Circularity

Waste as resource:

Economic and environmental feasibility analysis of the TeBiCE supply chains

Interreg CENTRAL EUROPE

Co-funded by the European Union

TeBiCE

Luca Maestri | Head of Circular Economy & Platform
24.03.26

TeBiCE project

Territorial biorefineries for Circular Economy

TeBiCE Project aims **to promote the exchange of biomass from primary and agri-food industries for the development of sustainable biorefineries**, through: 1) Innovation in digital technologies for industrial symbiosis; 2) Reduction of technical and economic barriers within the internal market; 3) Harmonization of regulations and standards governing the exchange of agri-food by-products.

WP1

1. Valorization potential

Analysis of the potential of the local agri-food supply chains

WP2

2. Pilot action development

Definition and development of the pilot valorization supply chains

WP3

3. Harmonization of the regulatory framework

Development of support tools for a harmonized regulatory framework

Circularity

Project | TeBiCE

Program | Interreg Central Europe

Start date | 04 / 2023

End date | 03 / 2026

2,02 M€

6 Countries & 8 regions

8 Partner

LP	Veneto Agricoltura
PP2	National Institute of Chemistry
PP3	Fraunhofer Italia Research Srl
PP4	Chemie-cluster Bayern GmbH
PP5	University of Warmia and Mazury
PP6	Kujawsko-pomorskie Voivodeship
PP8	Carinthia UAS
PP9	Slovak University of Agriculture in Nitra

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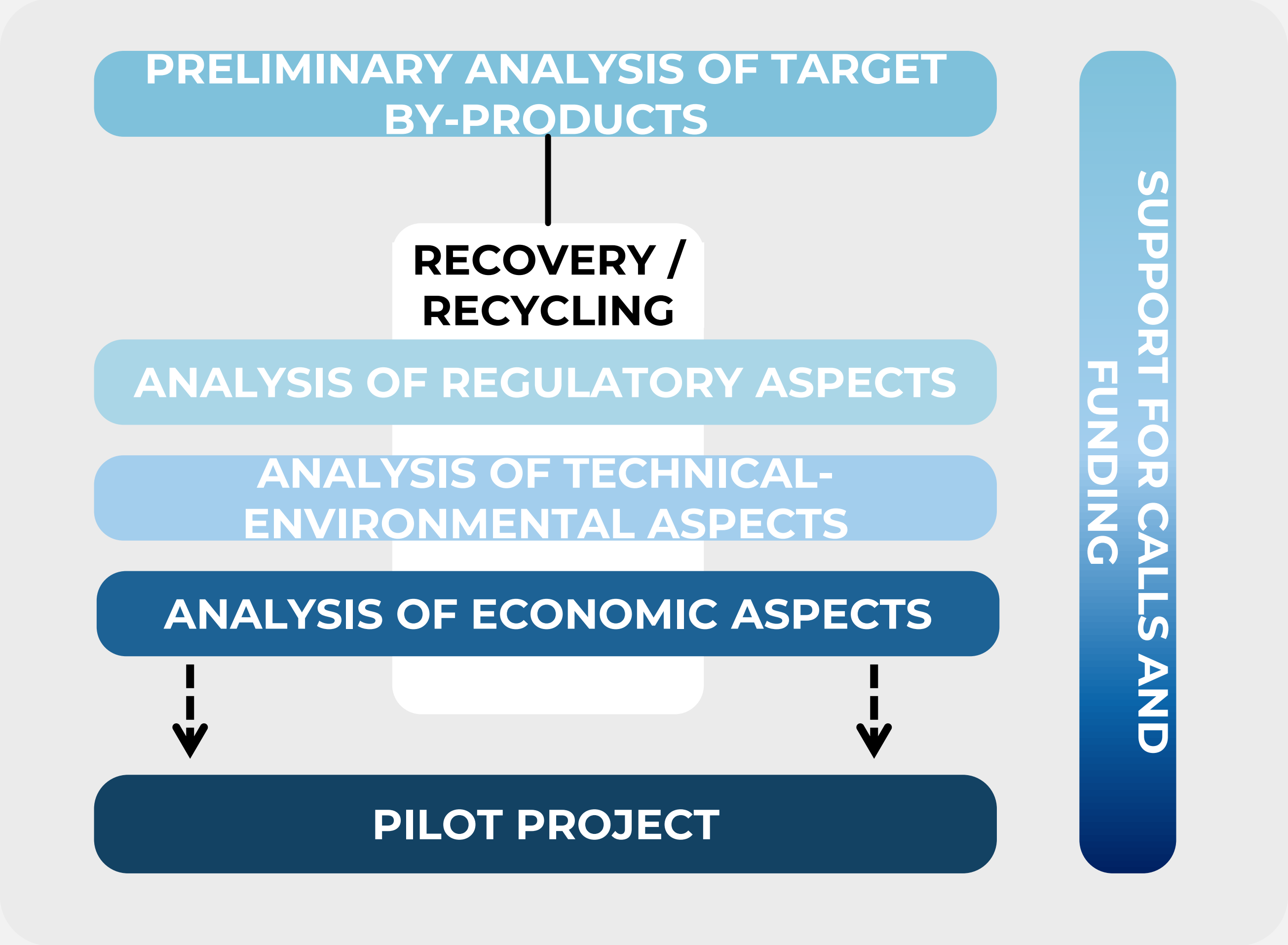
Circularity’s Approach

Circularity’s activities in supporting the development of pilot valorization supply chains were based on an integrated methodological approach, addressing regulatory, environmental, and economic aspects of the evaluated supply chains.

The development of **integrated supply chains** for the **collection, recovery, and valorization of waste and by-products** requires a **cross-cutting approach** across all phases of the study.



The methodology

For each partner, a reference agri-food supply chain was selected, and a methodology of engagement, contact, and analysis was activated to identify target waste streams and assess the feasibility of the proposed valorization solutions.

Analysis of territorial potential (WP1) and selection of the target supply chains for each partner

01

SELECTION OF STRATEGIC PILOT CHAINS

Mapping, contacting, and activation of companies involved in the pilot projects

02

ENGAGEMENT OF KEY STAKEHOLDERS

Qualitative and quantitative analysis of by-products using primary data

03

DATA COLLECTION AND BY-PRODUCTS ANALYSIS

Experimental activities for technical, economic, and environmental assessment

04

TESTING & TECHNICAL VALIDATION

Economic-environmental analysis of the pilot valorization supply chains.

05

FEASIBILITY ASSESSMENT

TeBiCE

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FEASIBILITY ASSESSMENT

Methodology | 1. Pilot chain selection

PP4	Chemie-cluster Bayern GmbH
	Rottal Hanf GmbH – Ering, Bavaria
	*Valorization of **“low cut” residues from hemp processing***

PP5	Univ. of Warmia and Mazury
	Cirwins Sp. z.o.o - Gdansk
	Valorization of frass from **Tenebrio molitor** larval farming

PP3	Fraunhofer Italia Research Srl (FHI)
	Vortex SB – Torino
	Food flours from **discarded apple peels** from purée production

PP6	Kujawsko-pomorskie Voivodeship
	Biogazownia Rypin SP. Z.o.o. -
	Anaerobic digestion of various agricultural waste matrices (rachis, silage, surpluses)

LP	Veneto Agricoltura
	TeraBona S.c.a.r.l. – Trebaseleghe (PD); Coccitech Srl - San Vendemiano (TV); Vortex SB – Torino
	***Biostimulants** and **food ingredients** from **discarded radicchio leaves** for large-scale retail*

PP9	Slovak University of Agriculture in Nitra
	Konopnè druzstvo, Kuruc Company Laudatosi, i2-industrial innovations – Nitra
	Valorization of **hemp processing** residues for C&D applications

PP8	Carinthia UAS
	Gemeinschaft Steirishes Kürbiskernöl ggA - Lebring
	High-protein flours from pumpkin seed press cakes

LP	Veneto Agricoltura
	Adami Srl – Colbertaldo di Vidor (TV); Coccitech Srl - San Vendemiano (TV); SAM Moldoi - Sospirolo (BL)
	*Production of **biostimulants** from **secondary lees** generated during tank washing*

PP2	National Institute of Chemistry
	Mirovita d.o.o. – Petrovce
	*Extraction of **pectin** from **discarded apple peels from juice production***

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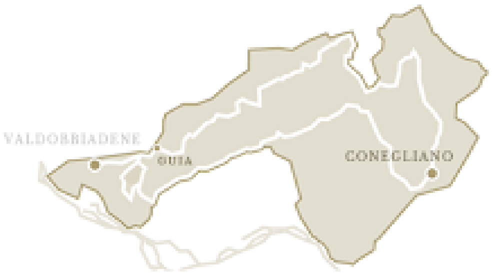
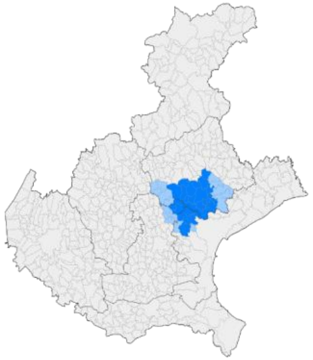
Methodology | 1. Pilot chain selection

Conegliano-Valdobbiadene Prosecco DOCG supply chain



The analysis focuses on the **by-products** and **waste** from Prosecco production: grape **pomace, stems, primary lees, washing waters & secondary lees, tartrates & bitartrates**.

Treviso IGP Red Radicchio



The analysis concerns the by-products derived from the processing and preparation phases of **red radicchio intended for large-scale retail** (GDO): **outer leaves, middle leaves, and roots**

Adige – Sud Tirol apples

The analysis concerns the by-products derived from the processing stages of **Sud Tirol apples** for **juice and puree production: peels and apple pomace.**

The methodology

For each partner, a reference agri-food supply chain was selected, and a methodology of engagement, contact, and analysis was activated to identify target waste streams and assess the feasibility of the proposed valorization solutions.

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Methodology | 2. Stakeholder engagement

Conegliano-Valdobbiadene Prosecco DOCG supply chain

- **Company**
  Adami S.r.l
- **Location**
  Vidor (TV)
- **Role in the chain**
  Viticolture, winemaking, bottling
- **Consortium**
  Consorzio di tutela del Prosecco Superiore DOCG
- **Partner for tests**
  Coccitech Srl – biostimulants
  SAM Moldoi – natural products and phytotherapy

Treviso IGP Red Radicchio

- **Company**
  TeraBona S.C.A.R.L
- **Location**
  Trebaseleghe (PD)
- **Role in the chain**
  Harvesting, processing and distribution
- **Consortium**
  Consorzio di tutela del Radicchio Rosso di Treviso IGP
- **Partner for tests**
  Coccitech Srl – biostimulants
  Vortex – food ingredient

Adige – Sud Tirol apples

- **Company**
  Vortex S.r.l SB
- **Location**
  Torino (TO)
- **Role in the chain**
  Technology partner for valorization
- **Technology**
  Drying & MW extraction
- **Partner for tests**
  Unknown company – Supplier of by-products from South Tyrolean apple processing for juice and puree production

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Methodology | 3. By-product analysis

PROSECCO DOCG

Pomaces & stems (85-90%)

*SP consisting of the **solid part of the grapes** remaining after pressing and the **woody stems**.*

Single company | 40 – 50 ton/year; DOCG[1] | 20 – 25 kton/year

Classification | By-product

Use | Grape pomace – delivered to distillery; Stems – used as soil amendment (no structured supply chain)[2]

Valorization | Extraction of polyphenols for cosmetics and nutraceuticals / ingredient for food or pet food.

Wine primary lees (5-10%)

Solid residue** formed by **yeasts** and **sediments** deposited during **primary fermentation.

Single company | 3 – 5 ton/year; DOCG | 1,5 – 2 kton/year

Classification | By-product

Use | Spreading on soils, composting / digestion, delivery to distillery.

Valorization | Extraction of polyphenols for cosmetics and nutraceuticals / ingredient for food or pet food.

Fermentation Lees & Wastewater (1-5%)

***Liquid residue** composed of **yeasts** and **sediments** deposited during the **secondary fermentation and tank cleaning**.*

Single company | 0,5 – 1 ton/year; DOCG[1] | 350 – 500 ton/year

Classification | By-product / Waste

Use | Wastewater treatment as waste material

Valorization | Source of tartaric acid, yeasts, and bioactive components for biostimulants, plant protection products, cosmetics, and nutraceuticals.

Tartrate salts (<<1%)

Crystals that precipitate from tartaric acids during **fermentation and subsequent cooling.**

Single company | 20 – 30 kg/year

DOCG | 7 – 35 ton/year

Classification | By-product

Use | Crystals that precipitate from tartaric acids during fermentation and subsequent cooling.

Valorizzazione | /

1. Prosecco DOCG production estimated at around 100 million bottles per year; 2. Delivery regulated by Ministerial Decree 30/03/2023, No. 185138.;

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RADICCHIO IGP

Harvesting – Outer leaves (35-40%)

SP generated in the field during the harvesting phase, consisting of the ***outermost radicchio leaves****: old, generally* ***damaged****, and a potential source of* ***pathogens****.*

TeraBona[1] | 350 – 400 ton/anno

Classification | By-product

Use | spreading on soil but issues related to the possible presence of pathogen sources; composting / digestion.

Valorization | Limited due to decomposition and pathogens.

Trimming – Roots & middle leaves (45–50%)

SP generated during the ***trimming phase,*** *mainly consisting of* ***roots and middle leaves****: potential source of* ***pathhogens.***

TeraBona | 450 – 500 ton/anno

Classification | By-product

Use | spreading on soil but issues related to the possible presence of pathogen sources; composting / digestion.

Valorization | feeding / mushroom substrates.

Refining Waste – Inner leaves (5–10%)

SP generated during the ***refining phase*** *for GDO, mainly consisting of* ***inner cleaned leaves****.*

TeraBona | 80 – 120 ton/anno

Classification | By-product / waste

Use | Composting / digestion but issues related to the morphology and the mixing with other matrices; burning / landfilling

Valorization | Food ingredient for food industry, pet-food or nutraceutical

1. Based on 2024 production data of approximately 2.500 tons of finished radicchio product. The waste shown in the slide comes from early, late, and variegated radicchio lines undergoing finishing processing

Methodology | 3. By-product analysis

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Methodology | 3. By-product analysis

Apple IGP

Apple pomace (juice)

SP generated during the ***apple pressing process for juice production****: a sugary, pulpy residue rich in flesh, peel fibers, and juice remnants.*

Single company (BIG) | 40 - 50 kton/anno

Alto-Adige production[2] | 150 – 175 kton/anno

Classification | By-product

Use | Animal feed, composting / anaerobic digestion, and soil amendment

Valorization | Pectin extraction for the food industry and polyphenols for the cosmetic and nutraceutical industries / food ingredients and pet food

Apple peels (pureè)

SP generated during the ***apple peeling process for purée production****: a* ***dry, low-sugar residue*** *consisting of* ***apple peel fragments****.*

Single company (BIG) | 5 – 6 kton/anno

Alto-Adige production | 20-25 kton/anno

Classification | By-product

Use | Animal feed, composting and soil amendment

Valorization | Pectin extraction for the food industry and polyphenols for the cosmetic and nutraceutical industries / drying & production of food ingredients and pet food

1. High Alto Adige-based producer with approx. 300,000 tons/year of processed fruit; 2. 2025 production, Assomela data, equal to approx. 1.056.981 tons/year

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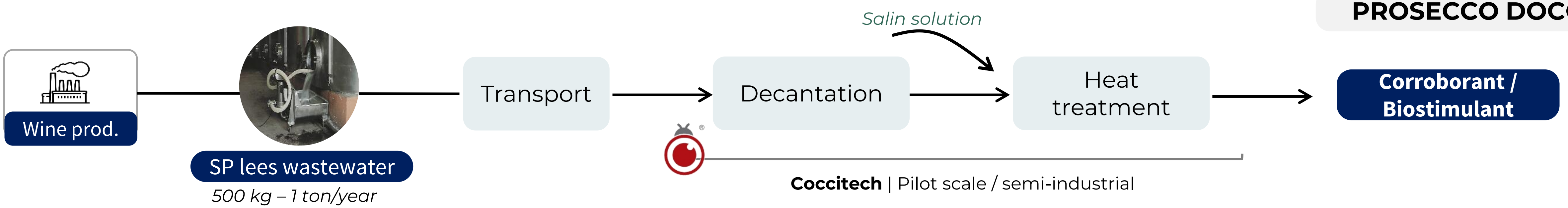
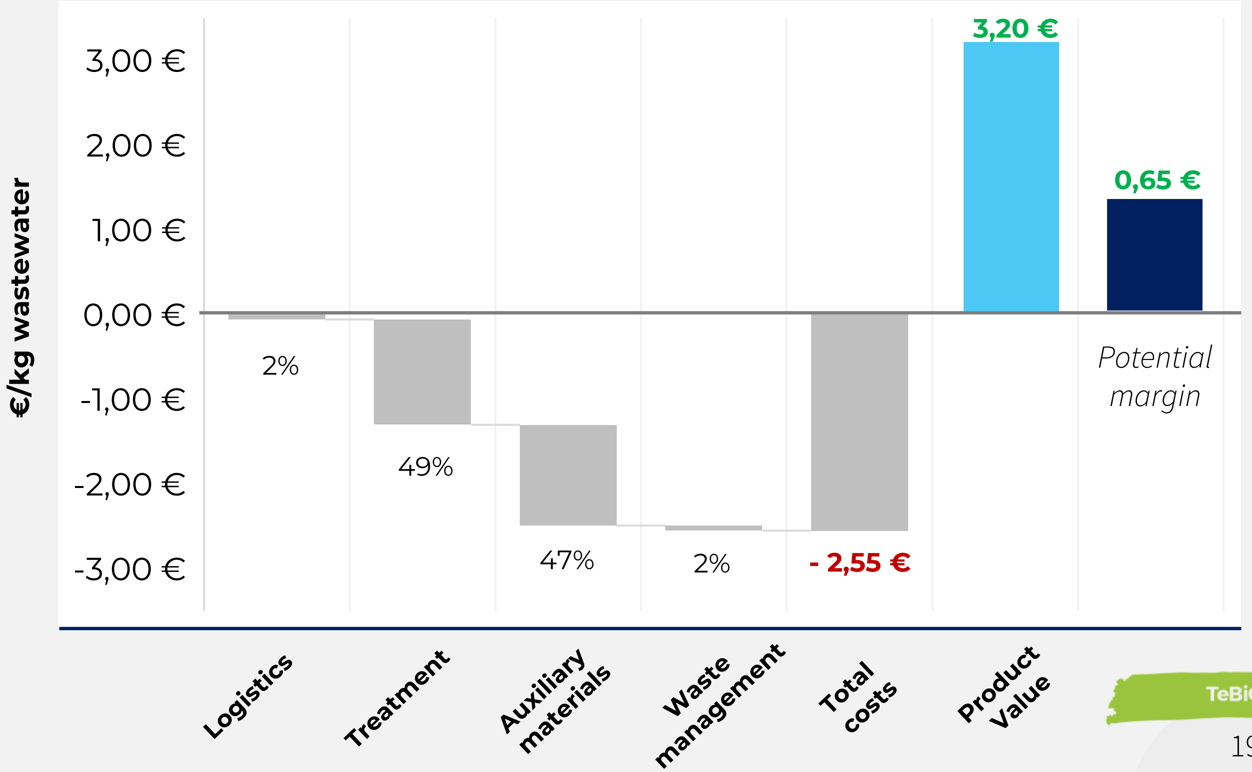
Methodology | 5. Testing & feasibility analysis

PROSECCO DOCG



Scenario

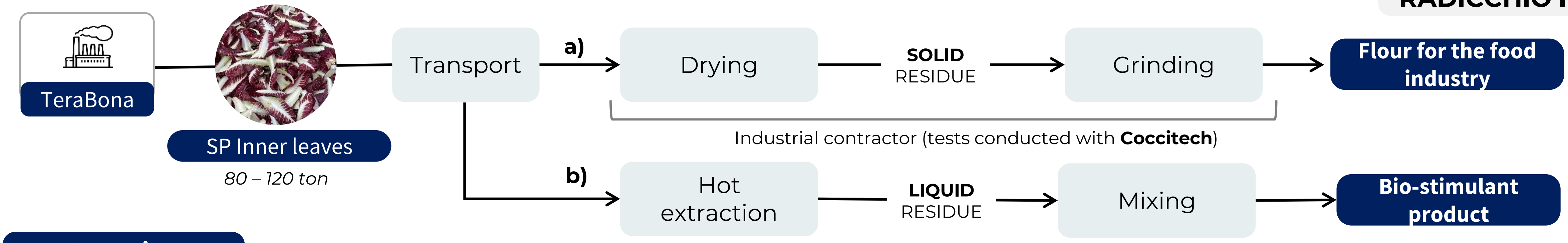
- **Semi-industrial scenario** based on Adami's maximum production (~1 t/year of lees) and on a Coccitech pilot / semi-industrial treatment aimed at developing a corroborant / biostimulant.
- **Conservative assumptions:** active **solid content** equal to **1%** of the treated lees.
- **Final product market value** prudently estimated **at ~ €20/kg**, based on market benchmarks (range: €10–80/kg)
- **Positive economic balance:** estimated margin of **~€0.6/kg of treated lees**, confirming the economic feasibility of the pilot scenario.
- **Scalability:** the scenario is not representative of scaling up to DOCG Consortium level, which would require assessing additional cost items: micro-collection, centralized storage, and investments in industrial plant infrastructure.
- **Environmental impact assessment:** LCA studies on similar products[1] show **significant environmental benefits from replacing small shares (~2%) of conventional chemical fertilizers used in agriculture**, across all impact categories—especially climate change, terrestrial/aquatic eutrophication, and soil acidification.



1. Life Cycle Assessment of Microalgal Biomass Valorization from a Wastewater Treatment Process; 2024, Crippa, Dolci, Grosso, Rigamonti

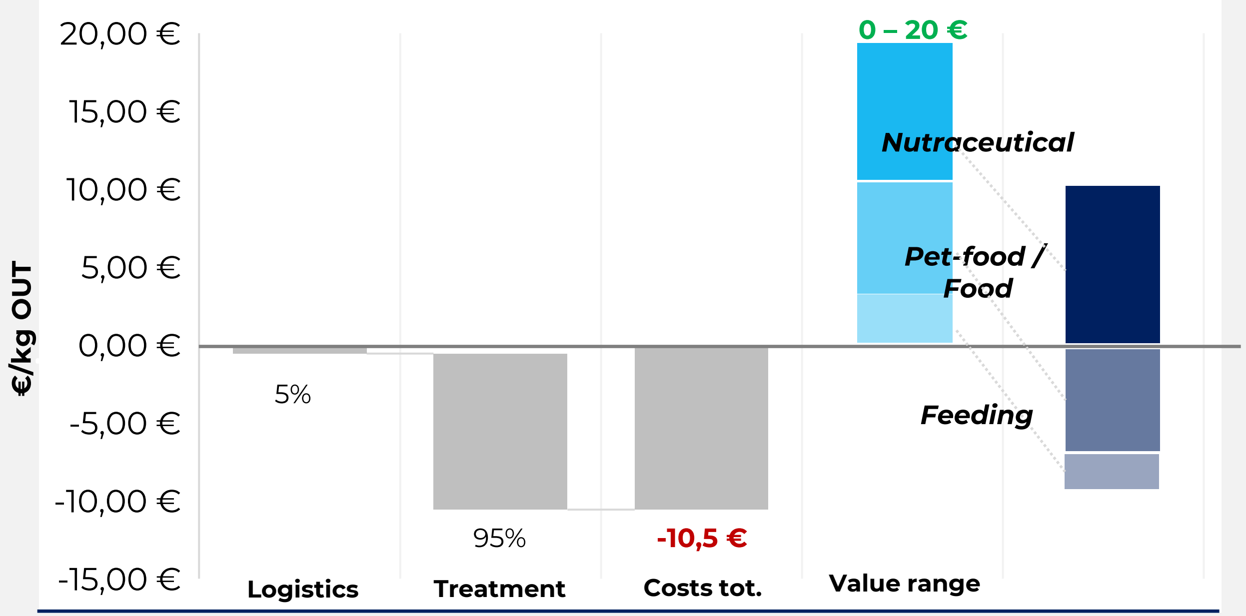
Methodology | 5. Testing & feasibility analysis

RADICCHIO IGP



Scenario a

- **Semi-industrial scenario** based on **TeraBona production (~80 t/year**) and on a process for developing a flour for food, pet-food, or nutraceutical applications.
- **Conservative assumptions: solid** content of **5%** and **sites distance** of approximately **100 km**
- **Market value and economic balance** of the final product strongly depending on the **nutritional properties** of the **resulting flour**, with **higher values for nutraceutical products**.
- **Analytical tests (HPLC and NMR)** show that SP can be a **high-value ingredient for nutraceutical and cosmetic applications** due to a significant presence of **phenolic compounds** (acids, anthocyanins, and flavonoids) with **antioxidant and anti-inflammatory properties**.
- **Scalability:** increasing treated SP volumes (with IGP involvement) and scaling up the plant (larger autoclaves) allow a significant reduction in the unit production costs of the flour.
- **Environmental impact assessment:** using flour derived from SP to replace virgin plant fiber can achieve **environmental savings of up to 60–70% in $CO_{2eq.}$** and **over 80% in eutrophication and acidification impact categories.**[1]



1. Estimate based on typical carbon footprint values of virgin plant fibers used in the sector.

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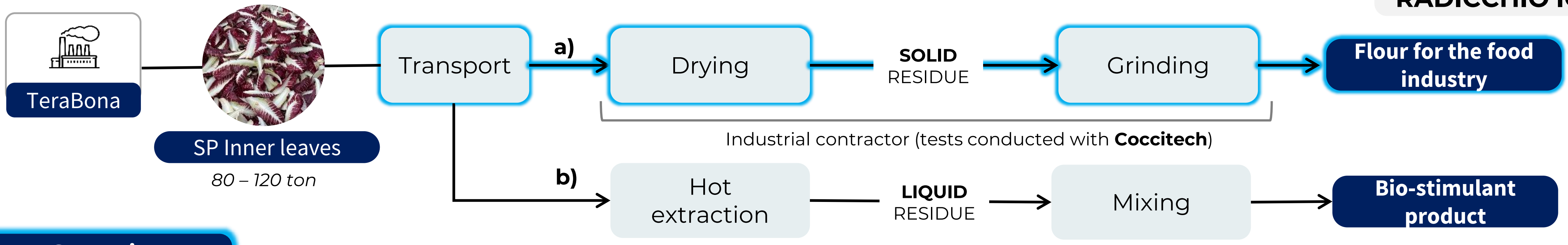
Methodology | 5. Testing & feasibility analysis

RADICCHIO IGP



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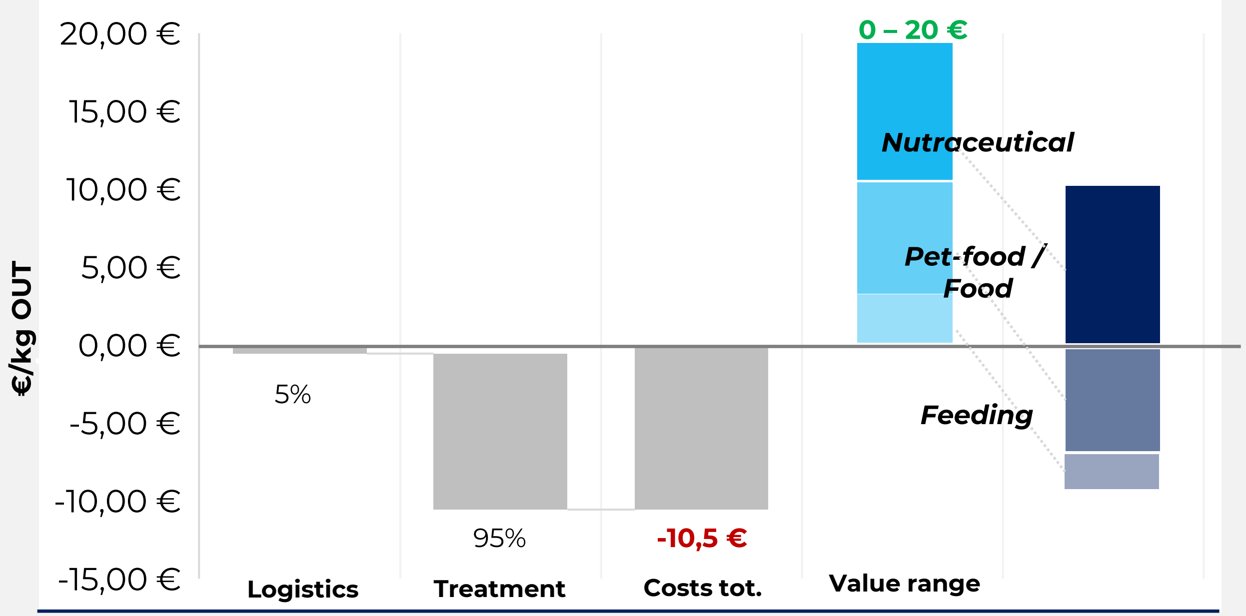

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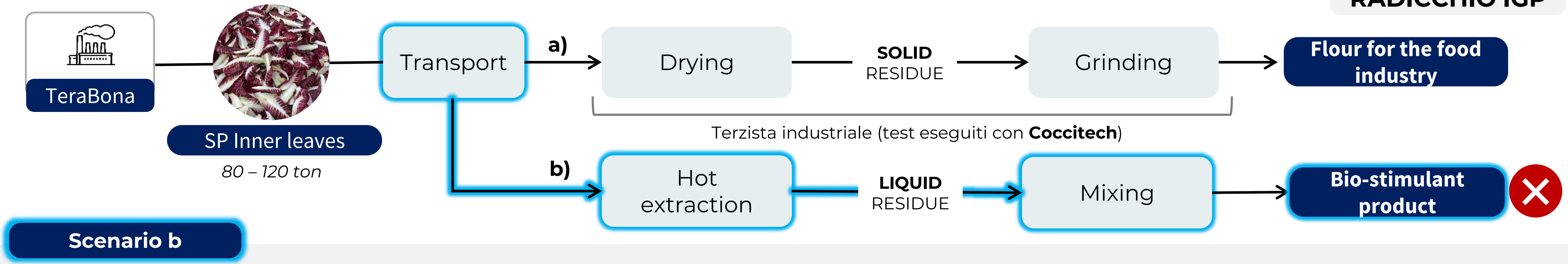
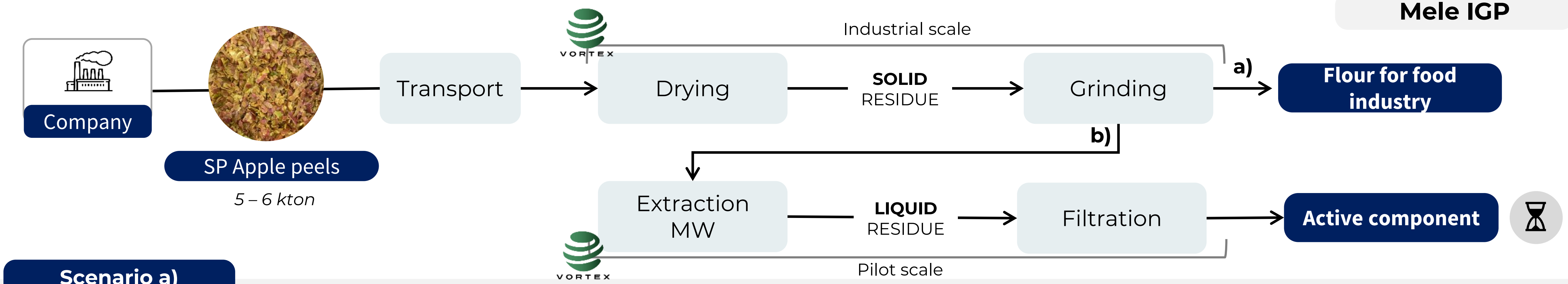


- *Alternatively to valorization as a food ingredient, an attempt was made to perform **hot extraction of radicchio leaves** and use the **resulting residue as a growth substrate for yeasts by mixing it in a solution of nitrogen, sugars, and vitamins**.*
- *Tests show **very limited cell growth**, significantly lower than observed with other agricultural by-products, **likely due to the presence of inhibitory compounds in the radicchio extract**; analytical tests are ongoing to confirm this hypothesis*
- *Considering these preliminary results, **no further feasibility or scalability assessments of the fermentation process** were carried out.*

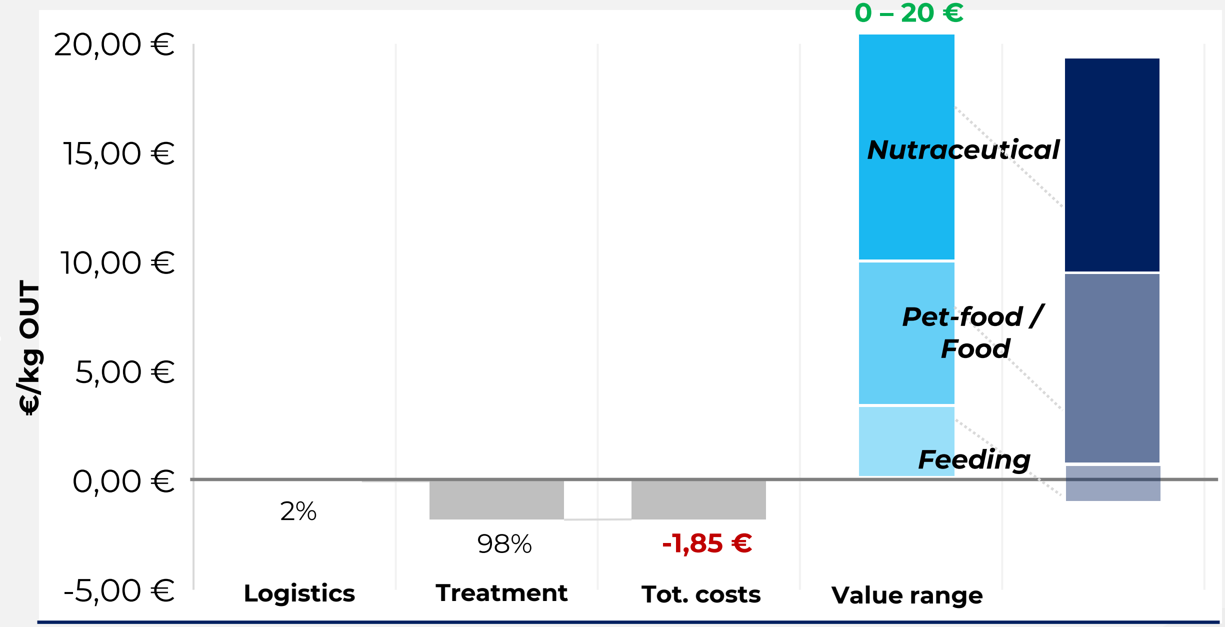
Methodology | 5. Testing & feasibility analysis

Mele IGP



Scenario a)

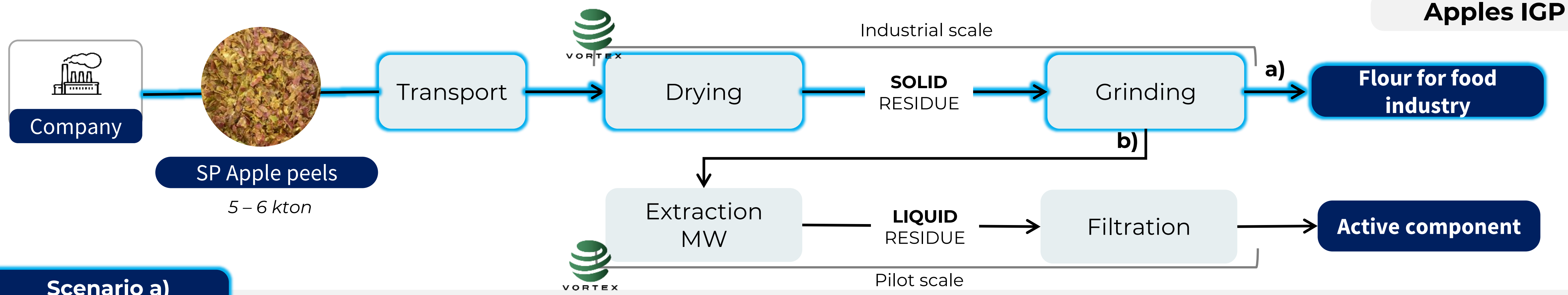
- **Industrial scenario** based on the production of one of the **main juice and purée producers in Alto Adige**, processing around **300.000 t/year of fruit**, from which approximately **5 kton/year of apple peels** can be estimated**.**
- **Conservative assumptions**: generation of **400 tons/month of SP**, solid content of **27.5%,** processing at **third-party facilities** (100 km, rotary drum plant), and **production of a flour with particle size < 250 µm**.
- **Analytical tests** (nutritional, HPLC, polyphenols, microbiological, and structural fiber) **show that SP are free of pathogens**, have a **low overall microbial load**, and **present a profile with potential antioxidant activity (flavonoids) and nutraceutical interest**.
- **Scalability:** Considering the **average annual apple production in Alto Adige** and the development of a recovery **supply chain for the peels**, up to **160.000 tons of SP could be recovered each year**, equivalent to approximately **€800k** in value assuming an average of **€5/kg**.
- **Environmental impact assessment:** using flour derived from SP to **replace virgin plant fiber** can achieve **environmental savings of up to 60–70% in $CO_{2eq.}$** and **over 80% in eutrophication and acidification impact categories**.[1]



1. Estimate based on typical carbon footprint values of virgin plant fibers used in the sector.

Methodology | 5. Testing & feasibility analysis

Apples IGP



Scenario a)

- **Industrial scenario** based on the production of one of the **main juice and purée producers in Alto Adige**, processing around **300.000 t/year of fruit**, from which approximately **5 kton/year of apple peels** can be estimated**.**
- **Conservative assumptions**: generation of **400 tons/month of SP**, solid content of **27.5%,** processing at **third-party facilities** (100 km, rotary drum plant), and **production of a flour with particle size < 250 µm**.
- **Analytical tests** (nutritional, HPLC, polyphenols, microbiological, and structural fiber) **show that SP are free of pathogens**, have a **low overall microbial load**, and **present a profile with potential antioxidant activity (flavonoids) and nutraceutical interest**.
- **Scalability:** Considering the **average annual apple production in Alto Adige** and the development of a recovery **supply chain for the peels**, up to **160.000 tons of SP could be recovered each year**, equivalent to approximately **€800k** in value assuming an average of **€5/kg**.
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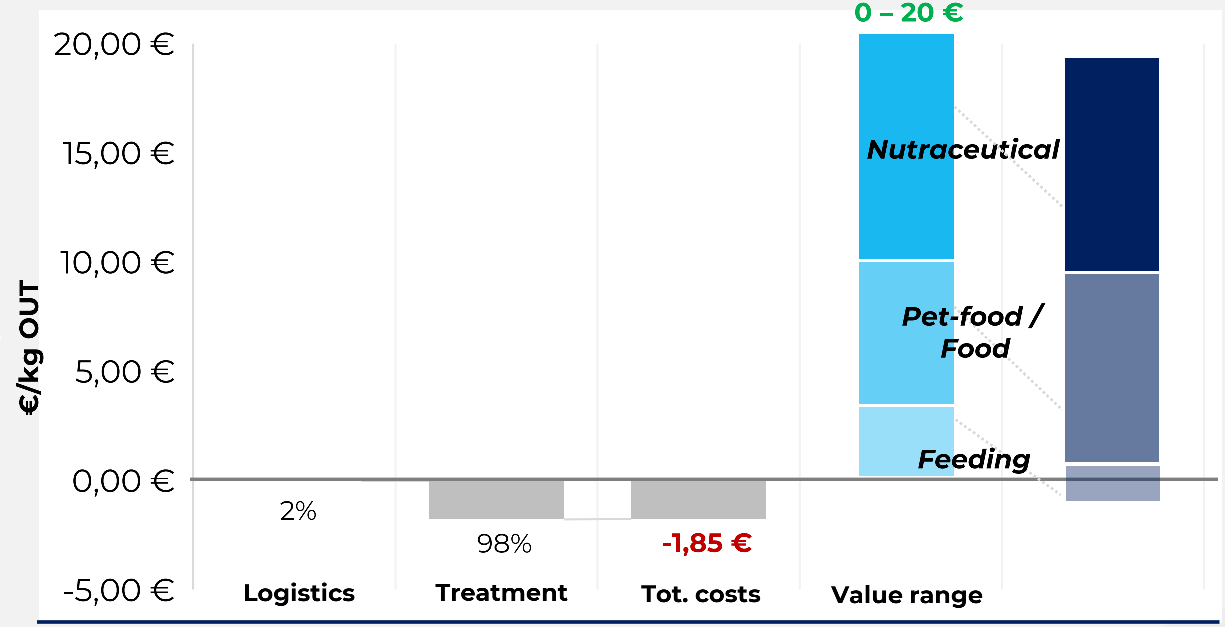

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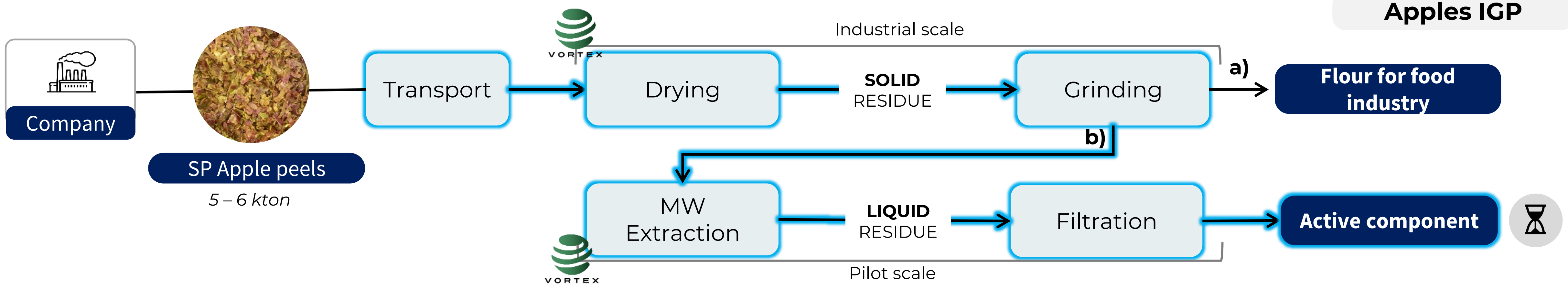

Scenario b)

- **Pilot scenario** in which the flour is diluted at a 1:20 ratio with distilled water and then subjected to **microwave extraction (Vortex patent)** with 300 W applied power to obtain **bioactive compounds for nutraceutical and cosmetic applications.**
- **Analytical tests** (nutritional, HPLC, polyphenols, microbiological, and structural fiber) show that **the extract consists of a dry residue of 1.43%,** composed of **insolubilized apple flour**, which is almost entirely made up of fibers and ash, with **only a minimal fraction of phenolic compounds exhibiting antioxidant activity**.
- The **obtained extract** represents a **high-intensity active ingredient**, with a content far exceeding that of a functional food ingredient.
- **Pilot-scale tests** do not allow a complete assessment of feasibility, but **production costs can be roughly estimated between €50 and €150 per liter**.
- **Microwave extraction** enables the transformation of a low-value fibrous by-product into a **standardized liquid ingredient** with **a high concentration of phenolic compounds**, suitable for high-value markets such as nutraceuticals, cosmetics, and bio-stimulants. **Industrial-scale testing is needed to evaluate the economic and environmental sustainability of the process.**

From waste to resource: feasibility conditions

TeBiCE

The valorization of agricultural by-products requires an integrated approach that combines scale, logistics, biomass composition, economic sustainability, and multi-criteria environmental assessments, while complying with regulatory frameworks.

SEASONALITY & PERISHABILITY

High seasonality and **rapid perishability** of agricultural by-products **limit the fractions that can actually be collected and valorized**, affecting production continuity and industrial models

LOGISTICS & MICRO-COLLECTION

The **sustainability of supply chains** depends on the development of efficient **micro-collection** and **storage networks**, which are often challenging in consortium contexts due to **costs, organizational complexity, and territorial dispersion**

BIOMASS COMPOSITION

The **chemical-physical profile** of by-products **determines the possible valorization pathways**, **end-use applications**, and **the value of the resulting product**, directly influencing the **overall efficiency and circularity of the system**

SCALE, INVESTMENTS & PARTNERS

Economic sustainability depends on the **available volumes**, **required investments**, and the **presence of industrial partners** in the territory. **Scaling to consortium-level volumes** and using industrial plants allows a significant reduction in unit production costs

ENVIRONMENTAL ASSESSMENT

Environmental analysis should not be limited to carbon footprint (CO_2) alone but **must consider other key impact categories for agricultural systems**, such as **eutrophication and soil/water acidification**

REGULATORY COMPLIANCE

Ensuring **regulatory compliance is essential**, both in **classifying waste** (by-product vs. waste) and for placing the resulting products on the market in the relevant sectors

Circularity

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