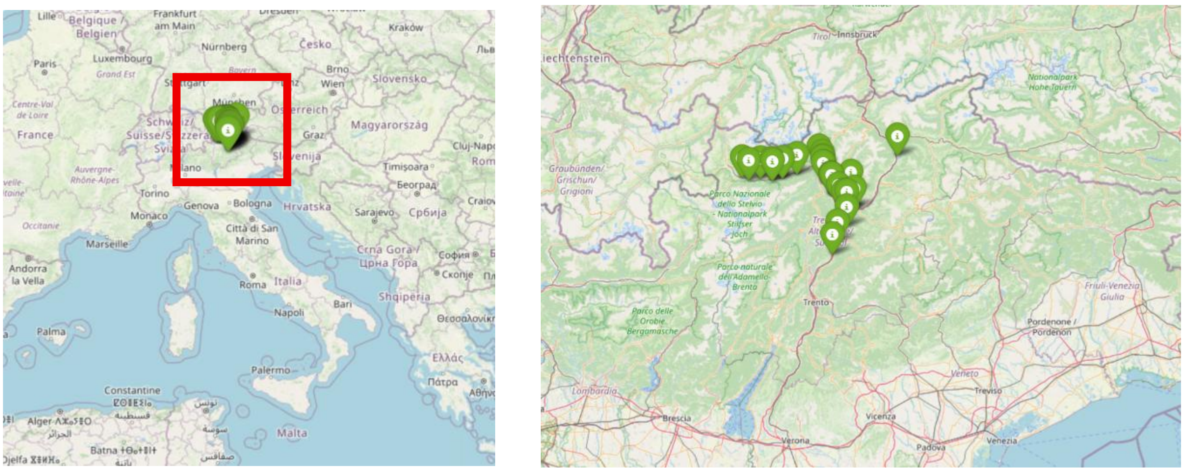

Figure 16: Apples production in the north-eastern Italy

Short Description

Within the TeBiCE project, apple residues were identified as a valuable resource to be valorised for the development of high-value products. This case study describes how by-products derived from apple processing production can be recovered and reprocessed to generate new raw material for pet food utilisation. The resulting ingredients are analysed in terms of composition to determine suitable end-users.

Sector

Mixed (Combination of production and processing)

Challenges Addressed

Key constraints and bottlenecks in the value chain

- Seasonality and storage: Apple harvest period runs from August to November (depending on the variety). Fresh produce is stored for long periods in refrigerated containers, leading to high energy consumption
- Moisture and Perishability: the by-products from apple processing contain a high-water percentage, which makes storage and transport critical for subsequent treatment.
- Logistics: the companies able to convert apple by-products into new products are located in different Italian regions. To overcome the logistical impact, the by-products need to be pre-treated before reprocessing.

Market, regulatory, environmental, or social challenges

Regulatory Aspects:

- Strict compliance required for food, cosmetic and feed applications (e.g. EU Novel Food Regulation, REACH).

Market Aspects:

- Low competition in the development of new apple by-products at the national level due to the territorial apple production (approx. 68% in Trentino-Alto Adige region: 46% in Alto Adige/South Tyrol and 22% in Trentino).

Solution Implemented

Description of the approach, innovation, or model adopted

To address the challenges of by-product valorisation in the apple supply chain, the project explored technological solutions to overcome identified bottlenecks. Moreover, an economic evaluation is provided to determine the potential success of the new ingredients produced.

Methodology

The methodology involved:

- Selection of priority streams (e.g. apple by-product derived by apple peeling vs by apple puree) for further technological development.
- Tests on apple by-products quantifying composition.
- Tests of new ingredients generated on formulated pet food.
- Preliminary evaluation of economic feasibility implications for potential product classes derived from the identified by-product.

Technology

- Extraction processes drying through a rotary drum system and grinding into different particle sizes
- Analytical methods for characterising bioactive compounds (e.g., polyphenols), microbes, etc.

The pictures show the peeling by-product and the resulting flour (<250 µm), respectively, in FIG. 17 A and B.

FIGURE 17: from apple peeling (A) to flour (B) through drying and grinding by Vortex company.

Partnerships

Several actors are engaged in the apple value chain through interviews and site visits:

- Apple producers (in the South Tyrol region, Italy)
- Re-processing company (Vortex, in the Piemont region, Italy)
- Ingredient user (Andriani SPA, in the Puglia region, Italy)

Why this solution?

Among the residues studied (from peeling and juice production), apple peel residues were selected for further development due to their lower sugar content and higher fibre content, which are of greater interest to the target market. Regarding the end-users, the target exploitation was investigated in pet food (kibble) because the fibres content helps the formulation and has a very good nutritional value.

Moreover, due to the use of by-products, the circular economy claim of the new product means a competitive advantage, compared to the similar product produced by the entire apple fruit.

Implementation Steps

Key actions taken

- October 24 – January 25: planning the exploitation of several streams from apple production and processing
- February 25 – June 25: Implementation of test analysis on selected target by-products
- July 25 – December 25: Test results evaluation, comparison with baseline scenario and solution optimisation
- January 26 – tbd: Development of a scalable and replicable model applicable to other

Results and impact

Higher value creation

Production of pet food (kibble) with an apple flour of 5% in the final formulation, optimal for new product structure due to fibre content (FIG.18)

Figure 18: pet food (kibble) produced by Andriani SPA

Increased raw material utilisation

The apple production in the region averages between 950,000 and 1,005,000 tons, approximately. 50% of Italy's entire pr. Considering an average usage for processing of about 75% and a waste of approximately. 25% after processing, 190,000 tons of by-product are generated in this area. With the creation of a market for this by-product, 160,000 tons of by-products could be recovered per year. The remaining 20,000-30,000 tons is employed as an amendment or disposed of by payment by the production company.

Efficiency gains through cooperation

Cross-sector collaboration enables the use of materials and a circular economy approach towards new ingredients, useful for pet food formulation.

Key Performance Indicators (KPIs):

- Input processing capacity: volume of apple production in the region

By-product quality: chemical content of flour (<250 µm) after processing

- Nutritional information: carbohydrates, fats, fibres, water
- Microbial characterisation: counting bacteria, yeast, etc.
- Analysis of NDF (neutral detergent Fiber), ADF (Acid Detergent Fiber) and ADL (Acid detergent Lignin)
- Polyphenols total amount

Sustainability & resource efficiency

- Energy consumption per kg of flour (after drying and drumming) and per kg of final product (excluding logistic costs)

Lessons Learned

Challenges faced during implementation:

- The by-product needs to be fresh to avoid contamination in terms of undesirable microorganisms growing

How they were managed

- The pre-treatment of by-products by drying guarantees the good quality of the subsequent ingredient

Key takeaways for future implementation

- The transformation costs are related to the quantity produced (especially if > 1 ton of volume)

Scalability and Replicability

Potential for broader application: The pilot activities concern broadly understood by-products in terms of chemical analysis that can be valorised in other sectors of interest (i.e. ingredients for human food)

Adaptation for SMEs at different development stages: Companies can gain knowledge and access to sources of new materials, establish business contacts to expand distribution and optimize costs as well as reach a wider group of recipients with your products

Contact Information

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H. Apple Pomace for Pectin and Animal Feed Production

Region

In Slovenia, apples are mainly grown for consumption, with only a small proportion being processed into apple juice and other products. Apples are mainly grown in small intensive and extensive plantations by farmers who usually process the quality apples into apple juice and other products. Most apples are grown and processed in the eastern part of Slovenia, where producers are mainly located in the region of Slovenia: Lower Sava, Savinja and Drava and also some in Gorizia (Figure 19).

Figure 19. Statistical region of Slovenia.

Short Description

Slovenia has an extensive and long tradition of grating apples for consumption. As not all apples are suitable for the market, second quality apples are usually processed into various products, such as apple juice, apple cedar, apple cider vinegar, dried apple products, etc. The processing of apples produces large quantities of apple waste, the disposal of which can cause enormous costs. As apples have a fairly high pectin content, apple residues are a promising source for pectin production. In addition to pectin, apple residues also contain large amounts of fibres (cellulose and hemicellulose), which makes apple residues an interesting source for the production of animal feed. As part of the TeBiCE project, the valorisation of apple residues for the production of pectin and animal feed was carried out by PP2, NIC.

Mirovita d.o.o. is a Slovenian producer of dried apple products, which was founded in 2007 as a subsidiary of Mirosan d.o.o., one of the largest apple producers in Slovenia. Mirovita's main products are dried apple products in various forms (crisps, flakes, sticks, cubes, segments, rings, peeled, unpeeled, coated with white chocolate). The production of dried apples produces many by-products such as apple peel and residues. These apple residues are a potential source for the production of pectin and also a very good and rich source of fibre for the production of animal feed. Therefore, the company Mirovita was included in the project as a producer of apple residues in apple pomace VC.

Sector

Processing (e.g., food production, manufacturing, etc.)

Challenges Addressed

Key constraints and bottlenecks in the value chain:

- Apple pomace residue is susceptible to decomposition by fermentation after processing; it should therefore be processed as quickly as possible.
- Apple pomace is very voluminous, which, together with its perishability and seasonal availability, poses a major storage challenge
- The fragmentation of apple producers in Slovenia reduces the possibilities of using apple pomace for the production of high-quality products such as pectin

Market, regulatory, environmental, or social challenges:

The main difficulty in the production of pectin is that apple producers are generally small and widely scattered and the larger apple processing plants are quite dispersed, which poses a major challenge for the transport of apple pomace, which is why there is no pectin production in Slovenia. Apple processing plants and apple producers are confronted with large quantities of apple residues in a relatively short period of time, as apple residues are mainly produced during the apple harvest. Usually, this problem is solved by using apple residues for the production of vinegar and animal feed, fresh or fermented, and they are also deposited in nature, which can lead to environmental problems.

Solution Implemented

Description of the approach, innovation, or model adopted:

The apple pomace and residues are susceptible to fermentation and should therefore be processed as quickly as possible. Drying and freezing apple pomace could be an option to temporarily prevent decay. The company Mirovita has a drying technology and can also dry apple pomace and use it for various proposals.

Mirovita continuously produces dry apple products, producing large quantities of apple pomace. To reduce the volume of apple pomace, they have introduced a process of pressing the apple pomace and extracting apple pomace and juice. This solution has proven to be very useful in reducing storage problems. The two resulting streams, apple pomace and second quality juice, are sent outside the company for processing.

Mirovita is interested in producing animal feed from apple pomace after processing apple residues. Animal feed could be produced by extruding a mixture of dry apple pomace and selected cereals. As part of our co-operation in the TeBiCE project, PP2, NIC has prepared the official technological scenario for the production of animal feed from apple pomace. The process is currently undergoing preliminary feasibility testing.

Since apple pomace is a potential source for pectin production and Mirovita continuously produces apple pomace as a by-product, NIC has prepared a proposal for the production of pectin. The formation of a strong and co-operative association of apple producers and companies that process apples on a regional level, as well as a good logistical system for the collection of apple residues, could be a good basis for pectin production in Slovenia.

Technology, methodology, or partnerships used:

Various methods were used to identify challenges. Information on the properties of apple pomace was collected through literature research and practical experience. Mapping of apple producers and fruit and vegetable processing plants was used to determine the distribution of producers and processing plants. During a visit to the company Mirovita d.o.o., some important collagens and solutions were also outlined. The use of the VCG.AI tool is also part of our strategy to find good solutions to the challenges outlined.

Why this solution?

The two solutions presented are two ways of utilising apple pomace, one for the production of a medium-value product, namely animal feed, and the other for the high-value product pectin. By utilising existing food processing plants, the investment is much lower.

Implementation Steps

Key actions taken:

The company Mirovita was invited to participate in the TeBiCE project in April 2024 and the agreement was signed at the end of 2024. In April 2025, NIC visited Mirovita and we discussed the opportunities and challenges of utilising apple residues and apple pomace. NIC would also like to use the VCG.AI tool to find an alternative solution by the end of 2025

Results and impact

Measurable benefits:

Products such as pectin or functional animal feed from apple pomace, which have a high price, will increase interest in the use of apple pomace as a source and have an influence on better utilisation of apple pomace residues.

SME Testimonials:

"We alone are too small for the production of pectin to be able to compete with the large pectin producers. But if we find more interested apple pomace producers in Slovenia who cooperate with us in pectin production, then pectin production in Slovenia is possible" (Andrej Zdolšek, Director of Mirovita)

Lessons Learned

Challenges faced during implementation:

The production of pectin was presented as very interesting in terms of the utilisation of the by-product, but requires suitable equipment, which in turn requires considerable investment that is too large for SMEs such as Mirovita.

How they were managed:

The production of pectin should be set up as a separate production company, liaising with producers and processors of apples and also with the food industry to secure buyers for their product.

The production of animal feed is much easier to manage as the company already has equipment for drying. The investment in additional equipment to mix and extrude the final product could be acceptable for Mirovita company.

Key takeaways for future implementation:

For the valorisation of apple pomace and residues into high-value products such as pectin, cooperation with apple producers is crucial for the creation of suitable processing facilities and a successful economic model. The application of a cascade approach for processing apple residues into various high value-added products is a new opportunity that needs to be developed and properly applied in the future. In the meantime, as we look for new, better opportunities, the production of animal feed from steel is the most economically acceptable way of utilising apple pomace.

Scalability and Replicability

Potential for broader application:

Pectin production can be used in regions with high apple production, which enables supra-regional co-operation and joint facilities. Feed production works well in smaller regions and benefits from cross-border co-operation, especially near regional or national borders.

Supporting resources needed for scaling:

Scaling pectin production requires funding through grants, investors and equipment financing to expand processing facilities. Partnerships with juice processors, co-operatives, buyers and research institutions ensure stable raw materials, market demand and process innovation. Supportive measures such as incentives for waste utilisation, tax credits and simplified regulations as well as appropriate investment and transport management enable faster and more efficient multiplication.

Risk and Mitigation Strategies

Potential risks encountered:

Process/technical

- Feedstock variability (cultivar, season, moisture) impacts pectin yield and quality; mitigate via characterization, specs, and blending.
- Pre-treatment efficiency (pH, temp, time, enzymes/acids) affects yield and galacturonic content; address with design of experiments and real-time control.
- Pectin yield/quality variability (gel strength, viscosity, molecular weight) requires optimization of chemistry and rheology testing.
- Animal feed formulation challenges (nutrient variability, anti-nutritional factors, residues) demand thorough analysis and blending strategies.
- Separation/purification bottlenecks (filtration, drying) risk fouling and incomplete recovery; plan CIP and alternative methods.

Logistics/Safety/Compliance

- Waste management (solid/liquid waste) and effluent treatment impact environmental compliance.
- Operational safety and allergen/pesticide residues require robust QA, sanitation, and training.
- Regulatory compliance for food-grade pectin and feed standards; supply-chain traceability.

Mitigation measures implemented:

- Mitigation: pilot testing, flexible process design, robust QA, and clear specifications.

Contact Information

Lead Organization: Mirovita d.o.o.

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Additional Resources: www.mirovita.si

Figure 20: Dried apple products from the company Mirovita d.o.o.

Figure 21: Production of dried apple products: top left – washing, peeling and cutting the apples; top right – apples prepared for drying; bottom - continuous drying chamber.

I. Corn Cobs into Granulates for Different Application

Region

The production of corn in Slovenia is an important part of the Slovenian agricultural sector and is mainly used for animal feed, bioenergy and local food. Corn is mainly grown in the Drava, Mura and Savinja regions river basins (Figure 22), where fertile soils and a favourable climate enable high yields.

Figure 22. Statistical region of Slovenia.

Short Description

Žipo Lenart d.o.o. is one of the larger agricultural companies in Slovenia. Žipo Lenart's activities include crop production and livestock breeding, supported by activities such as the collection of biomasses for heating purposes, grain drying and the production of feed mixtures and bedding. The most important raw materials are the company's own primary crops (maize, wheat, barley) and by-products (straw, corn cobs).

Žipo Lenart is active in the first phase of corn cob production, including field cultivation and harvesting of grain and cobs. During the corn cob harvest, impurities such as husks are produced. Žipo cultivates about 200 hectares of grain maize annually, applying the principles of precision farming. Various grain maize hybrids are selected so that they are adapted to local conditions and ensure high yields of both grains and cobs. Žipo Lenart also offers drying, milling and cleaning of the corn cobs.

Sector

☑ Primary Production (e.g., agriculture, forestry, fisheries, etc.)

Challenges Addressed

Key constraints and bottlenecks in the value chain:

- Collecting of corn cobs after harvesting of corn grain (from landfill)
- Storage and drying of corn cobs, since they are very voluminous, woody materials with middle water content.

Market, regulatory, environmental, or social challenges:

The main challenge lies in collecting corn cobs after the grain harvest, as they must be picked manually or with special equipment. Corn cultivation is often carried out by small, widely scattered farmers who mainly grow it for their own consumption. Corn cobs are usually processed together with other parts of the plant into animal feed or bedding, or they are dried and used to produce bioenergy.

Solution Implemented

Description of the approach, innovation, or model adopted:

In Žipo, corn harvesting machines have been developed and upgraded so that corn cobs are collected in a special container during the grain harvest. The collected corn cobs must be dried before further use. Žipo has equipment for drying grain and wood biomass so that the corn cobs can be dried, processed into granules, packaged and properly stored for later use.

Technology, methodology, or partnerships used:

In this solution, upgraded corn harvesting machines with special containers are used to collect the cobs during the grain harvest. The collected cobs are dried and processed into granulate using Žipo's existing equipment. Cooperation with local farmers and Žipo, as well as monitoring of drying and storage, ensures efficient collection, processing and high-quality production.

Why this solution?

This solution enables the simultaneous collection of corn grains and cobs, reducing labour and costs. It increases the value of a by-product by generating material for animal feed, bedding or bioenergy and also other applications. Utilising existing machinery and infrastructure makes the process more efficient and scalable than separate collection and processing methods.

Implementation Steps

Key actions taken:

Žipo was invited to participate in the TeBiCE project in March 2024 and the agreement was signed at the end of 2024. PP2 and Žipo had an online meeting where we discussed the possibilities of corn cob utilisation, opportunities and challenges. NIC would also like to use the VCG.AI tool to find an alternative solution by the end of 2025.

Results and impact

SME Testimonials:

We are very interested in utilising all by-products from primary plant production into products with medium to high added value. We want to utilise everything that is possible. (Mitja Krajnc – CEO).

Lessons Learned

Challenges faced during implementation:

Gathering corn cobs together with harvesting corn kernels was much easier and more practical than gathering corn cobs by hand or with another picking machine. The harvesting of corn kernels together with the collection of corn cobs took a little longer than the classic harvesting of corn kernels, as the corn cob collector has to be emptied. Since Žipo only has one customised corn harvester, the collection process takes a little longer. Therefore, it would be much easier to have two adapted combine harvesters to speed up the harvest and collection of the corn cobs at one location or at different locations, as the harvest and grain quality are very weather-dependent. Due to the intensive use of the adaptable maize combine harvester, the need to purchase a new adaptable combine harvester became clear.

How they were managed:

In Žipo, a specially adapted corn combine harvester was developed in collaboration with a research institution (University of Maribor) and a construction company (Interkorn Ltd.), which can collect maize cobs as well as harvesting corn kernels. The solution is shown in Figure 4. New and more adaptable maize combine harvesters are needed to speed up the harvesting and collection process.

Key takeaways for future implementation:

For the successful utilisation of corn cob biomass, the collection of corn cobs is a crucial and important process. The development of suitable, adaptable corn combines harvesters that allow the cobs to be collected at the same time as the corn grain is harvested will solve the biggest challenge in collecting the corn cobs. Two other important processes are the drying and storage of the corn cobs before processing. Before processing the corn cobs into granules, it is necessary to create drying facilities and storage facilities on land. These models can be adopted by similar agricultural enterprises such as Žipo from the Association of Farmers, producers of maize grains and other grains. It is also necessary to find the final use of corn cob granules in various sectors, from animal feed to building materials and other higher technological applications.

Scalability and Replicability

Potential for broader application:

The solutions presented can be applied to larger or similar agricultural enterprises such as Žipo or to associations of farmers, producers of corn grains and other cereals in co-operation with SMEs producing corn cob granules or end products. The presented utilisation of corn cobs can be applied not only regionally, but also supra-regionally, especially in the vicinity of border regions with similar crop production. These cases can be applied wherever there is a possibility to collect corn cobs with the presented solution.

Adaptation for SMEs at different development stages:

Some SMEs can collaborate in the development of new products from corn cobs and the commercialisation of these products. Suitable SMEs can co-operate in the development and production of adaptable parts of the corn combine harvester.

Supporting resources needed for scaling:

Primarily national and local funding for the utilisation of biomass from agricultural by-products, together with private investment and national and EU funding to support investment in facilities. In cooperation with research institutions and demonstration centres where new, better plants can be developed and tested. Building a good partnership between farmers, plant breeders, equipment and processing technology providers and end product manufacturers. Measures to promote the circular economy and the bioeconomy in order to utilise residues from primary production.

Risk and Mitigation Strategies

Potential risks encountered:

The end products made from corn cob granules are new products and as such require more time to be authorised on the market.

Contact Information

Lead Organization: ŽIPO LENART d.o.o.

Key Contact Person: Mitja Krajnc – CEO

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Additional Resources: https://www.zipo.si/en/home/

Figure 23. Production of agricultural crop (grains) at Žipo Lenart d.o.o.

Figure 24. Cattle breeding at Žipo Lenart d.o.o.

Figure 25. Grain drying and storage at Žipo Lenart d.o.o.

Figure 26. Maize cobs harvester with additional hopper built of divisible side walls in closed (left), opened (middle), and emptying positions (right). (Source: Dolšak B, Breznik A, Kaučič K, Imenšek N, Marčec M, Gselman P, et al. Design and initial testing of a maize cob collection system. Int J Agric & Biol Eng, 2024; 17(3): 108–114. DOI: 10.25165/j.ijabe.20241703.8218).

J. Integrating Regional Hemp into Circular Furniture and Textile Production

Region

Austria (Grüne Erde, Scharnstein) & Germany (Rottal Hanf, Ering).

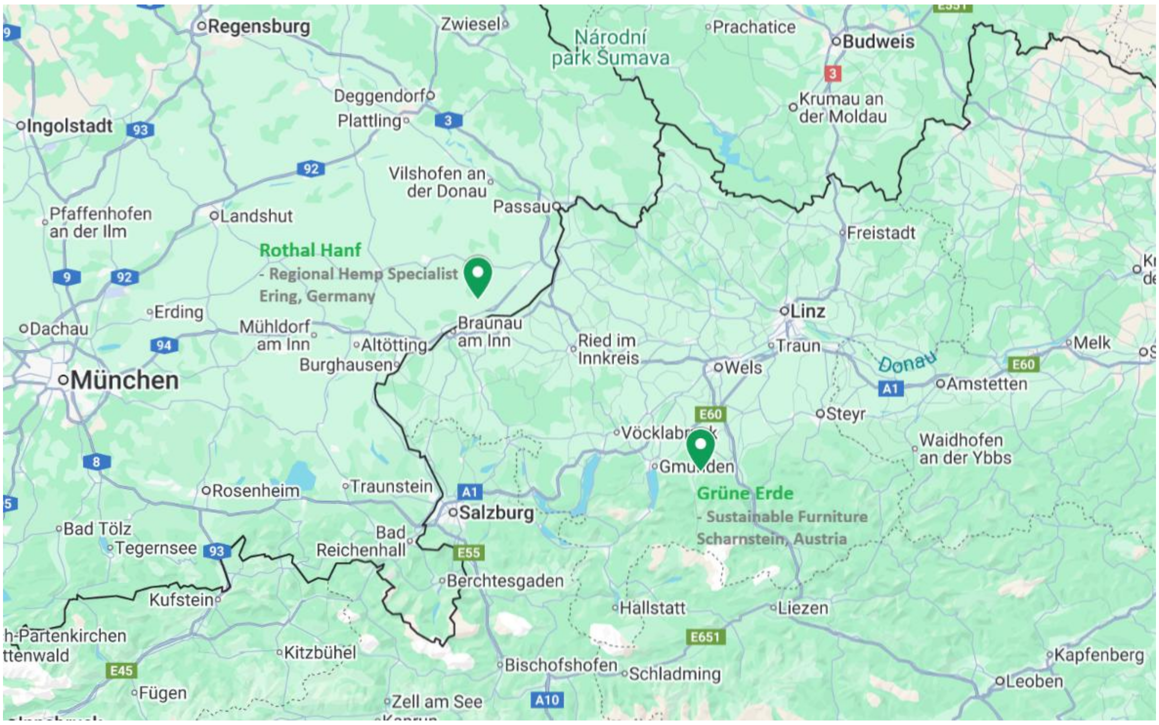

Figure 27. Austrian and German region

Short Description

This pilot partnership integrates locally sourced hemp into sustainable furniture and textile production, demonstrating circular economy practices and regional value chain innovation. Chemie-Cluster Bayern, as project partner, facilitated the initial matchmaking and guided subsequent steps between Grüne Erde and Rottal Hanf to consolidate the partnership.

Sector

Mixed (Combination of production and processing)

Challenges Addressed

Key constraints and bottlenecks in the value chain:

- Limited availability of regional, plant-based materials for sustainable mattresses
- Lack of established processing methods for hemp fibers in mainstream production
- Need for circularity and eco-friendly alternatives to imported materials (e.g., coco-latex)
- Due to the still underdeveloped value chain and diverse fields of activity, actors are often not aware of each other – making matchmaking and initial cooperation particularly challenging.

Market, regulatory, environmental, or social challenges:

- SMEs face challenges integrating new raw materials into established production lines
- Regional supply chains for hemp are underdeveloped
- Ensuring product quality and comfort while maintaining sustainability standards

Summary:

Grüne Erde and Rottal Hanf address critical challenges in creating a circular and sustainable value chain. Limited regional materials, scarce processing methods, and the need for eco-friendly alternatives are mitigated through collaboration, leveraging local expertise and shared sustainability values.

Solution Implemented

The partnership, facilitated by Chemie-Cluster Bayern, integrates regional hemp fibers into Grüne Erde's product lines (mattresses, upholstery, textiles), aligning ecological responsibility with circular economy principles.

Technology, methodology, or partnerships used:

- Exchange of material samples
- Mutual site visits and technical discussions
- Knowledge sharing via Chemie-Cluster Bayern facilitation events

Why this solution?

Hemp is a renewable, locally grown material that is hypoallergenic, naturally antimicrobial, breathable, and durable. Combining Grüne Erde's sustainable product expertise with Rottal Hanf's hemp processing capabilities overcomes supply chain constraints and reduces reliance on imported materials.

Implementation Steps

Key actions taken:

- Presentation of Grüne Erde's sustainability strategy at a Chemie-Cluster Bayern event
- Facilitation of online introduction and on-site visits
- Exchange of material samples and testing of hemp in product applications
- Evaluation of thermal, comfort, and durability properties of hemp fibers

Timeline:

Phase | Actions Taken

- Planning Phase | Sept 2023: Grüne Erde presents its circular economy vision at an awareness event under the leadership of Chemie-Cluster Bayern. 2024: Rottal Hanf joins Chemie-Cluster Bayern network; collaboration concept initiated.
- Implementation | End 2024: Online meeting facilitated by CCB to discuss material needs and collaboration. Early 2025: Exchange of product/material samples; site visit to Grüne Erde HQ, Austria. Mid 2025: Site visit to Rottal Hanf, Germany; evaluation of hemp material tests.
- Evaluation | Following the site visits and sample exchanges, both companies assessed results from the material tests, discussed the potential for material supply collaboration, and refined approaches for integrating hemp fibers into Grüne Erde products.

Results and impact

Measurable benefits:

- Integration of regional, sustainable hemp fibers into furniture and textile production
- Reduced environmental footprint by substituting imported materials
- Enhanced cross-sector collaboration and knowledge transfer in the Alpine region

- Industry clusters serve as catalysts, helping to assess the suitability of potential partnerships, thereby reducing risks and accelerating the cooperation process.

Figure 28. Hemp field from Rottal Hanf Ltd., Germany

Figure 29. Handmade mattresses from Grüne Erde Ltd., Austria

Key Performance Indicators (KPIs):

KPIs monitor the integration of regional hemp fibers, substitution of imported materials, adoption of sustainable, animal-free product lines, reductions in water use and carbon footprint, and the number of knowledge exchange events, material tests, and stakeholder engagements. These provide a framework for evaluating effectiveness and guiding future scaling.

SME Testimonials:

The collaboration serves as a promising example of using regional materials and cross-sector partnerships to advance circular economy practices, providing insights for integrating hemp fibers while maintaining product quality and performance.

Lessons Learned

Challenges faced during implementation:

- Adjusting product specifications to accommodate new materials
- Limited availability of processed hemp fibers at scale
- Building acquaintance and trust between the actors was essential before cooperation could begin.

How they were managed:

- Iterative testing and sample exchanges
- Through the moderation of Chemie-Cluster Bayern, the collaboration was enabled and individual needs could be addressed effectively during the introduction and cooperation process.
- Key takeaways for future implementation:
- Regional partnerships can successfully replace imported materials
- Early facilitation and matchmaking are critical for SME collaboration
- Circular economy principles require both technical and relational alignment
- Industry clusters play an essential role as trusted intermediaries, enabling structured matchmaking, reducing risks in early cooperation phases, and accelerating partnership building.

Scalability and Replicability

Potential for broader application:

- Approach can be applied to other regional SMEs and furniture/textile producers seeking circular economy solutions
- The iterative process of cluster-facilitated introductions and guided cooperation-building can be transferred to other areas of the bioeconomy, supporting trust-based collaboration across value chains.

Adaptation for SMEs at different development stages:

- Startups: leverage local resources and partnerships for niche sustainable products
- Growing SMEs: integrate new materials into existing production lines gradually
- Established firms: adopt modular strategies for sustainability transitions

Supporting resources needed for scaling:

- Funding for research and development
- Technical training on hemp processing
- Policy support for the circular economy initiative.

Risk and Mitigation Strategies

Risk Category	Potential Risks	Mitigation Strategies
Financial Risks	Investment in new materials and R&D	Leverage public-private partnerships and EU funding
Market Risks	Acceptance of hemp-based products	Consumer education and regional branding initiatives
Regulatory Risks	Compliance with EU and regional standards	Adhere to relevant regulations and certification schemes
Operational & Technological Risks	Integration into existing production; processing challenges for hemp fibers	Phased implementation, iterative testing, collaboration with specialized suppliers
Environmental Risks	Sustainable cultivation and resource use	Monitor agricultural practices and maintain eco-certifications
Stakeholder Risks	Resistance to new materials or processes	Early engagement of employees, partners, local communities

Scalability & Replicability Risks	Limited hemp supply or processing infrastructure	Develop modular sourcing frameworks and local supplier networks

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Practical Guidelines

How to Implement Biocircular Solutions for SMEs

Transitioning to biocircularity doesn’t require a complete business overhaul overnight. It starts with small, targeted actions that deliver quick wins and lay the foundation for long-term transformation. Whether you're a farmer, food processor, rural entrepreneur, or community innovator, the following steps provide a practical roadmap to embed biocircular thinking into your operations.

Biocircularity is more than a concept—it’s a practical pathway for SMEs to transform challenges into opportunities. These step-by-step guidelines, enriched with examples from the TeBiCE project, are designed to help businesses in agriculture and agro-food take action with confidence and clarity.

1. Assess Your Waste Streams

What to do: Begin by mapping out your production process and identifying by-products, residues, or waste streams that are currently underutilized or discarded.

Why it matters: Many materials thought of as waste—like pomace, peels, hemp stalks or sunflower seeds—can become valuable inputs for new processes or products.

2. Partner with Innovators

What to do: Reach out to research institutions, technical agencies, or innovation hubs to co-develop or test biocircular solutions.

Why it matters: Collaborations lower innovation risks and can unlock funding, expertise, and new business models.

3. Start Small

What to do: Choose a pilot project with manageable scale and tangible benefits. Begin with something that doesn’t require heavy capital investment.

Why it matters: Small-scale pilots help validate feasibility, build momentum, and minimise risk.

4. Measure Impact

What to do: Track your progress using simple but meaningful indicators:

- Waste reduction (kg/month)
- Cost savings (€ per ton of input/output)
- Energy efficiency gains
- Emission and pollution avoided
- New products or income streams

Why it matters: Quantifying your impact helps communicate success, attract investment, and inform strategic decisions.

5. Engage Stakeholders

What to do: Involve your staff, suppliers, local authorities, and customers in your transition to biocircularity. Share your goals and progress transparently.

Why it matters: Broad buy-in increases innovation quality, reduces resistance to change, and strengthens social license.

Final Thought:

The TeBiCE pilots demonstrate that biocircular transitions are not limited by business size or geography. Instead, they thrive where SMEs are willing to innovate collaboratively, take incremental steps, and embed sustainability into daily practice.

"Start with what you have. Use what you know. Do what you can. Biocircularity grows best when it's rooted in place."

"Circularity is a business opportunity, not a burden. The green transition will succeed only if it also brings prosperity. That's why we must align the circular economy, climate neutrality, and the bioeconomy into one coherent, opportunity-driven vision."

- Frans Timmermans, Former Executive Vice President for the European Green Deal, European Commission
  📖 Source: Circular Economy Stakeholder Conference, 2020

CONCLUSION & POLICY RECOMMENDATIONS

Key Takeaways

Biocircularity is a dual engine for profitability and sustainability. By valorising waste streams, reducing input costs, and tapping into growing green markets, biocircular strategies enable SMEs to thrive while contributing to climate and resource goals.

SMEs are not just participants—they are catalysts of the green transition. Their agility, local knowledge, and ability to experiment make them ideal laboratories for testing and scaling biocircular innovations in real-world conditions.

Cross-sector collaboration is the accelerant for change. When businesses, researchers, policymakers, and communities co-create solutions, innovation moves faster, risks are reduced, and systemic transformation becomes achievable.

Call to Action for Policymakers

To unlock the full potential of biocircularity and empower SMEs, policy support is essential. We recommend the following strategic actions:

- Incentivize biocircular R&D and innovation. Offer targeted grants, tax incentives, and access to innovation funds that specifically support pilot testing, technology adoption, and upscaling of bio-based and circular practices.
- Simplify and harmonize regulations for bio-based products. Establish clear, enabling regulatory frameworks for compostables, bio-based materials, food waste reuse, and renewable inputs to reduce market entry barriers for SMEs.
- Invest in SME capacity building and skills development. Fund training programs, mentorship schemes, and technical support services that equip SMEs with the knowledge and tools to transition to circular, bio-based business models.

A thriving biocircular economy depends on policies that are as innovative and adaptable as the businesses they aim to support.

"The bioeconomy and circular economy are complementary frameworks that together can enhance resource efficiency, innovation and regional development. Their integration is key to future economic resilience."

- OECD (Organisation for Economic Co-operation and Development)

🕮 Source: OECD Policy Highlights – Bioeconomy and the Circular Economy, 2022

BEYOND CARBON: THE CASE FOR HOLISTIC REGENERATION

Carbon credits, emissions targets, and net-zero commitments are important tools in our climate response — but they are not the whole story. When carbon becomes the sole metric for success, we risk ignoring the broader reality:

- We are not just in a climate crisis — we are in a systemic crisis.
- A biodiversity crisis, as habitats vanish and pollinators decline.
- A water crisis, as aquifers dry and agricultural runoff pollutes rivers.
- A soil crisis, as monocultures and chemical inputs erode the land's fertility.
- A livelihood crisis, as smallholders are excluded from green transitions that ignore local contexts.
- A social justice crisis, as land rights, cultural knowledge, and rural equity are pushed aside.

Focusing solely on carbon reduction can lead to perverse outcomes: afforestation that disrupts ecosystems, offset schemes that displace communities, or low-carbon technologies that intensify resource extraction elsewhere.

Climate solutions must not come at the expense of ecosystems, communities, or future resilience.

A Biocircular Alternative

Biocircularity provides a more holistic alternative. It views sustainability not as a narrow carbon ledger, but as an integrated system of regenerative loops that restore soil, strengthen biodiversity, create local jobs, and rebuild rural-urban linkages.

This approach echoes the landscape-scale thinking promoted by organisations like Commonland, which argue that real change begins by:

- Recognising the interconnectedness of ecological, social, cultural, and economic systems.
- Listening to local knowledge and designing solutions rooted in place.
- Valuing natural capital and human dignity together—not in opposition.
- Choosing long-term regeneration over short-term efficiency gains.

Restoring hope, dignity, and life to people and planet begins not with metrics, but with mindsets.

Final Thought:

The path to true sustainability doesn't just pass through carbon reduction. It passes through living soils, thriving communities, resilient economies, and healthy landscapes. Biocircularity invites us to step out of the tunnel — and into the system.

TAKE THE FIRST STEP TODAY

The TeBiCE project invites you to join the biocircular revolution. By adopting these practices, your SME can:

✓ Cut costs through resource efficiency.

✓ Open new markets with sustainable offerings.

✓ Future-proof your business.

Let's shape a greener, more prosperous tomorrow—starting now.

Quotes of partners, experts, and SMEs

"The future of business lies in sustainability—not as a trend, but as a foundation for long-term success."

- Marieta Okenkova, Slovak University of Agriculture in Nitra

“In the spirit of the circular economy, we aim to use all the raw materials in our yard. We use everything except when the wind blows away.”

- Mitja Krajnc, CEO of Žipo Lenart d.o.o., Slovenia

“Biocirculation – a local force for global change.”

- KPV team, Poland

“Insects are nature's perfect up-cycling machines.They create organic natural protein that we can feed to animals – and eventually humans.”

- Keiran Whitaker, Founder and CEO, Entocycle, United Kingdom

“Define the best model for returning to the agrifood industry.”

- Lorenzo Picco, CTO Vortex, Italy