INSET INDUSTRIAL SYMBIOSIS FOR ENTERPRISES AND TRAINING

Co-funded by the European Union

Industrial Symbiosis Best Practices

Synergy in Action: Unlocking the Power of Industrial Symbiosis for Sustainable Innovation

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1. Introduction

1.1. Context and Importance of Industrial Symbiosis

Industrial Symbiosis (IS) is a collaborative approach that enables businesses to create mutually beneficial exchanges of resources, turning waste, by-products, or excess materials from one industry into valuable inputs for another. This closed-loop system is at the heart of sustainable development, driving the Circular Economy (CE) by minimizing waste and optimizing resource use.

The significance of IS in advancing sustainability cannot be overstated. By fostering collaboration between industries and local communities, IS reduces environmental impacts, particularly by lowering energy consumption, minimizing waste sent to landfills, and reducing greenhouse gas emissions. This practice is crucial for industries aiming to reduce their carbon footprints, meet sustainability targets and adhere to increasing environmental regulations.

In addition to the environmental benefits, IS offers substantial economic advantages. By sharing resources, industries can significantly cut operational costs through reduced raw material needs, lower disposal fees, and decreased energy consumption. This efficiency drives innovation by encouraging companies to rethink traditional business models and explore novel solutions for resource optimization.

Key benefits of IS include:

- Reduced Operational Costs: Companies can save money by exchanging materials, energy, and services with others in the symbiosis network, minimizing the need for costly raw materials and waste disposal.
- Environmental Benefits: IS supports the reduction of environmental impact by promoting resource efficiency, reducing waste generation and enhancing the sustainability of industrial activities.
- Innovation and Competitive Advantage: By integrating IS into their

business strategies, companies can develop innovative solutions that set them apart in the marketplace, contributing to long-term competitiveness and industry leadership.

Through these interconnected benefits, IS represents a powerful tool in advancing the goals of both sustainability and economic efficiency.

1.2. Purpose of the Report

The purpose of this report is to showcase the transformative potential of IS by analysing real-world best practices and offering insights from organizations that have successfully implemented IS strategies. This report will provide stakeholders—whether policymakers, business leaders, or industry practitioners—with valuable examples of how IS works in practice, demonstrating the tangible benefits it brings across different sectors.

By featuring detailed case studies and interviews with key figures behind these successful initiatives, the report aims to:

- **Inspire Action**: Illustrate the practical applications of IS and how businesses, large and small, can adopt these strategies to achieve both environmental and economic goals.
- **Highlight Challenges and Solutions:** Address the common barriers companies face when implementing IS and provide solutions drawn from the experiences of those who have overcome them.
- **Promote Collaboration:** Encourage new partnerships and collaborations between industries, municipalities and stakeholders, facilitating the exchange of resources and ideas that foster a more sustainable, CE.

2. Analysis of Best Practices

2.1. Selection criteria

To identify and analyse the most impactful examples of Industrial Symbiosis (IS), it has been crucial to establish clear and comprehensive criteria that reflect both the success and potential for scalability of these practices. These criteria have guided the selection of case studies, ensuring that the examples chosen are not only innovative and successful but also applicable to a wide range of industries and contexts. The following criteria are proposed for selecting IS best practices:

- **Degree of innovation.** How novel or groundbreaking the IS practice is. A high level of innovation can be measured in terms of new technologies, processes, or business models that are being used to create synergies between industries.
- **Impact on sustainability.** The environmental and social impact of the IS practice. It focuses on how effectively the practice contributes to reducing waste, lowering energy consumption, minimizing carbon emissions, and supporting overall environmental sustainability.
- **Replicability and Adaptability.** Potential for the IS practice to be expanded or replicated in different locations, industries, or contexts. This includes both the geographic and industrial scalability of the practice.
- **Industry relevance.** How well the IS practice applies to the targeted industry and the specific challenges it aims to address. It considers whether the practice meets industry-specific needs, such as material efficiency, waste management, or energy optimization.
- **Level of collaboration.** This criterion assesses the degree of cooperation and partnership between the organizations involved in the IS practice. It includes both inter-business collaboration (e.g., between manufacturers, suppliers or

waste management companies) and broader collaboration (e.g., with local governments, research institutions and NGOs).

2.2. Detailed best practices

The selected IS best practices have been evaluated based on these comprehensive criteria to ensure that they represent the most innovative, impactful and scalable examples of IS (Annex I).

By applying these criteria, Consortium aim to highlight practices that not only contribute to sustainability and resource efficiency but also offer clear economic benefits and demonstrate the potential for replication and expansion across industries and regions.

These practices are detailed below:

1. **ICT- AICE (Spain)** – Integrates advanced technologies and business models to reduce waste, carbon emissions, and energy use. Enhances sector competitiveness and resource efficiency through multi-stakeholder collaboration.
2. **Tire Industrial Park of Izmir (Türkiye)** – Implements large-scale wastewater treatment to improve water quality and ecosystem resilience. Serves as a model for sustainable urban water management and municipal collaboration.
3. **Manresa in Symbiosis (Spain)** – Demonstrates CE principles by reducing landfill waste and increasing energy recovery. Scales from city to regional levels, fostering synergies across multiple industrial sectors.
4. **Chihuahua Green City (Mexico)** – Company-driven model promoting industrial collaboration for waste reduction, energy efficiency and

renewable integration. Scales from city to state level, supporting sustainability across industries.

5. **CLES initiative (France)** – Implements Industrial and Territorial Ecology to optimize resource use and reduce CO_2 emissions. Multi-stakeholder cooperation fosters CE practices at the Port of Strasbourg.
6. **Nuove Tecnologie e Arredamenti (Italy)** – Converts industrial waste into value-added products using eco-design. Strengthens SME collaboration and sustainability in the furniture and green building sectors.
7. **PROSEED (Switzerland)** – Upcycles food waste into reusable raw materials, cutting CO_2 emissions. Creates CE opportunities for food processors and ingredient manufacturers.
8. **Industrial Zone Tezno (Slovenia)** – Develops smart energy infrastructure for industrial zones, optimizing consumption and storage. Highly replicable across industrial areas for resource efficiency.
9. **Kooperativa 103 (Slovenia)** – Shared production space for small businesses reduces costs and optimizes resource use. Encourages collaboration, knowledge-sharing and sustainability.
10. **BIOVA (Italy)** – Transforms food waste into premium products through a closed-loop supply chain. Strengthens stakeholders' collaboration and promotes sustainable food production.

Best Practice 1. ITC-AICE (Spain)

Basic information

The Institute of Ceramic Technology (ITC) is a research and development entity based in Castellón de la Plana, Spain. Founded in 1969, it is the result of collaboration between the Universitat Jaume I (UJI) and the Association for Research in the Ceramic Industries (AICE), with the aim of addressing the needs of the Spanish ceramic cluster.

The ITC is dedicated to enhancing the competitiveness of companies within the ceramic sector through innovation, research and technological development. It offers a wide range of services, including technical and strategic consultancy, specialised training and technology transfer. Additionally, it boasts advanced technological infrastructure and a multidisciplinary team to undertake various projects.

Main activities:

- Own research and development: Internal lines with a certain risk, aimed to acquire knowledge.
- Research and development for companies: Industrial objectives at short and medium term.
- Technological consultancy: Application of the knowledge for solving industrial problems.
- Analysis and tests: From raw materials to finished product.
- Training: Training of new professionals, postgraduate training and custom training for companies.

IS implementation overview

At ITC-AICE, IS is implemented in various areas, but the main one is the development of projects to utilise waste from different sectors as raw materials in the ceramic industry.

- **Life Eggshellence project:** To demonstrate the technical feasibility of using eggshells as a secondary raw material in the manufacture of ceramic tiles, thus valorising an important waste from egg-producing companies (https://www.lifeeggshellence.eu/).
- **Life Replay project:** A new life for waste ceramic inkjet inks (https://lifereplay.eu/es/).
- **Eros project:** To reuse of waste generated in the aerospace and wind industry (waste from production plants and end-of-life wind turbine blades).
- **Life Hypobrick project:** To demonstrate the feasibility of manufacturing unfired bricks from waste.
- **Cobat project:** Establishment of a physicochemical treatment process to recover as far as possible all the cobalt from used batteries and its subsequent use for synthesising a cobalt blue ceramic pigment.
- **iWAYS project:** Developing a set of technologies and systems to recover water and heat, as well as materials from ceramic, steel and chemical sectors (https://www.iways.eu/).
- **Life Rewaincer:** New model for applying and using reclaimed water in industrial environments in the ceramics sector (https://liferewaincer.facsa.com/en/). Participation in projects to promote collaboration and resource optimisation among companies:
- **Sharebox project:** Development of a platform to encourage resource exchange between companies, reducing production costs, industrial consumption of natural resources and supporting decision-making.

- **Simval project:** Implementation of IS in the productive sectors of the Valencian Community as a preliminary step towards adopting a CE.
- **SPIRE-SAIS project:** Addressing new skill requirements in IS and energy efficiency in energy-intensive industries (https://www.aspire2050.eu/sais).
- **CircLean project:** Participation in a network that promotes the development of IS across the EU, bringing together industries, authorities, industrial associations, and researchers (https://circlean.arctik.digital/).
- **Circer Project:** Identification of potential IS initiatives within the ceramic cluster, considering economic activities located in the same geographical region.
- **IS training and workshops** in municipalities across Castellón province and the Port of Valencia to encourage IS practices among participating companies.

Process details

In the case of waste utilisation, the technologies, processes and systems employed are highly diverse and depend on the type of waste being repurposed. To facilitate this, ITC-AICE collaborates with public and private entities that develop industrial prototypes, which are then installed in partner companies.

Projects aimed at promoting IS within the region are based on business participation through dedicated meetings. These meetings assess opportunities to improve resource efficiency and identify economically viable solutions that keep resources in productive use for longer.

The methodology has been developed as a step-by-step approach as follows:
STEP 1: Collect information on "Offer and/or Demand Resources" by analysing resource flows and streamlining the exchange process. Understanding the

characteristics, limitations, quality and quantity of a company's resources is essential in IS. This way, companies can have comprehensive data and share it with other interested parties. The activities focus on the identification of potential synergies during a face-to-face workshop. The next step is to evaluate the possible existing synergies, assessing the different solutions from an economic, social and environmental point of view. Once their viability has been studied, the different entities involved are informed and an action plan is established to implement them.

STEP 2: Gather information on current "IS practices" implemented, to disseminate best practices carried out at internal or external level, provide data for sustainability reports, improve the company's image and promote IS in its environment.

STEP 3: Implement a methodology for the self-assessment of the sustainability of identified synergies. A self-assessment tool has been defined and designed to cover the assessment of various dimensions associated with sustainability criteria, including technical, environmental, social and economic aspects. Each dimension contains multiple established indicators. The results of the tool allow users to identify the benefits of IS practices and highlight key aspects to review their feasibility.

Partnerships and stakeholders

- **Asociación Española de Fabricantes de Azulejos y Pavimentos Cerámicos** (ASCER, https://portal.ascer.es/): Comprised of more than 100 companies, it is an organisation dedicated to supporting, advocating for and promoting the Spanish ceramic industry. Its objective is to assist the Spanish ceramic sector in R&D&I, training and employment.
- **Ayuntamiento de Onda** (https://www.onda.es): A municipality in the province of Castellón, featuring industrial estates comprising companies from the ceramics sector, among others. For several years, collaboration has

been undertaken with these businesses to implement Ce and IS projects in the area through interviews with companies within the industrial estate to optimise resource utilisation.

- **Diputación de Castellón** (https://www.dipcas.es/es/): An organisation composed of the municipalities of the province of Castellón, its objective is to improve services in municipalities with fewer inhabitants and contribute to the economic development of rural or sparsely populated areas.
- **Consorcio territorial por el empleo de la Plana Baixa** (https://activemlaplanabaixa.es/): Established by associations of municipalities to promote job creation, socio-labour integration and economic, business and social development within the territorial scope of the Consortium.
- **Federación de Parques Empresariales de la Comunidad Valenciana** (FEPEVAL, https://www.fepeval.com/): FEPEVAL is an association of managing entities of industrial estates in the Valencian Community, aimed at improving the management and services of industrial areas.

Environmental, Economic and Social Impact

The Spanish ceramic sector has implemented IS practices since its inception to enhance efficiency in production processes. According to the 2023 Circular Economy Report on the Ceramic Tile Sector, (https://portal.ascer.es/wp-content/uploads/2024/12/2_Presentacion-EC_Sector-baldosas-Ceramicas.pdf), the reuse of solid waste from ceramic tile companies by atomised granule manufacturers was estimated at 9.5% incorporation of solid waste.

- Raw materials savings: 810,000 tonnes.
- Waste reduction: 93% of the solid waste generated.
- Reduction in CO2 emissions: 51,000 tonnes of CO2 equivalent.

- Energy savings: NA.
- Water conservation: NA.
- Cost Savings: 25 million euros in savings associated with unused virgin material.
- ROI: NA.
- Revenue from Secondary Markets: NA.
- Job creation: NA.
- Number of people educated or engaged in IS practices: NA.
- Number of cross-sector collaboration or partnerships: NA.

Timeline and milestones

During the years that the ITC-AICE has been working to promote IS throughout the value chain of the ceramic tile manufacturing sector, this roadmap has been drawn up to promote IS within a territory. However, these projects are indeed long-term and difficult to implement.

The key stages in the implementation of IS can be defined in the following phases:

1. Resource audits in companies.
2. Data analysis (water/energy/waste).
3. Training and awareness-raising actions focused on CE and energy issues. Creation of the role of Facilitator.
4. Synergy search sessions.
5. Development of strategic plans, and roadmaps for on-site improvement and IS.
6. Development of Waste-Resource platforms, circularity observatories, and examples of successful case studies.
7. Execution of joint projects (search for joint financing), for example, pooled services.

8. Free advice to companies on issues of eco-design, product lifespan, logistics-packaging, energy efficiency, virtualisation, servitisation and resource sharing.
9. Creation of associations for joint management.
10. Improve information transparency for conscientious consumers in their decision-making process of environmentally friendly purchasing.
11. Creation of spaces to promote public investment, aimed at services for citizens and spaces aimed at private investment for the implementation of industrial activities with a marked circular component.
12. Training rooms for schools.
13. Guided visits to companies by the public.
14. Creation of competitions with ideas to promote circular businesses.

Challenges and solutions

During the implementation of the different projects that have been carried out by the ITC-AICE, various obstacles have been detected which, in most cases, have hindered or even put an end to all the efforts that have been made.

Firstly, the collaboration and involvement of companies throughout the entire process of mapping and resource flow is necessary; their active involvement is necessary for the implementation of industrial IS in any territory.

In another sense, the figure of a facilitator is necessary, someone who is an active promoter of the integration of IS at the territorial level. The facilitator must coordinate the relationships between public institutions, society and companies so that the cooperation between them is as close as possible.

Finally, IS projects are “continuous” and should be designed as long-term projects considering the involvement of public and private entities. In the economic sphere, it is necessary to have multi-annual resources that consider a strategy of support for the development of industrial estates by public administrations.

Potential of replication

IS can be scaled up and adapted to different sectors and contexts, not only within the classical industrial sphere but also in agriculture, construction, transport and other emerging sectors in the industrial, urban and rural spheres.

The key lies in identifying synergies between companies from different industries, and undervalued resources in cities or towns to improve energy and resource efficiency and optimise the use of products and by-products. In addition, cross-sector collaboration can foster innovation, improve sustainability and create more resilient and profitable business models.

The key to successful implementation lies in society's awareness of the need for a change in the production model, the construction of cooperation networks that transcend immediate interests and promote a shared vision of long-term sustainability, considering economic criteria but also environmental and social ones, since all three are necessary for balanced development.

Best Practice 2. Tire Industrial Park, Izmir (Türkiye)

Basic information

Tire Industrial Park (TOSBİ)[1] was established in 1993 to ensure the orderly development of industry, prevent environmental issues, and optimize resource utilization. Covering an area of 410 hectares, TOSBİ hosts approximately 83 facilities operating in sectors such as food, plastics and energy. The zone supports industrialists with infrastructure services, including electricity, natural gas, wastewater treatment and logistics. Since 2008, it has established its own electricity distribution system to provide local energy to businesses. In 2016, the capacity of its wastewater treatment plant was expanded to enhance environmental sustainability.

In 2012, with the support of İzmir Development Agency (İZKA), a 500 kWp solar power plant was established. TOSBİ has developed biogas production and waste management projects to improve industrial efficiency and provide businesses with low-cost energy. Advanced treatment systems are applied to enable the reuse of treated wastewater for agricultural irrigation. However, heavy traffic and a lack of junctions between Tire and TOSBİ are among the main challenges affecting transportation in the region.

With its infrastructure services such as electricity, natural gas, wastewater treatment, and logistics, TOSBİ provides comprehensive support to industrialists. Additionally, it stands out as an industrial zone committed to environmental practices and sustainability projects.

[1] In Türkiye, Organized Industrial Zones (OIZ) correspond to Industrial Parks (https://investinizmir.com/why-izmir/developed-investment-infrastructure/organized-industrial-zones/).

IS implementation overview

An IS initiative (TOSS - Tire Organized Dairy Industrialists Food Treatment Processing Industry and Trade Co. Ltd.) has been implemented at TOSBİ to utilize waste from dairy factories and enhance resource efficiency. One of the main objectives of this initiative is to create a sustainable cycle by converting wastewater generated from production processes into energy through anaerobic wastewater treatment systems for biogas production. Additionally, the organic sludge from the wastewater treatment plant is recovered in the biogas facility to generate energy, after which it is used for fertilizer production, contributing to soil improvement in the agricultural sector. As a result of this process, expenses related to waste and wastewater disposal, as well as energy costs, are reduced.

Through energy recovery from wastewater and treatment sludge, Türkiye's energy production potential is enhanced, while waste management is carried out in line with the zero-waste principle. Key industrial enterprises participating in this process include Ak Gıda and Sütaş, with TARFAŞ focusing on feed production and ENFAŞ managing energy production through the biogas facility.

Process details

There are three separate wastewater pipelines within TOSBİ. The wastewater from dairy factories under TOSS is collected in the existing pumping pool and directed to the DAF (Dissolved Air Flotation) unit via pumps. Here, floating substances such as oil and grease are removed, after which the wastewater is re-collected in the pumping pool and then transferred to the equalization tank.

The anaerobic wastewater treatment system takes place in four main reaction steps: Hydrolysis, Acidification, Acetate Production and Methane Production. Each of these processes is carried out by different bacterial groups, and each step serves

as a nutrient source for the next stage. After passing through the anaerobic reactor, the wastewater enters the degasser unit, where escaping gases are captured before being directed to the aeration tank.

The biogas obtained during the anaerobic treatment process is stored in the biogas storage system. After anaerobic treatment, the wastewater undergoes an aerobic biological treatment process. In the aeration tank, blower-supported jet nozzle aerator systems are used. Here, COD (Chemical Oxygen Demand) removal is achieved with the help of microorganisms, improving water quality. After aeration, the wastewater is transferred to the biological sedimentation tank, where the settled sludge is directed to the sludge thickening tank, while the treated water is discharged into the Küçük Menderes Basin.

In the sludge management process, excess biological sludge from anaerobic and aerobic processes is concentrated in gravitational thickening tanks before being transferred to the decanter system for dewatering. During the sludge dewatering process, cationic polyelectrolyte dosing is applied to minimize the water content in the sludge. The sludge is then sent to the biogas plant for a second methane production stage. In this process, organic waste from the Menderes Basin (agriculture, food factories, etc.) is also used, with approximately 10% contributing to energy production in the biogas facility.

In terms of energy management, the methane gas produced from biogas is used for energy production. The generated biogas is used in cogeneration systems to produce electricity, hot water, and steam. While a significant portion of the gas is directly combusted for energy conversion, some of it is recovered to reduce system losses. With a total aeration tank capacity of 11,000 m³, the treated discharge water

is directed to the Cumalı Stream and monitored in compliance with environmental regulations.

Through these systems, a COD removal efficiency of 80-90% is achieved, reducing the environmental waste load, enabling energy recovery through biogas production, and implementing a sustainable production model.

Partnerships and stakeholders

The cooperative TOSS, established with 11 dairy producer companies in TOSBİ, has Ak Gıda and SÜTAŞ as its two most important companies.

Environmental, Economic and Social Impact

Quantitative and qualitative data, such as waste reduction, resource savings, cost reduction, or improved efficiency achieved after implementing IS in the industrial park:

- Waste reduction: An average of 639 tons of sludge per month is used as fertilizer, achieving this level of waste reduction.
- Reduction in CO2 emissions: Considering that approximately 10% of the total 4.2 MWh of electricity produced daily at the biogas plant is generated from biogas obtained from wastewater coming through TOSS, a reduction of 175.14 kg CO_2 e/day and 63.92 tons CO_2 e/year in CO_2 emissions is achieved. (According to the Ministry of Energy and Natural Resources of Turkey, the current emission factor for electricity production is 0.442 tons CO_2 e/MWh, while for biogas-based electricity production, the emission factor used is 0.025 kg CO_2 e/kWh, based on DEFRA data.) Since approximately 10% of the electricity is generated from TOSS-sourced biogas, a 10% energy savings is achieved.
- Energy savings: The wastewater treatment infrastructure at TOSBİ is not suitable due to the high COD levels in the effluent waters from dairy product

facilities. If these waters had continued to be processed within TOSBİ, the high energy inputs required would have been mitigated through the cooperative infrastructure that was established, thereby ensuring energy savings within TOSBİ. However, there is no numerical data available regarding this energy savings.

- Water conservation: The main companies under TOSS that contribute to COD in wastewater are triggered to optimize their water usage when the COD level of the inlet water to the treatment plant is too high, as the disposal of such high-COD effluent incurs significant costs. While there is no numerical data on water savings efficiency, process optimization is achieved.
- Cost Savings: Additional revenue is generated through energy sales and the sale of solid liquid fermented organic and organ mineral fertilizers.
- ROI: The factory is considered amortized based on the elimination of penalties and other costs previously incurred due to the discharge water mentioned above.
- Revenue from Secondary Markets: Revenue is generated through fertilizer sales.
- Job creation: A total of 20-25 people has been employed.
- Number of people educated or engaged in IS practices: Training sessions have been conducted, particularly for producer stakeholders, on the subject.
- Number of cross-sector collaboration or partnerships: Partnerships have been established in the agriculture, livestock, dairy, and energy sectors.

Timeline and milestones

Although 11 dairy and dairy product factories did not conduct a pre-feasibility study, it was determined that the COD levels of the wastewater from these factories were at least five times higher than the wastewater discharge limits. As a result, the factories initiated a clustering process. Additionally, when it was observed that this

wastewater was later used in livestock farming, which is essential for dairy and dairy product production, and that microbial contamination in the wastewater subsequently affected milk yields, the process was also evaluated from the perspective of animal and human health.

Based on this assessment, TOSS was established as a unique example in Turkey, officially starting its operations in May 2012.

Website: http://www.tireorganizesutaritma.com.tr/.

Challenges and solutions

In the IS application, high COD values were initially detected. To address this issue, preventive measures were taken by informing the dairy factories, which are the sources of the wastewater.

Since liquid fertilizer applications are not effective during rainy weather, the issue was resolved using lagoon systems. Additionally, temperature control was ensured during biogas production, increasing the process efficiency.

Potential of replication

This model can be applied in other organized industrial zones (OIZs), particularly in those with dairy product manufacturing factories and agro food integrated industrial facilities. Additionally, whey, a by-product of this process, can be used as a raw material in various industries such as food and feed production. Therefore, similar processes from this model can be implemented in other industrial zones with a high concentration of dairy and food industries, enhancing environmental and economic benefits.

Best Practice 3. Manresa in Simbiosi (Spain)

Basic information

"Manresa in Symbiosis" was Catalonia's first IS initiative, launched to promote resource efficiency and CE practices among local industries. Developed with support from the Catalan Waste Agency, Manresa City Council, and the Bages Region Waste Management Consortium, the project demonstrated how companies could exchange waste, optimize resource use, and reduce environmental impact through collaboration.

Building on this success, the Bages Circular Industry project was created to scale up IS across the region. Led by the Bufalvent Business Association, with support from the Bages Regional Council and Manresa City Council, it now serves over 1,500 companies. The initiative has become a national reference, fostering collaborations that improve economic competitiveness and sustainability. By integrating synergy mapping, shared infrastructure, and resource optimization, Bages Circular Industry strengthens the region's industrial ecosystem and positions it as a leader in CE innovation.

IS implementation overview

"Manresa in Symbiosis" was Catalonia's first IS pilot project, launched to demonstrate how collaborative resource management can reduce waste, improve efficiency and create new business opportunities. It was promoted by the Catalan Waste Agency, Manresa City Council and the Bages Region Waste Management Consortium, with technical management provided by Símbiosy. Other key collaborators included the Barcelona Provincial Council (Diputació de Barcelona), the CTM-Eurecat Research Center, and the Bufalvent Business Association.

The project aimed to transform waste into resources by fostering cooperation between industries and public entities. It focused on mapping industrial waste flows, identifying synergies, and implementing innovative CE solutions. The initiative served as a proof of concept for IS in Catalonia, demonstrating its feasibility and benefits through real-world applications.

A detailed ecosystem analysis was conducted to understand local resource streams, which helped identify potential synergies between businesses, industrial parks, and municipal services. This mapping process laid the groundwork for industrial cooperation, allowing companies to explore new ways to exchange materials, reuse by-products and collectively optimize energy and water use.

A multi-stakeholder Advisory Committee was established to monitor progress, ensure alignment with policy objectives and provide strategic direction. This structure enabled ongoing engagement between companies, public administration and technical experts, fostering an environment of continuous improvement and innovation.

To engage businesses, the project carried out individualized audits to assess companies' resource usage and waste generation. In parallel, sector-specific workshops were organized to explore opportunities for shared solutions in industries such as plastics, metal, and biomass. Based on these findings, synergies were implemented, focusing on waste valorisation, resource exchange and process optimization.

The project also placed a strong emphasis on training and awareness, providing technical workshops, university programs and public awareness campaigns. These

initiatives ensured that local businesses and stakeholders gained the knowledge and skills needed to adopt and sustain CE practices.

As a result, "Manresa in Symbiosis" successfully demonstrated the viability of IS and led to the creation of the Bages Circular Industry project, which expanded the model across the region.

Process details

A key component was the industrial ecosystem analysis, conducted using Syner platform, a specialized digital tool for mapping material and energy flows between industries. This platform helped identify 30+ potential synergies, connecting businesses, industrial parks, waste treatment plants and the agricultural-forestry sector. The mapping process provided a data-driven approach to resource management, allowing for better coordination between stakeholders.

One of the major innovations was the creation of Manresa Il·lumina, the region's first industrial energy community fully composed of Small and Medium-sized Enterprises (SMEs). This initiative enabled businesses to jointly manage energy production and consumption, reducing costs and increasing the use of renewable energy sources. The energy community model demonstrated how IS could extend beyond material exchanges to include shared energy solutions.

Another milestone was the development of a district heating network, powered by locally sourced biogas and forest biomass. This system provided renewable heat to industrial facilities and public buildings, including Manresa's hospital and businesses in the Bufalvent industrial estate. By utilizing biogas from the local landfill and wood residues from forestry activities, the project significantly reduced dependency on fossil fuels and improved overall energy efficiency.

To support biomass utilization, a centralized biomass storage facility was established, allowing for efficient collection, processing, and redistribution of forest biomass and post-industrial wood. This infrastructure ensured a stable supply of raw materials for biomass-based heating systems and helped local industries adopt low-carbon energy alternatives.

Waste management was another critical focus. The project facilitated joint waste collection and treatment programs among businesses, leading to cost reductions and improved recycling rates. Specific initiatives included the valorisation of industrial by-products, such as repurposing waste materials from one company as raw inputs for another.

Beyond technical implementations, the project emphasized capacity-building and knowledge transfer. Training sessions, workshops and collaborations with universities and research centres ensured that IS principles became embedded in local business practices.

Partnerships and stakeholders

- **Catalan Waste Agency** (Government of Catalonia) - https://residus.gencat.cat/es/inici/index.html
- **Manresa City Council** - https://www.manresa.cat/
- **Bages Region Waste Management Consortium** - https://www.consorcidelbages.cat/
- **Símbiosy** - https://simbiosy.com/
- **"Diputació de Barcelona"** (Barcelona's province supra-municipal public entity) - https://www.diba.cat/es/
- **CTM** (Manresa's Research Technical Centre, now Eurecat) - https://eurecat.org/home/es/

- **Bufalvent Business Association** - https://www.bufalvent.cat/

Environmental, Economic and Social Impact

The Manresa in Symbiosis project generated significant environmental, economic, and social benefits, both in quantitative and qualitative terms:

- Waste Reduction: over 11,000 tons of organic waste were estimated to be valorised through IS strategies. Additionally, 750 tons of plastic waste were upgraded, and 256 tons of mixed waste were diverted from landfills, significantly improving waste management efficiency.
- Reduction in CO2 Emissions: By substituting fossil fuel-based energy sources with biogas and biomass-based thermal energy, the project contributed to substantial carbon footprint reductions.
- Energy Savings: The IS model led to the generation of 12 GWh of thermal energy and 7 GWh of electric energy through biogas valorisation from landfills and water treatment plants. This initiative improved local energy efficiency and enhanced renewable energy adoption in industrial processes.
- Water Conservation: The implementation of industrial water reuse systems and optimization of water treatment processes contributed to improved water management practices, reducing consumption and waste.
- Cost Savings: The project enabled industries to achieve approximately €135,000 per year in waste treatment cost savings through improved waste valorisation techniques.
- Return on Investment (ROI): The energy generation initiative, which required an investment of €6,000,000, was projected to yield €1,200,000 per year in revenue, demonstrating strong economic viability.
- Revenue from Secondary Markets: Businesses participating in the initiative benefited from new revenue streams generated by selling secondary raw materials and by-products.

- Job Creation: The project supported local employment by engaging 50 technical workers and managers in its execution. Additionally, new roles emerged in waste management, renewable energy operations and CE consulting.
- Education and Engagement in IS Practices: The project facilitated knowledge-sharing initiatives, training workshops and cross-sectoral collaboration, engaging a significant number of industrial stakeholders.
- Cross-Sector Collaboration: The project successfully connected 28 companies, fostering 8 synergies, with 4 in implementation and 4 in the study phase.

Timeline and milestones

The Manresa in Symbiosis project followed a structured development process, moving from local implementation to regional expansion:

2015:

- May: Data collection phase initiated with the identification of companies, resources, and the creation of a database on the INEX platform for Manresa.
- November: Project communication and engagement began, involving local industries to raise awareness and encourage participation.

2016:

- January: First workshop with industries to identify potential IS synergies.
- June: Second workshop for detailed analysis and validation of identified synergies.
- October: Establishment of the Synergies Office in Bufalvent to facilitate project execution and provide technical support to industries.
- December: Monitoring and evaluation of initial IS benefits.

2017: Expansion beyond Manresa, engaging industries across the Bages region.

2018: Official launch of Bages Circular Industry, scaling the IS initiative across the county with financial support from the Bages Regional Council and Manresa Municipality.

Challenges and solutions

Implementing an IS project in Manresa and scaling it to the broader Bages region came with multiple challenges:

- One of the primary challenges was gaining the trust and engagement of companies. Many businesses were initially reluctant to participate due to a lack of awareness about IS, concerns over confidentiality in sharing resource data, and uncertainty about potential benefits. **Solution:** to address this, the project team conducted awareness-raising workshops, one-on-one meetings and case study presentations that demonstrated successful IS initiatives in other regions. By emphasizing cost savings, efficiency improvements and regulatory compliance benefits, more companies recognized the value of participating. The creation of the Simbiosi Office further institutionalized this engagement, providing dedicated support to companies.
- Another major obstacle was the technical complexity of identifying feasible synergies. Not all waste streams were suitable for reuse and some required additional processing to be viable. **Solution**: the project adopted a phased approach, starting with a resource mapping exercise to identify companies with complementary waste and resource needs. It then conducted feasibility studies and pilot trials before full implementation.
- Legal and regulatory barriers posed significant challenges, particularly in waste classification, transportation and permitting for industrial waste reuse. Some resource exchanges were subject to strict environmental regulations,

which complicated implementation. **Solution:** the project team worked closely with local authorities.

- Some synergies required capital investment in equipment, infrastructure or process modifications. **Solution:** The project explored various funding mechanisms, including public-private partnerships, government grants and financial incentives.
- Once the pilot project was completed, the challenge became ensuring long-term continuity and expanding the initiative to a regional level. **Solution:** the establishment of the Simbiosi Office under the Bufalvent Business Association ensured ongoing support for companies. Later, with funding from the Bages Regional County and the Municipality of Manresa, the service was expanded into Bages Circular Industry, allowing for greater regional impact and continuity.

Potential of replication

The IS model implemented in Manresa and later expanded to the Bages region provides a scalable and adaptable framework that can be applied to other industrial areas, regions and even different economic sectors.

Several factors contributed to the scalability of the Manresa IS initiative, making it a transferable model:

- The use of databases and platforms like INEX to map waste streams and identify potential synergies was crucial. Any region implementing IS can benefit from a systematic data collection and analysis process to assess available resources and opportunities.
- The establishment of the Simbiosi Office ensured ongoing support for businesses, serving as an intermediary between companies, regulatory bodies and technical experts. This structure can be replicated in other industrial clusters or regions.

- The financial backing from local government bodies (Bages Regional County and Manresa Municipality) alongside private sector engagement played a crucial role in sustaining the initiative. Other regions could adopt a similar funding model to ensure long-term viability.

Best Practice 4. Chihuahua Green (Mexico)

Basic information

Chihuahua Green is a public-private state program that leads companies in Chihuahua towards a CE and IS. It is managed by COPARMEX Chihuahua in collaboration with the Government of the State of Chihuahua. The program boosts the competitiveness of businesses by assisting them in developing their sustainability plans, offering innovative services specifically focused on CO2 reduction, material circularity, green energy and IS.

Chihuahua Green is the evolution of the pilot project "Chihuahua Green City," funded by the European Union Delegation in Mexico for the municipality of Chihuahua, extending to the rest of the companies and territory of the State.

IS implementation overview

Chihuahua Green is in northern Mexico, one of the most important productive regions in the country, borders the southern United States to the north. The program offers services to companies and public organizations in the State of Chihuahua that want to start CE projects through IS. It promotes the creation of facilitation offices in all regions and municipalities of the state of Chihuahua, helping them become "hubs" of the CE, from which they can support their companies, considering the nature of their productive sectors.

There are many services offered by Chihuahua Green:

- **Chihuahua Eco-market**: is a free virtual tool designed for buying and selling waste and resources between companies.
- **Mapping surplus resources:** with SYNER platform, companies and facilitation offices identify business opportunities from surplus resources

through IS, where a company's waste or by-products can be raw materials for another company.

- **Training and education**: access to training courses offered for companies, facilitators, and citizens who want to learn more about CE, IS, decarbonization and efficient resource management.
- **Certification OASIS:** offer the certification that recognizes sustainable practices in companies in Chihuahua. It is a distinction awarded to companies that drive business competitiveness through sustainable practices that validate their commitment to sustainability and innovation. This certification is available for companies of all sizes and sectors, with a special focus on manufacturing, agro-industrial and construction industries, and it enhances business competitiveness in a comprehensive manner
- **Corporate carbon footprint calculation**: help companies in evaluating and managing their carbon emissions. This service helps companies better understand their carbon footprint and provides opportunities for reduction.

Additionally, the Chihuahua Green website is a portal that gathers general information, as well as success stories from companies, to educate and inform about CE and IS at the local, national and international levels.

Some successful synergies involve:

- Generation of ecological blocks for construction made with chamotte (Interceramic and Grupo Cementos de Chihuahua).
- Production of ecological shoe soles, primarily for footwear in the medical industry (General Electric HealthCare - Recilogic - company from Guanajuato).
- Use of rice husk from Innovak (Scrap Store).

- Waste processing plant for companies in the Chihuahua Industrial Complex for reintegration into production processes or the creation of other eco-products.
- WWTP and Photovoltaic Park / Chihuahua Industrial Complex, for the reduction of 48 MWh of energy.
- Heat and cold networks among companies in the Chihuahua Industrial Complex.
- Utilization of aluminium slag, a synergy between Superior Industries and Grupo Cementos de Chihuahua.
- Utilization of rubber waste, from Continental for the reuse of vulcanized rubber.

Process details

Many digital platforms and tools are used to implement IS:

- **Syner:** is a platform that locates and connects companies (finds synergies) through a system of coding and mathematical algorithms based on success cases and data processing, which allows answering questions such as: automatic detection of synergies / potential business between companies based on surplus resources.
- **Symtrack:** this software used for tracking and managing IS projects is made available to the various facilitation offices. IS projects require the management of a large amount of data and information about companies, their resources, opportunities, follow-up meetings, etc. They need tools that assist IS project facilitators in managing and making the most of the information collected and generated during the development of their work.
- **Corporate carbon footprint calculation:** digital calculation of carbon emissions for companies.

Partnerships and stakeholders

Promotors:

- Coparmex (Business Association) - https://coparmex.org.mx/
- Government of the State of Chihuahua, Mexico - https://www.chihuahua.gob.mx/

Facilitators:

- Recilogic - https://www.recilogic.com/
- Simbiosy - https://simbiosy.com/

Environmental, Economic and Social Impact

This data is not available as Chihuahua Green includes 3 facilitation offices with different IS projects and a main objective:

- **Chihuahua Green City:** facilitator office located in the Municipality of Chihuahua, originally created as a pilot project for IS, driven by COPARMEX Chihuahua and initially funded by the European Union Delegation in Mexico. Objective: 15% reduction in the carbon footprint of the local industry (148 MtCO2e).
- **Poniente 2050:** facilitation office located in the Municipality of Cuauhtémoc, covering 31 localities in the northwestern region of the state, with a focus on the primary sector. Objective: reduction of 28,000 tons of CO2 in the Cuauhtémoc Industrial Complex.
- **Juarez Circular Hub:** facilitation office based in Ciudad Juárez, a border municipality located in the northern part of the state of Chihuahua, adjacent to El Paso, TX, United States. Objective: engage more than 48,000 companies in their transition to the CE.

Timeline and milestones

2016: Agreement with LCBAM: The Municipality of Chihuahua signed a collaboration agreement with the Low Carbon Business Action Mexico (LCBAM) program.

2017: Forum on CE for the Northern States of Mexico: An event is held in Chihuahua for the Low Carbon Business Action Mexico (LCBAM), which facilitates B2B meetings between Mexican and European companies to promote low-carbon technologies.

2018:

- Mission to the Netherlands: A mission is made to the Netherlands to learn about landfill management efforts, with the goal of replicating them.
- Cuauhtémoc Sanitary Landfill: The project for the Cuauhtémoc sanitary landfill starts in Chihuahua, with a visit from EU delegates.

2019:

- The European Union Ambassador to Mexico visits Chihuahua, engaging in discussions with leaders of the Cuauhtémoc Sanitary Landfill Project.
- COPARMEX Chihuahua representatives are invited by the EU delegation to participate in the Green Expo Forum in Mexico City.
- The CE Forum for the Northern States of Mexico takes place, attracting more than 300 Mexican companies, along with European leaders and experts in CE.

2020:

- Launch of the Chihuahua Green City Pilot Project: Four IS projects are established between large companies, and the Chihuahua Green City facilitator office is formed.
- Virtual B2B meetings are held to explore the concept of IS for the city of Chihuahua.

2022:

- The IS pilot project begins in Chihuahua, involving collaboration between the Government of Chihuahua, the Municipal Government of Chihuahua, the EU delegation, and COPARMEX Chihuahua.
- Circular Economy Forum: The first results of the Chihuahua Green City Project are showcased.
- Thirteen European Union ambassadors visit Chihuahua to learn about the results of the Chihuahua Green City program.
- COPARMEX signs an agreement with the Government of Chihuahua to collaborate on an industrial decarbonization program, which includes:
    - Pilot Program for Decarbonization of the Cuauhtémoc Industrial Park.
    - Grand Vision for the Circular Economy in the State of Chihuahua.
    - Phase II of Chihuahua Green City: Technical Office for project identification.
- The mapping of Juárez companies begins to establish symbiotic projects in the Juárez region.
- A strong alliance is formed between Chihuahua Green City, the Municipal Government of Chihuahua, Ciudad Juárez and the State Government of Chihuahua.
- The first green financing model in the state is created to help small businesses acquire green technologies.

2023:

- Creation of Chihuahua Green: The state initiative, Chihuahua Green, was consolidated for the state of Chihuahua.
- Mapping in the Poniente 2050 region is carried out, and an office is established for the 31 municipalities in the west.
- The creation of the Chihuahua Green platform begins to better support industries in their transition to a CE. This platform includes six tools to help

both industries and facilitators manage projects more effectively and identify decarbonization opportunities.

- The OASIS certification is introduced to help businesses adapt to environmental regulations, reduce operational costs, attract talent and meet their sustainability and development goals.

Challenges and solutions

One of the most significant challenges faced was political in nature. Convincing public administrations that this initiative could guarantee both economic development and sustainable growth was crucial. The objective was to demonstrate that this approach would not only foster a greener future but also generate a positive impact on the economy and society at large.

Another major hurdle was encouraging businesses to sign up and recognize the potential for business opportunities in sustainable practices. Many companies were initially sceptical about the benefits, making it essential to show them how adopting IS could result in tangible savings, improved resource efficiency and new market opportunities. Overcoming this mindset shift was crucial for ensuring their participation and engagement in the project.

Potential of replication

The program's scalability is one of its greatest strengths. Initially launched as a city-level pilot in Chihuahua, it has since expanded into a successful statewide initiative, demonstrating its potential for broader application. The lessons learned and the experience gained throughout its implementation have provided a solid foundation to serve as a replicable model for other regions. This structured approach ensures that investment and effort yield meaningful and lasting results, rather than remaining isolated within a single location.

One of the key factors behind its scalability is the program's flexibility in adapting to different economic and industrial contexts. By focusing on fundamental principles—such as collaboration between public and private sectors, fostering innovation, and promoting sustainable practices—the model can be adjusted to fit various industries and geographic areas. This adaptability ensures that it can be implemented in regions with distinct socio-economic dynamics while maintaining its core objectives.

The goal is not just to replicate the initiative on a case-by-case basis but to establish a framework that can be systematically applied nationwide. By expanding the network of participating businesses, institutions, and stakeholders, the program fosters an interconnected ecosystem that facilitates knowledge-sharing and collective problem-solving. This large-scale approach amplifies the program's impact, enabling businesses to leverage shared resources and expertise for more sustainable and efficient operations.

Furthermore, this model is not limited to one sector. Its principles can be applied across industries, such as manufacturing, agriculture, and energy, to enhance CE practices, improve resource efficiency and reduce environmental impact. The program's success has already sparked interest in other regions, signalling its viability as a scalable solution that can drive long-term, systemic change.

Best Practice 5. CLES initiative (France)

Basic information

The CLES (Coopérations Locales et Environnementales en Synergies) initiative promotes CE practices within the Strasbourg industrial port area, the second largest inland port in France. Launched in 2013, it supports the collaboration of a pool of 400 businesses to reduce waste, optimise resources and reduce environmental impact while increasing competitiveness.

Led by the Groupement des Usagers du Port (GUP), the initiative is animated by Initiatives Durables. Its partners are the Port Autonome de Strasbourg, the Eurométropole de Strasbourg, ADEME and the Région Grand Est. CLES is an environmental initiative that involves identifying opportunities for collaboration between various players in the same area, with a view to developing a CE. Topics covered include energy efficiency, waste recovery, pooling of equipment and services and generally any project aimed at reducing greenhouse gas emissions and costs.

Based on the principles of industrial and territorial ecology, CLES is a national model of sustainable industrial collaboration, showing how businesses can prosper economically while respecting the environment and increasingly demanding regulatory obligations.

More information: https://www.cles-ports-de-strasbourg.eu/qui-sommes-nous/presentation/ and https://www.cles-ports-de-strasbourg.eu/qui-sommes-nous/acteurs/

IS implementation overview

Launched in 2013, the CLES initiative was developed to enable companies in the port area to be more sustainable. By encouraging collaboration between port companies, the initiative aims to optimise the use of resources, minimise waste and improve environmental and economic performance.

The success of CLES depends on the commitment of its member companies (32 in 2024). CLES fosters synergies by helping companies to work together on shared services, waste recovery and energy optimisation, enabling them to reduce their operating costs and carbon footprint. The initiative demonstrates how industries can work together within the same ecosystem to achieve financial and environmental benefits.

To ensure the success of this collaborative model, CLES organises several strategic activities to promote cooperation and sustainable development. The initiative frequently organises workshops designed to stimulate creativity and discover new opportunities for synergies between companies. These sessions enable participants to think together and explore innovative ways of improving efficiency and sustainability. In addition, CLES forms specialist working groups to focus on specific areas such as resource optimisation and waste reduction. These teams work together to identify best practice and develop solutions tailored to the specific needs of the port industry.

Site assessments are another key activity within CLES, providing companies with in-depth analyses of their operations to identify potential areas for resource sharing and waste recovery. This process uncovers untapped opportunities for collaboration and ensures that resources are used as efficiently as possible. As part of its efforts to extend the reach of the initiative, CLES is also emphasising the

importance of building a collaborative network of stakeholders. By connecting businesses, public institutions and organisations, the initiative strengthens its collective impact and ensures that its objectives are pursued in a coherent way. Inclusive decision-making is at the heart of the initiative's approach, with institutional partners and member companies actively involved in strategic and operational decisions. This collaborative decision-making process ensures that all parties are aligned and that the initiatives implemented meet the needs of all stakeholders.

Since its inception, CLES has grown significantly from a small-scale initiative to a national model of CE practices. Public financial support from bodies such as ADEME, the Région Grand Est and the Eurométropole de Strasbourg has enabled the initiative to develop over time. By demonstrating the potential of collaborative efforts, CLES has shown that businesses can thrive economically while prioritising sustainability and environmental protection

Background to the implementation of synergies under the CLES initiatives:

- Local recycling of paper and cardboard waste
- Energy recovery from wood waste
- Recycling of plastic sheeting
- Exploring the use of ash
- Shared repair services for wooden pallets
- Recycling of organic residues
- Shared purchasing of consumables and services
- Joint training sessions
- Pooling of sports sections exploring the pooling of a childcare service
- Recycling of Big Bags
- Revalorization of unsold food items

- Donations of light poles
- Exploring the potential for collective self-consumption via photovoltaic panels
- Joint purchase of electric vehicle charging stations
- Employer mobility plan for the ports of Strasbourg / Plan de mobilité employeur des ports de Strasbourg (PEPS)
- Recovery and use of waste heat.

More information here: https://www.cles-ports-de-strasbourg.eu/qui-sommes-nous/presentation/

Process details

IS at the Port Autonome de Strasbourg (PAS) is based on cooperation between public and private players, in particular the Groupement des Usagers du Port (GUP), which brings together port companies. This dynamic has been strengthened with the development of the Deux-Rives district, involving a dialogue between urban development and the maintenance of economic activities.

In 2013, a study funded by the Eurométropole de Strasbourg and the PAS was carried out by a specialist consultancy. The aim of this technical analysis was to establish an in-depth diagnosis of the flows and resources of 15 pioneering companies, selected for their economic and environmental impact. The aim was to identify production processes, materials used, waste generated and logistics requirements.

The results identified opportunities for industrial synergies based on the CE. Putting companies in touch with each other facilitated the emergence of collaborative projects, which then required specific support to become a reality.

Processes and tools put in place:

- Exchanging resources: reusing waste from one company as a raw material for another.
- Pooling purchases: group orders for energy and supplies to optimise costs and reduce the carbon footprint.
- Optimising logistics and sustainable mobility: reducing transport flows and solutions tailored to employees.
- Energy substitution: analysing consumption to replace energy-hungry resources with more sustainable alternatives.

Support systems and technologies:

- Flow modelling to identify potential synergies.
- Monitoring energy consumption and CO_2 emissions to measure environmental impact.
- Collaboration with laboratories to analyse the feasibility of certain synergies involving chemical transformations.
- Involvement of consultancy firms to assess the technical aspects of waste management and resource exchanges.

Managing and structuring the network:

- Initiatives Durables is responsible for coordinating the approach and structuring cooperation between companies.
- Company working groups to initiate exchanges.
- Collective intelligence workshops and facilitation of discussions to formalise synergies.
- Synergy identification matrix and action sheets to analyse issues and prioritise initiatives.
- 1-to-2-year action plans to monitor and evaluate projects.

This collaborative framework has helped to establish a sustainable dynamic and gradually integrate technological solutions tailored to the needs of the region.

Partnerships and stakeholders

Partners:

- Groupement des Usagers des Ports de Strasbourg (GUP): The Groupement des Usagers des Ports de Strasbourg (GUP) represents more than 85 companies located in the port area, advocating better accessibility, safety, skills development and economic growth. With more than 60 years' experience, it serves as an essential link between port companies and public institutions.
  The GUP also supports the CLES approach, promoting industrial ecology and sustainable development, while shaping the future of the port through discussions on major infrastructure and development projects.
- Initiatives Durables: Initiatives Durables is a regional network dedicated to promoting responsible development among businesses and territories. It supports and showcases members committed to Corporate Social Responsibility (CSR) while fostering excellence in the Grand Est region's economic ecosystem.
  Beyond its network role, Initiatives Durables is a pioneer in the Economy of Functionality and Cooperation and has developed expertise in facilitating Industrial and Territorial Ecology initiatives, notably through its involvement in the CLES project.
- Port Autonome de Strasbourg: The Port Autonome de Strasbourg (PAS) is a public institution responsible for managing and developing the Strasbourg port area. Its mission includes optimising efficient flow management and supporting the establishment and sustainability of businesses.

PAS prioritizes enhancing services for companies while adhering to environmental responsibility principles and increasing the port's overall attractiveness as a strategic hub

- Eurométropole de Strasbourg: The Eurométropole de Strasbourg is an intercommunal cooperation uniting 33 municipalities in the Strasbourg area to promote financial solidarity and shared interests. It plays a key role in economic development, urban planning, environmental protection and enhancing the quality of life.
  With an ambitious agenda, the Eurométropole aims to position Strasbourg as one of Europe's most dynamic cities by boosting its international influence, economic competitiveness, and local environmental and public service standards.
- Programme CLIMAXION: CLIMAXION is a collaborative programme by ADEME and the Région Grand Est, dedicated to advancing energy transition and the CE. It supports local stakeholders in implementing practical solutions focused on energy efficiency, renewable energy, resource conservation and sustainable development.

More information here: https://www.cles-ports-de-strasbourg.eu/qui-sommes-nous/acteurs/

Companies involved in the CLES initiative in 2024:

- Trédi
- Prodair – Air Products
- TEPSA
- NLMK Strasbourg
- Armbruster Frères
- Malteries Soufflet

- Chalot Transports
- Batorama
- Sermes
- Croisieurope
- Blue Paper
- ES Centrale Biomasse
- Skako Vibration
- Comessa
- Boortmalt
- Efrapo
- Schroll
- Rhine Europe Terminals
- Soprema
- ECF Llerena
- Lesaffre Panification France
- Biospringer
- Senerval
- Lesaffre Culinary Strasbourg
- SARM
- Suez RV Nord
- Veolia SOVEES
- Emi&Creno
- R-CUA
- Solibat.

Environmental, Economic and Social Impact

Quantitative and qualitative data, such as waste reduction, resource savings, cost reduction, or improved efficiency:

- Waste Reduction: The CLES initiative recovered 3,777T of various materials, making a significant contribution to local sustainability efforts. Notable waste reduction efforts include local recycling of paper and cardboard, plastic sheeting, Big Bags, sample jars and glassines.
- Reduction of CO2 Emissions: Since 2018, thanks to the efforts of the initiative, 18,588 teqCO2 have been avoided. This reduction has been achieved through more efficient logistics, waste management and energy practices.
- Energy Savings: In 2023, 653,648 m3 of biomethane were produced, equivalent to 6,497 MWh.
- Water Conservation: In 2015, Rhenus Logistics Strasbourg implemented an environmentally friendly truck washing station that recycled 75% of rainwater. This station was made available to CLES companies for truck cleaning until 2022, promoting water conservation in the region.
- Cost Savings: The synergies created by CLES have led to significant financial savings. On average, participating businesses save €6,000 annually due to shared resources and optimised operations. Since 2015, direct gains are estimated at €1.296m.
- Revenue from Secondary Markets: CLES has helped businesses generate additional income through the valorisation of secondary materials and collaborative projects, opening new markets for by-products that would otherwise go to waste.
- Job Creation: The initiative has contributed to job creation within the local economy, as new projects and synergies have led to the development of new roles and business opportunities.

- ROI: The initiative has led to positive ROI for many participating businesses, driven by shared cost savings, resource efficiency, and new revenue streams from waste valorisation.
- Number of people educated or engaged in IS practices: CLES promotes sustainability through joint training sessions, where companies learn about IS practices and how they can implement CE principles in their operations. Additionally, businesses have engaged in joint purchases of electric vehicle charging stations, helping to reduce the carbon footprint of transportation in the port area. In 2023, 30 teachers, 45 young people and 42 other people were made aware of the jobs in the port area.

Timeline and milestones

The CLES (Local and Environmental Cooperation in Synergies) approach has been structured in phases, each lasting two years since phase 4. The sixth phase was completed at the end of 2024, and the seventh phase is currently being structured for 2025, with the finalisation of the contractual agreements between the stakeholders.

Since its launch in 2013, the process has seen a gradual increase in the number of companies involved, from 15 founding companies to 32 by the end of 2024, including the major players in Strasbourg's industrial and port zone.

Each phase is organised into several key stages:

1. Planning and funding (6 months before the start of a phase)

- A draft agreement is submitted to the partners.
- The GUP (Groupement des Usagers du Port) is responsible for coordinating with the institutional partners involved in the project, as well as for the administrative and financial management of the project.

- The search for funding is essential: the first few years were 100% supported by public funds (Climaxion, Région Grand Est, ADEME, Eurométropole de Strasbourg). There has been a gradual transition to 50% private funding, with companies recognising the economic, social and environmental benefits of their participation.

2. Implementing actions and running the network (2 to 3 years per phase)

- Ongoing animation:
  - Monthly newsletter on industrial and territorial ecology news.
  - Strategic watch on grants, reforms and new initiatives.
  - Running the 'Le bon coin des synergies' group to promote opportunities for exchanging resources.
- Thematic working groups:
  - Waste
  - Water
  - Energy
  - Human resources
- Events and community involvement:
  - Organisation of an annual event for employees.
  - Specific actions according to identified priorities.

3.Monitoring and evaluation (throughout the phase)

- Territorial action unit: governance body bringing together the partners twice a year (four meetings per phase) to monitor the progress of actions.
- Company committees: review of past actions and anticipation of future steps. Company committees act as a forum for companies and partners in the process.

The seventh phase, known as 'CLES 2050', is currently being structured, and will continue this momentum by strengthening the objectives of decarbonising activities, promoting collaboration between businesses and gradually integrating solutions tailored to the region's industrial and environmental challenges. The evolution of the financing model and the expansion of the network of players confirm the sustainability of the approach.

Challenges and solutions

As part of the CLES process, several challenges have been identified, requiring a pragmatic approach to overcome them. These obstacles, or rather risks, mainly relate to three dimensions: the commitment of companies, external risks and cooperation between players.

1. Convincing companies and securing their commitment

One of the main challenges is to convince businesses of the benefits of a collective approach. If some companies do not immediately see the benefits, there is a risk that they will become disengaged, leading to a form of inaction on a regional scale. This loss of commitment could result in financial disengagement, threatening the long-term viability of the project, particularly as the contribution of companies is an essential resource for its operation. To mitigate this risk, the strategy is to show companies the tangible and measurable benefits, both economic and environmental. It also involves structuring the actions so that they meet immediate needs while involving the companies in a long-term perspective.

2. External risks and their impact on the approach

Some risks cannot be controlled locally but have a direct impact on companies and, consequently, on the CLES approach. For example, the health crisis in 2021, followed by the conflict in Ukraine, led to a rise in energy prices, putting several

companies in difficulty. This type of macro-economic event has a negative impact on their ability to invest in collective initiatives and can jeopardise the momentum they have built up. Although the Strasbourg port area has not experienced any major failures, these crises are a reminder of the need to remain flexible and adaptable. To achieve this, economic and strategic intelligence is essential to anticipate changes and offer companies solutions tailored to their economic reality.

3. Cooperation between companies and public players

Another major obstacle is the need to maintain effective cooperation between companies and public and private players. A lack of commitment or communication between these parties could slow down the progress of the project and limit its impact. However, this difficulty remains limited thanks to the mutual willingness of the various players. To guarantee this dynamic, the approach is based on balanced and participative governance, in which companies play an active role in the decisions and direction of the project.

4. Financial, organisational and operational challenges

The CLES approach, which received 100% public funding in its early years, now relies 50% on annual contributions from member companies (€1,240/year/company), who contribute via their membership fees to the GUP. Finding new funding, as well as maintaining the commitment of current members, is a constant challenge. From an organisational point of view, it is crucial to maintain a balance in the representation of everyone's interests in the various governance bodies of the initiative, without allowing negotiations to slow down the project. The operational challenge lies in renewing the activities to maintain the interest of the companies and guarantee their commitment, both financially and in terms of governance. This means proposing new synergies and renewing the initiatives on a regular basis.

5. The challenge of local residents

CLES member companies are seeking to limit their carbon footprint, odour nuisance and technological risks, while working with local residents to improve social acceptability. This industrial and territorial ecology approach enables them to reduce their environmental impact and participate in working groups aimed at reviewing their practices. The Port of Strasbourg has also recruited a consultation officer to facilitate dialogue between industrialists and local residents and promote greater acceptance of industrial activities by the local population.

The challenges encountered in the CLES approach are numerous, but they are gradually being overcome thanks to an approach based on communication, adaptability and the structuring of actions. The key to success lies in the ability to bring companies together, anticipate economic developments and maintain effective cooperation between all the players involved.

Potential of replication

The potential for replication of the CLES approach depends on several factors, in particular the resources of the companies involved and the specific characteristics of each area or sector of activity. The approach itself is not directly replicable, as it is based on the unique characteristics of each area of activity, the companies that make it up, and the resources available. It is a port area where businesses and industries work together on well-defined resources and waste, benefiting from specific funding, and for which a system of governance with clearly established priorities has been put in place. However, the methodology used to lead the CLES approach, the way in which the players are brought together, the way in which relationships are sustained and the way in which new members are integrated, is replicable. It has already been successfully applied to sites such as the Écoparc Rhénan and the Plaine des Bouchers in Strasbourg.

Sharing experience and exchanging best practice are essential if this approach is to be adapted to other contexts. The tools and methods used to unite businesses and encourage them to take part in collective initiatives can be transposed, if they are adapted to the specific characteristics of each new zone.
The issues at stake, the type of businesses and economic fabric, and the intentions of the local players all vary from one area to another and must be considered to guarantee the effectiveness of the initiative.

The coordination methodology is based on three main points:

1. Raising awareness: tools such as games and murals are used to engage stakeholders from the outset.
2. Identifying potential synergies: this involves identifying ways in which companies can work together to optimise resources and improve practices.
3. Animation for a fixed period: A mixture of structural actions, the results of which are only visible in the long term, and simpler actions that deliver rapid results to maintain the commitment of companies and manufacturers.

Although the CLES approach is not entirely replicable due to its territorial and sectoral characteristics, certain tools and practices can be transposed, particularly as part of IS initiatives. The key lies in adapting these tools to each specific context, while guaranteeing a solid and viable economic model. For companies to make a lasting commitment, it is crucial that the actions taken offer a tangible return on investment. For example, investments in energy or sustainable development must be profitable in the medium or long term, otherwise companies will be reluctant to commit, especially if these projects require decisions to be taken on other scales, sometimes beyond the local framework.

In short, replication of the approach depends on careful adaptation to each new context, while demonstrating that the projects are economically viable and meet concrete needs. Success in other contexts will depend on the ability to structure and lead initiatives while ensuring consistency with the economic objectives of the participating companies.

Best Practice 6. Nuove Tecnologie Arredamenti (Italy)

Basic information

Founded in 1957 in Sardinia (Italy), Nuove Tecnologie Arredamenti is a small company embracing the philosophy of energy conservation and sustainable production. With over 30 years of experience, the company specializes in bio-environmental consulting and applying ecological paints and natural construction materials. The company is family-owned, and specific expertise has enabled it to develop an environmentally friendly product line. They focus on natural wood and eco-friendly varnishes while also offering low-emission products. Their main goal is to minimize waste production by incorporating eco-design principles that extend product life cycles.

The company actively participates in projects for raw material recovery, collaborating with Sardegna Ricerche and engaging in experimental projects with African countries. Despite their commitment to sustainability, a previous initiative, "Rete Ecologica Natura," involved about 20 companies, including agricultural suppliers and successfully used industry waste such as wool for mattresses and cushions. However, the project faced setbacks due to production errors and funding gaps, forcing the company to source materials outside Sardinia while maintaining its commitment to sustainability.

IS implementation overview

The motivation behind implementing IS within the company stems from a strong cultural conviction regarding the benefits of sustainability. Over the years, growing consumer awareness and media attention have highlighted the advantages of sustainable production, reinforcing their commitment.

Previously, the company built a cooperative, Sardinia Green Synergy, focused on IS across different sectors, from wool processing to organic cosmetic production. The initiative was based on shared values, formalized through a charter of principles ensuring ethical sourcing and sustainability.

One of the company's core IS initiatives involved wool waste recovery. Sardinia has an abundance of sheep, with a ratio of five sheep per inhabitant. However, sheep wool is often classified as industrial waste, left to degrade in valleys. Through IS, the company partnered with "Cravolu" from Nule to clean and process the wool, converting it into yarn for textiles, carpets, and insulation panels. The use of wool mattresses and panels in eco-construction became a defining aspect of their symbiotic efforts, enabling nearly a decade of production. The manufacturing process for wool reuse is constantly evolving to address technical problems (e.g., contamination by moth larvae that makes the product unsuitable for the reuse system in the construction industry but confirms the validity of the offering for high-quality fabrics and natural dye applications, attracting artists and designers).

Process details

Nuove Tecnologie Arredamenti follows a structured process to implement IS, integrating sustainable practices in their material sourcing and production. The key steps include:

- **Waste Recovery and Material Sourcing**: The company recovers materials from multiple industries, including sheep wool, recycled textiles, and wood industry by-products. Sardinia has a significant sheep population, yet the wool is often discarded as industrial waste. By repurposing this wool into various applications, the company prevents environmental degradation while promoting sustainable resource use.

- **Cleaning and Processing:** The recovered wool and textiles undergo rigorous cleaning to ensure suitability for reuse in mattresses, textiles, and insulation panels. In collaboration with "Cravolu", the company processes the wool into yarns, carpets, and natural textile products.
- **Manufacturing and Product Development:** The repurposed materials are transformed into eco-friendly furniture, carpets, cushions, and textile products. The company utilizes traditional craftsmanship combined with modern sustainability techniques, ensuring their products maintain high-quality standards while reducing waste. They have also explored the use of hemp fibres as an alternative raw material, although challenges remain in achieving commercial viability.
- **Quality Control and Certification:** The company pursued ISO 14001 certification to validate its closed-loop production system.
- **Distribution and Market Integration:** Products are sold directly to consumers.
- **Water and Energy Efficiency Measures:** The company integrates rainwater recycling and photovoltaic energy in its production facility, significantly reducing its environmental footprint. These innovations demonstrate that small businesses can achieve sustainability with the right infrastructure, even in resource-limited settings.

The company has come to realize that with limited institutional support and inconstant consumer demand for sustainable products, it is necessary to develop strategies to enhance consumer education and on promoting changes in consumption patterns to facilitate a more sustainable market.

Partnerships and stakeholders

- **Sardegna Ricerche:** A key research partner supporting the company in developing sustainable solutions and material recovery projects. Their collaboration has led to advancements in processing recovered materials, particularly in the textile and wood industries.
- **Cravolu:** A wool processing facility that has played a crucial role in transforming sheep wool waste into valuable textile products. Their expertise in cleaning, treating, and spinning wool has been instrumental in enabling the company's production of sustainable carpets and mattresses.
- **Regional Government (POR 2000-2009):** Provided financial assistance through the European Regional Development Fund (ERDF), which facilitated the creation of an eco-friendly woodworking facility.
- **Universities and Training Programs:** Collaborated with local universities to offer training and educational programs on sustainable material use. These partnerships have included master's courses, technician training, and student internships, creating opportunities for knowledge exchange and skill development in eco-friendly production.
- **Sardinia Green Synergy (Former Cooperative):** A network of like-minded businesses that once shared IS strategies. Though dissolved due to financial constraints, its foundational principles continue to inspire the company's sustainability efforts.
- **Local and Regional Farmers:** Originally part of a broader supply chain for natural fibres and raw materials, providing wool and plant-based components for eco-friendly furniture and textile production.

Environmental, Economic and Social Impact

- Waste Reduction: 50% or waste reduction. The company actively repurposes wool that would otherwise be discarded, preventing unnecessary waste in landfills.
- Reduction in CO2 Emissions: By prioritizing natural materials over synthetic alternatives, the company contributes to lowering carbon emissions associated with furniture production. The system has a power of 19.50 kW. Its energy needs are partly met by photovoltaic energy, which significantly reduces the system's carbon footprint (approximately 3.75 kg of CO2 emitted per hour. Approximate calculations).
- Energy Savings: 30%. Implementation of photovoltaic panels reduces reliance on non-renewable energy sources in production processes.
- Water Conservation: Rainwater collection systems reduce dependence on municipal water supplies, contributing to sustainable resource use.
- Cost Savings: The cost savings is not less than 5% compared to the costs of raw materials. This percentage considers the costs of treating recycled materials before introducing them into the production cycle.
- ROI: NA.
- Revenue from Secondary Markets: turnover € 400,000.00 total approx. The company diversifies its revenue streams by selling upcycled wool-based products and eco-friendly furniture.
- Long-Term Financial Stability: The pursuit of sustainable business models positions the company for long-term economic resilience.
- Job Creation: 10 workers are employed by the company. Furthermore, the company supports the creation of jobs along the recovery, recycling and reuse chain of secondary materials. The company supports skilled artisans and promotes craftsmanship in sustainable furniture making.

- Number of people educated or engaged in IS practices: over 50 participants in the training sessions. Collaboration with universities and training programs raises awareness and builds expertise in IS.
- Number of cross-sector collaboration or partnerships: over 10 partnerships Ongoing participation in sustainability networks fosters knowledge exchange and innovation.

Timeline and milestones

Nuove Tecnologie Arredamenti has evolved through key milestones that reflect its commitment to sustainability, IS and overcoming challenges. Below is a refined timeline based on verified events:

Early 2000s:

Establishing a Sustainable Vision: The new production line of the company was founded focusing eco-friendly furniture production, prioritizing low-emission materials and waste reduction. The founders, experienced in bio-environmental consulting, aimed to integrate sustainable materials into furniture design.

2005–2010:

CE and IS Initiatives: The company actively engaged in IS, collaborating with local artisans, textile manufacturers and agricultural cooperatives. They introduced recycled wood and textiles into production and experimented with repurposing sheep wool for sustainable applications.

2011–2015:

Wool Repurposing and Sardinia Green Synergy Cooperative: The company launched a wool recovery initiative, turning discarded Sardinian sheep wool into mattresses, carpets and insulation panels. The Sardinia Green Synergy cooperative was formed to facilitate cross-sector collaboration.

2016–2018:

Institutional Support and Expansion. Through funding from POR 2000-2009, the company established an eco-friendly woodworking facility. Additionally, it obtained ISO 14001 certification, reinforcing its commitment to CE principles and sustainability standards.

2019–2021:

The company faced significant challenges due to wool contamination issues, which halted its use in construction materials. The COVID-19 pandemic further exacerbated financial difficulties, leading to a near shutdown. Emergency funding allowed operations to continue, but partnerships and initiatives were frozen.

2022–Present:

Business Recovery and Future Expansion: Post-pandemic, the company has been working to revive partnerships and IS efforts. A key focus is on relaunching Sardinia Green Synergy with a more sustainable financial strategy. They are also advocating for policy incentives to support CE businesses and expanding their product reach in textile and artisan markets.

Challenges and solutions

Challenge 1: low market demand for sustainable products

One of the main challenges faced by Nuove Tecnologie Arredamenti is the lack of widespread consumer demand for sustainable furniture and eco-friendly materials, making it difficult to compete with non-sustainable mass-produced alternatives. **Solution:** The company has invested in consumer education initiatives, leveraging social media, workshops, and collaborations with educational institutions to raise awareness of the benefits of sustainable furniture. Additionally, they have worked on enhancing their marketing strategies to appeal to environmentally conscious buyers and niche markets that prioritize sustainability.

Challenge 2: financial constraints and limited access to funding

To sustain IS efforts, SMEs need financial support. Sporadic supports provided by local governance systems, as well as sustainability incentives, are often insufficient to cover operational costs. **Solution:** Despite these barriers, the company successfully obtained financial support from the European Regional Development Fund (ERDF) in the past. To ensure long-term financial stability, they are actively pursuing private investment and crowdfunding options while advocating for increased government subsidies and financial incentives for small sustainable businesses.

Challenge 3: regulatory barriers and lack of policy support

Navigating regulatory frameworks has proven difficult, as bureaucratic processes and lack of clear policies on sustainable material usage create obstacles to implementation. The absence of standardized sustainability criteria limits the company's ability to scale their eco-design solutions. **Solution:** Nuove Tecnologie Arredamenti is working closely with industry associations, policymakers and research institutions to advocate for clearer regulations and incentives that support sustainable manufacturing. Their participation in policy discussions aims to push for greater transparency and support for CE initiatives.

Challenge 4: Production Setbacks Due to Material Processing Issues

A significant setback in their wool processing initiative arose when contamination from moth larvae rendered wool panels unusable for bioconstruction. This setback led to financial losses and reduced the scope of there is initiatives. **Solution:** The company has since partnered with Cravolu, a specialist in wool treatment, to enhance the cleaning and processing stages. Additionally, they are exploring new

treatment methods and collaborations with textile researchers to ensure that their materials meet high durability and safety standards.

Challenge 5: Difficulty in Maintaining Long-Term Partnerships

Many of the company's previous IS partnerships, including the Sardinia Green Synergy cooperative, were dissolved due to financial instability and a lack of sustained institutional support. Without strong networks, scaling IS efforts remains difficult. **Solution:** To rebuild a robust partnership network, the company is working on new synergy initiatives, with a stronger focus on securing governmental backing and private investment. They are also strengthening ties with universities, research centres, and regional suppliers to ensure greater collaboration and long-term commitment.

Potential of replication

Nuove Tecnologie Arredamenti's approach to IS offers a scalable and adaptable model that can be replicated in multiple industries. By demonstrating how small businesses can integrate IS principles, the company provides a framework that can be applied across regions with similar sustainability challenges.

Key Factors Supporting Replication:

- **Adaptability to Different Sectors:** The company's methods for repurposing waste wool, recycled textiles, and eco-friendly wood can be extended to construction, fashion, and agriculture, where by-products often go to waste.
- **Scalability of the Business Model:** The modular approach to waste recovery and processing makes it feasible to replicate in areas where local raw materials are underused.

- **Consumer Demand for Sustainability:** Growing interest in eco-friendly products in global markets strengthens the viability of this model for businesses catering to environmentally conscious consumers.
- **Policy and Funding Opportunities**: The European Union's CE initiatives offer funding to support businesses looking to adopt similar waste-reduction and resource-efficiency strategies.
- **Cross-Sector Collaboration**: The company has highlighted the importance of partnerships with research institutions, suppliers, and local stakeholders, which would be essential for any organization looking to replicate its model.

With increased collaboration, policy support and industry engagement, this model can be adapted to multiple contexts, driving sustainable production and CE expansion worldwide.

Best Practice 7. ProSeed (Switzerland)

Basic information

ProSeed is a Swiss startup founded in 2023, originating from a collaboration with HES-SO, University of Applied Science and Art of Western Switzerland. The company's professional profiles and core competencies are centred on food techniques for the valorisation of wet by-products in the food industry, engineering and business management.

ProSeed's IS approach creates value from waste while reducing environmental impact. Their business model is built on two key components: raw material procurement from by-product streams and innovative processing technology. ProSeed offers modular processing units that enable food and beverage producers to process by-products on-site, creating a symbiotic production system. This allows manufacturers to transform their waste into revenue streams while contributing to a more sustainable food system.

Operating at the intersection of sustainability and food technology, the company specializes in sustainable supply chain solutions and has developed proprietary stabilization technology that converts previously overlooked waste streams into premium food ingredients. Using machines designed by European manufacturers, Martigny's production site has the capacity to produce 200 tonnes of barley flakes a year, equivalent to the waste produced by 5 million litres of beer.

IS implementation overview

ProSeed was established to address a critical gap in the food production industry: the sustainable reuse of wet by-products that would otherwise be discarded as waste.

The company works as an intermediary between breweries generating these by-products and ingredient manufacturers in need of new raw materials. This approach aligns with IS principles, fostering cross-sector collaboration to minimize waste and maximize resource efficiency.

The implementation of ProSeed's IS model is based on an innovative drying process designed to significantly extend the shelf life of brewer's spent grain.

Typically, these by-products spoil within 4–8 hours, rendering them unsuitable for further use. ProSeed's proprietary technology extends the shelf life to 18 months by mechanically dewatering and drying the material, creating a stable product that can be reintegrated into the supply chain.

A key component of this implementation is the plug-and-play modular drying system, which is designed to be installed directly at breweries, soy manufacturers and other food processing plants facing similar challenges.

The technology is housed within a compact standardized shipping container, allowing for easy installation, minimal spatial requirements and scalability. Breweries can integrate this system without requiring major infrastructure changes, making it highly adaptable across different production environments.

Once the wet by-product is processed, the resulting dried material—such as barley flakes—is sold to ingredient manufacturers, particularly millers who further refine it into flour or protein concentrates. The process not only reduces waste but also generates additional revenue for breweries by transforming what was previously considered a disposal cost into a valuable commodity.

To support the broader adoption of IS practices, ProSeed launched the ProSeed Upcycling Link Program (PULP), a structured initiative that connects businesses committed to upcycling and IS. PULP serves as a platform for knowledge exchange, industry collaboration, and market expansion, further reinforcing the sustainability and economic viability of IS initiatives.

By combining technological innovation with a scalable business model, ProSeed demonstrates how IS can drive both environmental sustainability and economic gains, creating a replicable framework that other industries can adopt to optimize resource utilization and waste management.

Process details

ProSeed's IS implementation involves a structured sequence of technological and operational processes that ensure efficient valorisation of wet by-products. The entire process is engineered to be highly energy-efficient and seamlessly integrated into existing production facilities.

The key steps include:

1. **Installation of the modular drying system**. A standardized, plug-and-play drying unit housed within a containerized system is placed at the production site of breweries or other food processors generating wet by-products. This setup allows for quick deployment and minimal disruption to existing operations.
2. **Mechanical dehydration.** Before drying, the wet by-product undergoes a mechanical pressing step to extract excess moisture. This step is crucial for enhancing energy efficiency in the subsequent drying phase by reducing water content early in the process.

3. **Drying process**. The dewatered by-product is subjected to an innovative low-energy drying process that consumes 50% less energy compared to conventional drying technologies. This technology ensures that the final dried material maintains its food-grade safety and quality, making it suitable for reintegration into the food supply chain.
4. **Quality control and food safety assurance.** Throughout the drying process, rigorous quality checks are conducted to ensure compliance with European food safety standards. The system is designed to retain the nutritional integrity of the by-product while preventing microbial contamination.
5. **Final packaging and logistics.** Once dried, the material is packaged in bulk and transported to ingredient manufacturers, such as millers and protein processors. These manufacturers further refine the dried product into high-value ingredients like flour, fibre concentrates or protein powders for various food applications.
6. **Integration into existing industrial ecosystems.** The dried by-products are designed to seamlessly integrate into existing food production infrastructure, requiring no additional processing steps or new equipment investments by manufacturers. This integration enhances the economic viability and adoption potential of the ProSeed model.

This streamlined process not only reduces waste but also creates new economic opportunities for breweries and food processors, enabling them to monetize their waste streams and participate in a CE.

The energy efficiency of the drying system and its capability to operate on 100% renewable energy sources further solidify its role as a sustainable solution for IS.

Partnerships and stakeholders

- **Research Collaborations:** HES-SO (Swiss University of Applied Sciences). https://www.hes-so.ch/en/homepage, EPFL Sustainable Materials Laboratory https://www.epfl.ch/labs/sml/
- **Financial Support:** ProSeed IS project received grants from public and private foundations.
- **Industry Partners:** Collaborations with breweries, bakeries, soy manufacturers, flour mills, and ingredient manufacturers (Schweizer Brauerei-Verband https://bier.swiss/, Zenhäusern company https://www.chezzen.ch/
- **Investors:** Incubator The Arc https://theark.ch/en/, Innosuiss Swiss Innovation Agency https://www.innosuisse.admin.ch/en, Fonds national suisse (FNS) https://www.snf.ch/en , Zenhäusern company https://www.chezzen.ch/ and local private sector funding to scale operations.

Environmental, Economic and Social Impact

ProSeed actively participates in IS networking events across Europe. They organize roundtable discussions, such as the launch event of their pilot project, which attracted 180 attendees. Strategies to ensure long-term impact include:

- Maintaining industry partnerships through networking and incubator programs.
- Promoting IS adoption via press, social media, and stakeholder engagement.
- Hosting educational initiatives to spread awareness about upcycling potential.
- Waste reduction.

- Energy savings: 50% reduction in energy consumption, using potentially the 100% of renewable energy.
- Job creation: Founded as a start-up employing three team members, ProSeed has expanded to permanently employ nine specialists across production quality control, agri-food systems engineering, management, and marketing. The company's innovative food waste recovery systems have generated substantial employment ripple effects throughout the supply chain. By transforming by-products into valuable ingredients, ProSeed has helped secure existing jobs in partner breweries and bakeries that would otherwise face higher disposal costs and reduced profitability.
- Number of people educated or engaged in IS practices: Informed: around 200; Engaged: more than 30.

Timeline and milestones

2021: Research and Concept Development: ProSeed's journey began as a research project during Aurélien Ducrey's master's thesis at HES-SO. The research focused on the valorization of brewer's spent grain, a major by-product of the beer industry. Encouraged by positive feedback from industry players, the research phase extended into further feasibility studies and early prototyping.

2022: Proof of Concept and Technology Development: Building upon initial research, the team conducted pilot tests to refine the drying technology. This phase involved laboratory testing to ensure food-grade safety and compliance with European regulations. At the same time, ProSeed engaged with breweries and ingredient manufacturers to assess market demand and explore potential partnerships.

2023:

- Company Formation and Pilot Implementation: Following the successful demonstration of the concept, ProSeed was officially established. With the

support of public and private funding, the company installed its first modular drying unit at a brewery to validate the real-world performance of the system. This milestone marked the first full-scale industrial pilot, proving the effectiveness of the plug-and-play drying technology in a commercial setting.

- Securing Financial Support: ProSeed secured €1 million in grants from public and private foundations, allowing the company to transition from prototype to operational model. This funding enabled further development, production scaling, and market expansion.

2024:

- Expansion of Industrial Partnerships: With a validated model, ProSeed expanded collaborations with breweries, soy manufacturers, and flour mills. The company launched the ProSeed Upcycling Link Program (PULP) to create a network of businesses committed to IS and upcycling solutions.
- Scaling and Market Penetration: The company initiated the broader deployment of its modular drying units, targeting multiple breweries and food manufacturers. The goal was to replicate the success of the initial pilot and encourage widespread adoption of the technology, reinforcing the scalability of ProSeed's model.

Future Goals: Industry-Wide Adoption and Policy Advocacy

ProSeed aims to further integrate IS into mainstream food processing industries by advocating for more supportive policies and increased financial incentives. The company continues to innovate its technology, ensuring that its drying system remains energy-efficient, cost-effective and adaptable to multiple industrial contexts.

Challenges and solutions

Challenge 1: Short Shelf Life of Wet By-Products. One of the most pressing challenges in IS is the rapid spoilage of wet by-products such as brewer's spent grain. Without immediate processing, these by-products degrade within 4–8 hours, making them unsuitable for reuse in food applications. This constraint has historically led to large volumes of waste being discarded rather than repurposed. **Solution:** ProSeed developed a mechanical dehydration and drying process that extends the shelf life of these by-products to 18 months. This not only reduces waste but also creates a stable, food-safe material that can be reintegrated into the supply chain.

Challenge 2: Space Constraints at Production Sites. Breweries and other food manufacturers often operate in space-limited facilities, making it difficult to install additional equipment for processing by-products. Traditional drying units require substantial infrastructure modifications, discouraging companies from adopting such technologies. **Solution**: ProSeed designed a modular, plug-and-play drying system housed in a standard shipping container. This allows for easy on-site installation without requiring extensive infrastructure changes. The unit can be placed outdoors or in available production areas, making it a flexible solution adaptable to different industrial environments.

Challenge 3: High Energy Consumption of Conventional Drying Technologies. Traditional drying methods are energy-intensive, leading to high operational costs and reduced sustainability. Companies seeking to implement IS must balance economic feasibility with environmental responsibility. **Solution:** ProSeed's drying technology consumes 50% less energy than conventional systems and can operate entirely on renewable energy sources. This significantly reduces carbon emissions and enhances the financial viability of the process for adopters.

Challenge 4: Industry Reluctance to Adopt New Processes. Many companies hesitate to integrate IS solutions due to concerns about operational disruptions and uncertain economic returns. Additionally, regulatory compliance requirements for food safety further complicate the transition. **Solution:** To build industry trust, ProSeed engaged in extensive collaborations with breweries and flour mills, demonstrating the reliability and cost-effectiveness of its model. The company also ensures full compliance with European food safety standards, making its solution more attractive to food industry stakeholders.

Challenge 5: Financial Barriers to Scaling Up. While research and development phases often receive government or institutional funding, companies face difficulties securing investment for scaling up IS solutions. Many startups struggle to bridge the gap between laboratory validation and full-scale commercial deployment. **Solution:** ProSeed has participated in local, national and European calls for tenders for the sustainability of industrial processes and business innovation, obtaining grants from public and private foundations, and enabling the company to go from prototype to market-ready implementation. The company is also fighting for more political support and financial incentives to help other companies adopt IS models.

By tackling these key challenges with innovative and adaptable solutions, ProSeed wants to position itself as a leader in IS, paving the way for broader adoption of sustainable resource management practices across the food industry.

Potential of replication

The ProSeed model presents a high potential for replication due to its modularity, adaptability and economic viability. By addressing common industrial waste challenges through plug-and-play drying technology, the company has

demonstrated how IS can be efficiently integrated into existing food processing infrastructures. The scalability of this approach makes it applicable to various sectors beyond breweries, such as soy production, coffee processing and fruit pulp industries, all of which generate high-moisture by-products requiring stabilization.

Key Factors Supporting Replication:

- Standardized and Modular Design
- Energy Efficiency and Sustainability
- Adaptability Across Sectors
- Regulatory Compliance and Food Safety
- Economic Incentives and Financial Viability
- Case Study on Scaling Efforts

ProSeed has already expanded beyond its pilot project and is working on implementing its system in multiple breweries across Europe. The success of its ProSeed Upcycling Link Program (PULP) is a testament to the company's ability to facilitate cross-industry partnerships, helping other businesses integrate CE principles into their operations.

To support wider adoption, ProSeed has also engaged in knowledge-sharing initiatives and participated in EU-funded projects focused on IS. By forming strategic partnerships with academic institutions, private investors and regulatory agencies, the company is working to accelerate industrial adoption at a broader scale.

Best Practice 8. Industrial Zone Tezno (Slovenia)

Basic information

Industrial zone Tezno is a business and industrial zone with more than 200 companies and just under 4.000 employees, engaged in industries ranging from metal processing to information technology, research and development.

After the collapse of the single industrial giant – Tovarna Avtomobilov Maribor – individual companies began growing in the zone, not really following a common goal. Therefore, the institute Business Production Zone Tezno was established as a non-profit organization that manages and develops the zone. Its responsibilities include the distribution of energy and water, as well as providing business premises. In 2019 a Smart City Platform has been introduced as a pilot activity fostering IS in the zone, which became a living laboratory or pilot environment for IoT technological solutions fostering IS.

Therefore, the institute presents a top-down approach to setting up symbiosis among companies in the zone and pilots the introduction of IS through various projects.

IS implementation overview

The Business Production Zone Tezno strives to ensure that the zone and its entities operate in the spirit of social responsibility. By managing the zone, the institute is a sort of a platform within the zone, which brings together the stakeholders within the zone to participate in modern energy solutions that emphasize the green transition and IS. One such project was piloting the Smart City Platform for which the Industry Zone became a pilot area. By introduction of IoT technologies in the processes of managing waste in the zone, the digital support for analysis the waste generation

was set up, which is used by producing companies in the zone, which can thus better analyse their material flows and identify the valorise the waste of other companies as the first step of the symbiosis among the companies.

The platform has already contributed to waste reduction by reduction of 4.370 litres of fuel for transport vehicles per year and a reduction of 14 tons of CO2 exhausts.

Another project for achieving symbiosis among the companies within the zone is the pilot to develop a sustainable energy cycle concept involving solar energy, energy storage systems, charging infrastructure and mobility solutions. The "Digitalization of Energy Infrastructure Management and Control System" (DUEISVEzaCT) project will play a key role in this effort, introducing advanced systems for monitoring and managing energy consumption, battery energy storage systems, and infrastructure management within the zone. As individual companies within the zone could not apply for the project, financed through the national ministry for Environment, Climate and Energy. Within this synergy collaboration the energy flows will be optimised so that the energy will be produced within the zone and its usage commonly utilised through a joint system of management and distribution.

Maybe not as technological, but still greatly needed and provided within the zone is the set-up of the joint human resources and human resource development through education centre within the zone.

Exchange of staff and experts between the companies and common training of future experts shows the long-term orientation of the zone and is a great opportunity for fostering IS.

Process details

For the IS connected to waste management the specially developed informational tool was created by the University of Maribor, which was linked to the sensor devices to create waste disposal units' smart.

This meant that the users of the industrial zone, which became a living lab testing area of the new platform had to agree to the usage of this technology, as it was an innovation within our industrial zone.

The technology the platform is linked to is the Smart ECOdip, which is the basis of smart waste collection that helps in analysis of the waste and material flows within the companies of the industrial zone that use this innovation.

Furthermore, the platform will also enable the smart management of the lightning within the zone, as well as the smart water and consequently wastewater management of the industry within the zone.

With the other project – DUEISVEzaCT, the zone is in the process of modernization to become more self-sufficient. For this purpose, the main resource the companies have will be shared – and that is roof space for creation of electricity, where the electricity will be managed by the institute for the entire zone, just like the institute provides it now. However, not only electricity, but also heat recovery will be used, to follow the EU regulation of linking waste heat with heating systems.

Already the waste heat is being used to a smaller extend between companies, for the heating of production units.

In the past the heat was collected in the cooling pipes and was used for the open-air swimming pool, offering a service for the general population of the city and thus forming a symbiosis between the industry and the local environment. However, when the zone stopped being the owner of the swimming pool, the facility was abandoned and transformed.

Partnerships and stakeholders

The partners of the pilot project of the Smart Street are:

- Business Production Zone Tezno Institute
- University of Maribor – Faculty for Logistics
- University of Maribor – Faculty for Electrical Engineering and Computer Sciences
- University of Maribor – Faculty for Criminal Justice and Security
- Public utility company for Waste Management SNAGA

The main stakeholders are the City of Maribor and the companies within the zone, especially: Kemol, Starkom, Stamle, Zem-Himoing, Cimos, BNM Avtomobilska industrija, Feropol, Elpos inženiring, Fortis Maribor, Hagspiel, Lasertehnik Marfin, Palfinger, Pichler & Co, Piktronik, Srius Maribor, Stork, TAM Europe, Trgofort, Valtis, and Vamar.

Environmental, Economic and Social Impact

- The pilot testing showed a reduction of 168 rounds of waste collection transports.
- Annually the reduction of CO_2 was calculated at 14 tons.
- The reduction of energy lowers the consumption of fuel by 4,370.
- The application for water waste reduction is still in the planning phase, so no data is yet available.

- The costs for reduced waste management are significant, whoever they haven't been fully presented yet, as the project was still in a pilot phase and not fully market driven.
- The ROI has not yet been calculated as the project was in the pilot phase and not fully market driven, also the implementation of technology was not solely financed by the companies.
- The revenue from the secondary market will be applicable when the full-scale operation starts soon.
- So far 7 jobs were created for the implementation and monitoring the Smart City Platform.
- Almost all 4,000 employees at the companies within the industry zone were introduced to the pilot project as awareness raising, however, only several 1-3 technician level staff at each of involved companies were education in the technology, approximately 40 people.
- The living lab set up at the industrial zone was a perfect platform for collaboration of academia and industry.

Timeline and milestones

The first and most obvious milestone was the creation of the institute, which started managing the industrial zone, which became the first managed industrial zone in Slovenia.

Through the management the joint services became the second milestone, as the provision of electricity for individual companies through the institute became a way of energy management within the zone and the first leverage for implementation of synergies among the companies.

The collaboration with the University of Maribor both in spatial planning and with the Regional Development Agency for Podravje – Maribor in development of city level and regional development strategies allowed for the further development of the industrial zone with impact on attracting companies that could establish IS with each other.

The pilot project Smart Street, led by the university, was the first such pilot project and the most important milestone, as it brought companies together and demonstrated the positive impact on the environment and reduction of costs following the implementation of the innovative technologies. However, it was only the beginning, as the next milestone is foreseen with the next project: DUEISVEzaCT, which will set up digitalized management of the energy infrastructure shared by the companies within the industrial zone.

Challenges and solutions

The initial challenge was setting up the joint management of the industrial zone altogether. As a small and non-for-profit institute, there was scepticism among the entrepreneurs in the industry zone, who were mostly looking for cheap space to utilize for their production.

However, with personal approach and high-quality work, and by representing the common interest of the companies – for example, negotiating energy prices for electricity in the zone, for all the companies – the institute was able to provide benefits for the companies.

Also, maintenance of the zone infrastructure such as water or gas pipelines and road infrastructure within the zone raised the level of trust into the institute.

This is how they were able to follow the companies more directly and suggest improvements and collaboration between them as they had an overview of their production, their needs, and their material and energy flows.

Thus, they were able to connect the ice-cream making factory to use excess heat for preparation of atmospheric conditions for ice-cream production as a typical small-scale example of IS.

However, the real challenge was the impact on the environment that as the zone wanted to reduce, while at the same time their companies wanted to reduce the costs of operations, waste and energy management and therefore trusted them in implementing innovations such as the Smart City Platform in collaboration with the university of Maribor.

In a way the institute was the answer to the challenges the companies had in human resources, as they had no opportunity to actively pursue symbiosis among companies in the zone, nor did they have legal frameworks of setting up such cooperation – and that's where the institute, managing the entire zone, came into play.

Potential of replication

The replication is not so much connected to their cases, as it is in the top-down approach. The manager of the industrial zone is the one that can IS and it is an opportunity which should be actively implemented. However, to do this, the industrial zone manager must have the capacity for this, which above all means the staff with knowledge of material flows, energy flows, legal frameworks,

connections to knowledge providers and if possible, to local/regional level policy makers.

This means that the team managing the zone should follow the mission of achieving IS within the zone, as it's the perfect platform to achieve just that.

Best Practice 9. Kooperativa 103 (Slovenia)

Basic information

Kooperativa 103 – synergy between food producing and processing SMEs: Rok's nut butter (LLC), Kokica (LLC) and Matic Vizjak (gainful activities of the farm) and their business partners within the value chain.

IS implementation overview

The co-op Kooperativa 103 is made up of three companies: Rok's nut butter, Kokica and Matic Vizjak.

All three companies have the activity of manufacturing of prepared meals and dishes. As they were all too small to be interesting for big producers, yet too big to produce from home environment, they joined into Kooperativa 103. As a cooperative they jointly got the facilities and equipment for production and processing of their products, as well as packaging and storing.

As all members of the co-op are part of food production and processing sector, they are aware of the quantities of fruit and vegetables which are thrown away as waste yearly.

The first symbiosis was established with the producer of pears. As they are not always suitable for being sold directly on the market as fruit (depending on the looks and ripeness level), the cooperative started using pears that would be discarded as biological waste to produce a spicy sauce.

Another example was symbiosis with a tomato producer. The cooperative set up a new type of tomato sauce, like ketchup.

Further examples of symbiosis include production of fruit smoothies based on waste bananas, strawberries and apples.

The added value of such symbiosis is their scale.

Large scale producers of fruit and vegetables are already supplying large producers of fruit and vegetable-based products, however small-scale local producers are left out of such value chains, causing them to discard the fruits and vegetables they cannot directly sell. Therefore, such symbiosis considerably reduces food waste among small local producers.

Furthermore, by sharing production equipment among members of the cooperative a new symbiosis is achieved, as the production and packaging costs and energy use is reduced. And the carbon footprint is reduced also by joint storage and logistics capability, as they deliver the products jointly through their distribution channels, reducing individual cargo transports.

Furthermore, through human resource pulling they are constantly looking for a way to reduce waste in their production line, or how to reuse the byproducts of their production and have thus developed a way to use byproducts of marmalade production to prepare ice cream flavours as a new product.

Process details

As the successful synergy of the three companies is based in the joint usage of production equipment, the following list is not complete as with further development new equipment is added. Kooperativa 103 is jointly using/offering usage of the following technology at their premises:

- cooking kettle
- de-waxer
- grinding machine
- slicing and chopping (slicer) machine
- semi-automatic filling machine
- top and side labelling, side and top labelling unit
- pasteurisation, hot filling, juices
- manual and automatic filling
- portion packs 2000 pieces per hour
- popcorn popper
- coating machine (chocolates, granola, etc.)
- filling machines - from 40 g to 1 kg
- tablet counting machine (capsules, tablets)
- large colloid mill for processing (from 0,03 mm to 0,4 mm)
- planetary mixer (honey cream), homogeniser
- induction welding machine
- small bottling plant
- capping machine for filling bulk material
- cold store
- freezer
- industrial printer for printing declarations

The processes are adopted in a way to fully utilise the equipment and technological processes used, especially the reuse of byproducts in preparation of snacks, so they can be reused as ingredients of other products such as natural flavours for drinks, for flavouring of popcorn or ice-cream flavours.

In addition, the joint storage facilities are also optimized for storage of products and joint logistics for transport. The symbiosis consists of achieving optimal storage

condition through heating and drying of the storage space by linking the atmospheric conditions of the production and storage facilities. In practice this ensures that the drying of fruit is located at the place where heat is produced for cooking or popping of corn, further drying the air in the room, while the cooling facilities are used both for preservation of ingredients, cooling processes of preparing the final product and storage of items that require low temperature.

At the same time, packaging, which is based on environment friendly materials that need to be stored in the dry spaces, is also stored at the same area with dry atmospheric conditions.

In addition, many simpler protocols for production, maintenance and above all hygienic standards are applied, so that the use of chemicals is reduced to a minimum, while still maintaining the highest possible standards for production of meals and or beaveries.

Partnerships and stakeholders

- https://shop.pokica.com/en/
- https://roksnutbutter.com/en
- https://kmetija-vizjak.si/

Environmental, Economic and Social Impact

Due to the small scale of the Kooperativa 103 the overall impacts are mostly on the qualitative level:

- Considerable reduction of food waste through prolongation of usage period or processing of items that would otherwise be discarded as waste into food or drink products.
- The Kooperativa 103 is noticing reduced costs for energy and fuel used in transport, due to reduced need for energy and fuel consumption, which

shows the reduction of energy used for heating and cooling as well as production itself and thus indicates a reduced carbon footprint.

- Additionally, there is a reduction of energy used, due to symbiosis of production processes (organising production so that the equipment isn't losing work temperature while passing from one product to another).
- The shared use of equipment and even staff, the costs are reduced as the investments and maintenance costs are reduced, as well as operating costs of the equipment.
- By jointly purchasing the equipment, the lower initial costs were covered faster and companies started creating revenue earlier.
- Secondary markets are starting to develop as a byproduct of the operations of Kooperativa 103, mostly through further offering of the facilities of the coop to new users or entering new markets with occasional products when additional waste food is being used to create new, occasional products (such as smoothies).
- The joint marketing canal allowed for creation of 2 new jobs for direct sale, which would not be possible for any of the individual companies within the Kooperativa 103.
- 3 people gained on the job experience in setting up IS.
- There is one clear cross-sector cooperation with the producer of packaging for the purposes of produced food and beverage, with more occasional cooperation based on seasonal demand and potential waste of fruit that is not directly sold and becomes the input material for the processing.

Timeline and milestones

The Kooperativa 103 did not set out to create the IS and has therefore not set indicators to follow, but the effect on the three individual companies can be measured individually.

Within a year of cooperation Kokica d.o.o. has doubled the number of its employees. Additionally, it created an added value per employee, which is above the national added value, and over 50% above the regional added value per employee, and the revenue has increased for 22%.

A very important milestone was obtaining the Start-Up Slovenia award, which allowed the mainstreaming of their main product in the large distribution chain. Another milestone that was set by Kokica was expanding the market.

As the most important milestone one can count the survival of the company beyond the initial phase of return of investment, which then enabled the company to further expand their product range and are now even able to support other companies as a small-scale business angel, both in financial but even more in knowledge support.

They have reached foreign markets with their main products – Popcorn and are about to reach the next milestone of offering their product through Amazon, which will change their capacity for storage as Amazon is setting different rules for availability of the products in their own storage facilities.

Further milestone was the optimisation of the packaging for their product, as this allowed them to be present in vending machines and improved the storage capacity, with the possibility to store 6 units instead of one in the same space.

Another milestone was setting up the resail point for the products of Kooperativa 103 and some other local producers, where the milestone was reached by setting

up a local shop in Maribor, where the main criteria for an article is the production and local character of the product.

Challenges and solutions

Several obstacles were identified, that were in fact tackled by the setting up of the Kooperativa 103, which is a type of organic symbiosis between its founding members.

The first such challenge was the raw materials for production, where there is a connection with producers of corn, however, it was the ingredients for flavouring of popcorn that led to connection Kokica with other two companies founding the Kooperativa 103. The challenge was closely linked to the quality of the product and the availability, which was not linked to the larger global markets. Therefore, the rational was to find local producers, which might not have the lowest price, but are able to guarantee the high quality of the product, availability of the product, and reduce the supply chain carbon footprint.

Furthermore, through shared equipment and shared production lines the knowledge exchange happened, and joint development of new products became possible.

One of the biggest challenges for Kokica was the packaging of popcorn, which was traditionally in bags, which must be airtight. Such bags take up a lot of space as there is air inside the bag. This causes the waste storage space, as well as lower number of products placed on retailer's shelves. By jointly developing new packaging from recycled materials and developing their own graphic options for their product, they developed a system of replacing one unit in storage (in a bag) with six units (in a new packaging), which can be further personalized within their own production line with no additional costs or burthen to the environment.

Furthermore, this solved the challenge of placement of their product in the vending machines, as the bags got caught in the mechanisms, while the new packaging does not and again 6 units can be placed instead of one, offering more sale opportunities and increasing the revenue.

In addition, this also increased the symbiosis among the companies within the Kooperativa 103, as the new packaging is appropriate for a larger variety of products of each company and they are therefore reducing the costs and carbon footprint in production of packaging and its labelling as well as personalization, while also using recycled materials. This way the joint development of the packaging with joint intellectual capacity of the three companies of the coop and the external company, which is in a partnership relationship with Kokica, they have created a new container with a multipurpose use, which does not seem revolutionary, but includes many innovative features.

Potential of replication

Companies are always looking for success stories, to find inspiration, or to find ways to optimise their own processes.

Large ventures are often very appealing, but difficult to replicate, unless a commonly available technology was used to create the change.

In the case of Kooperativa 103 it was the logic behind the companies that was crucial, as they all realized that small companies need to find their niche and cooperate among themselves. A joint usage of equipment and facilities is a common procedure within cooperatives, however, using the compatible equipment for various products was not common. Usually, the different producers of the same product would make use of shared equipment, while in this case the final products vary, yet they can technically be produced on the jointly owned

equipment in shared use. And by shared production facilities the upgrade to shared storage and logistic capacity was a logic next step.

The takeaway for other companies that would be interested in replication is that they should know their material flows and their production processes, as the optimisation and customization of their production processes can show many opportunities for collaboration and/or symbiosis with other producers who may have a different product but have similar production processes.

This is a pure case of production processes being more important than material flows, as material flows are only a part of IS achieved between the companies that joined together to form Kooperativa 103.

Another takeaway is the legal structure, as there are different possibilities that could formalize the cooperation between these three companies, however, a cooperative was more liable than a consortium or partnership agreement. Still the companies are setting up partnership for specific projects they are doing, with companies outside the coop, which can also set up symbiosis on non-permanent basis, such as usage of waste food or food byproducts that are used for specific production, which is possible through the efforts of the cooperative.

Best Practice 10. BIOVA (Italy)

Basic information

Founded in Turin in 2019 by two young entrepreneurs, BIOVA Project began with a focused mission: reducing bread waste by transforming it into craft beer. What started as a neighbourhood initiative has evolved into a comprehensive food innovation hub.

BIOVA operates through a IS model that connects all stakeholders in a sustainable ecosystem. Bakeries and supermarkets donate their unsold bread, which BIOVA collects and delivers to partner breweries. These breweries transform the reclaimed bread into unique beer products, which are then distributed back through the same bakeries and supermarkets that initially provided the bread waste.

This closed-loop system creates value from what would otherwise be discarded, addressing the persistent problem of food waste while creating a marketable product. The company's name itself suggests a commitment to biological innovation and value addition.

BIOVA exemplifies how entrepreneurial thinking can transform environmental challenges into business opportunities while fostering community collaboration and sustainability.

IS implementation overview

BIOVA Project exemplifies IS through its innovative business model that transforms food waste and by-products into value-added food products. The company operates nationally in Italy with 2 founder full time, 2 employees and one intern, 3 of whom actively work on IS initiatives.

The core IS activity consists in:

- **Bread Recycling Partnerships.** BIOVA has established strategic partnerships with multiple retail and food service businesses such as supermarket chains (COOP Nord-Ovest, Carrefour, Eataly), from whom BIOVA collects the unsold bread for beer production, resulting in co-branded beer products. The HoReCa chains cooperation (as Capatoast, Forno Brisa in Italy) allows similar bread collection and beer production with co-branding arrangements.
- **Industrial Food Waste Recovery.** The partnership with major pasta brands in Italy (i.e. Pasta Berruto) consolidates the collection of broken pasta pieces that would otherwise be discarded, repurposing them for beer production and snack manufacturing.
- **Internal Circular Systems.** The third step seals the closed-loop production: BIOVA reuses its own beer production by-products as raw materials for developing a range of snack products, creating a further internal symbiotic process.

BIOVA's approach to IS is deeply embedded in its business model, with dedicated staff responsible for creating industrial partnerships to integrate symbiotic practices. BIOVA becomes a B-corp.

Process details

BIOVA has implemented a range of innovative technologies, processes and systems to optimize its IS approach, ensuring the efficient transformation of food waste into new value-added products. The evolution from bread-to-beer conversion to the creation of protein-rich snacks from brewing by-products highlights the company's commitment to maximizing resource efficiency and minimizing environmental impact.

The process begins with raw material recovery, where unsold bread from bakeries and supermarkets is collected and repurposed in beer production. This step involves a careful selection and preparation phase to ensure consistency in quality and brewing performance. Similarly, broken pasta pieces, which would otherwise be discarded, are incorporated into the brewing process, demonstrating the adaptability of BIOVA's system.

Once the beer production is completed, the brewing process generates a substantial amount of spent grain, a by-product rich in proteins and fibres. Rather than disposing of this material, BIOVA has developed an innovative waste valorisation system that transforms spent grains into high-protein snacks. This step involves drying, milling and incorporating the spent grain into new formulations, reducing raw material consumption by 40% compared to traditional snack production.

To ensure efficiency and scalability, BIOVA integrates traceability and quality control systems, leveraging digital platforms to monitor waste recovery, production efficiency and environmental impact. These systems enable precise tracking of raw materials and by-products, ensuring compliance with food safety standards and optimizing the overall CE model.

The most recent development in BIOVA's IS approach is the integration of fermented beverage production. By utilizing citrus albedo waste in kombucha fermentation, the company further expands its resource recovery efforts, reinforcing the closed-loop philosophy that underpins its business model. Through continuous innovation and process optimization, BIOVA exemplifies how

technology and IS can work together to create a truly sustainable and economically viable circular food system.

Partnerships and stakeholders

BIOVA's approach to IS is deeply embedded in its business model, with dedicated staff responsible for creating industrial partnerships to integrate symbiotic practices.

BIOVA has established strategic symbiotic relationships across various food industry and consumers' stakeholder, such as:

- **University and research centers**, to promote and increase awareness and knowledge on IS. They cooperate with Sciences Enogastronomiques Pollenzo https://www.unisg.it/, University of Torino https://www.unito.it/
- **Retail Partnerships supermarket chains, social farms**, to recover raw material at low cost and give the opportunity to retailers to reduce waste disposal costs. At the same time, Consumers can purchase products with strong sustainability credentials.
- **HoReCa and industrial food collaboration** to find co-branding of manufactured products. The resulting co-branded products strengthen their sustainability positioning in the market.
- **National and international food fairs** as SIAL (Paris), Tutto Food (Milan), Cibus (Parma). Participation gives the visibility.

Environmental, Economic and Social Impact

BIOVA's IS initiatives have significantly contributed to waste reduction and resource efficiency:

- Food waste Reduction: 12,000 kg of bread saved from supermarkets, producers, and restaurants, repurposed for beer production.

- Waste valorization: 8,000 kg of spent malt saved annually, reused to create protein-rich snacks.
- CO2 emission reduction: each production cycle results in 1,350 kg less CO2 emitted, thanks to waste recovery and sustainable brewing practices.
- Water and energy savings: through circular production methods, BIOVA minimizes the need for virgin resources, though precise figures are under assessment.

The economic benefits of BIOVA's model extend to cost savings and new revenue opportunities:

- Cost savings: €11,000 in public expenses saved by diverting surplus food from landfills, reducing disposal costs.
- New revenue streams: the introduction of co-branded sustainable products strengthens market positioning and increases demand for CE products.

In addition, BIOVA actively promotes education and awareness around CE principles:

- **Community engagement:** collaboration with universities and research centers fosters knowledge-sharing and promotes sustainable practices.
- **Consumer awareness:** educational campaigns and transparent communication highlight the benefits of upcycled products, encouraging sustainable consumer behaviour.
- **Cross-Sector partnerships:** strong cooperation with retailers, HoReCa, and industry stakeholders strengthens the ecosystem of CE practitioners.

BIOVA's impact goes beyond its immediate operations, inspiring broader change in how industries approach waste and sustainability.

Timeline and milestones

2019

Since its foundation in 2019, BIOVA Project has evolved through different phases, progressively refining and expanding its IS model. Each stage has been marked by careful planning, strategic execution and continuous evaluation to ensure long-term sustainability and growth.

BIOVA Project was founded in 2019 in Turin with the ambitious goal of reducing food waste, specifically unsold bread, by transforming it into craft beer. The initial phase focused on validating the concept, securing early partnerships with local bakeries and breweries and testing the feasibility of beer production using reclaimed bread. In 2020, after the pilot phase, BIOVA expanded its collection network by establishing agreements with major retailers such as COOP Nord-Ovest, Carrefour and Eataly. The results confirmed the effectiveness of the model in significantly reducing food waste, strengthening BIOVA's commitment to CE principles.

2021

By 2021, the company shifted its focus towards brand positioning and strengthening its presence in the HoReCa sector. BIOVA introduced co-branded beer collaborations with partners like Capatoast and Forno Brisa, leveraging these partnerships to enhance product visibility and consumer awareness.

2022

As the project matured, 2022 marked an important step towards diversification. Recognizing the potential beyond bread, BIOVA initiated a partnership with Pasta Berruto to recover broken pasta pieces, integrating them into its production cycle. This expansion laid the groundwork for new product development, demonstrating

that BIOVA's IS approach could be successfully applied to various food waste streams.

2023

In 2023, BIOVA took another leap forward by launching a range of CE snack products derived from brewing by-products. These protein-rich snacks, made from spent grains, not only reduced raw material usage by 40% compared to conventional snacks but also reinforced BIOVA's commitment to closing the production loop. The success of this initiative highlighted the scalability of BIOVA's model and its potential application across multiple food industry segments.

2025

Looking ahead to 2025, BIOVA continues to innovate with new sustainability initiatives, particularly in the fermented beverage sector. This expansion into new product categories reflects the company's ongoing commitment to creating value from waste and further establishing itself as a leader in sustainable food innovation.

Each phase of BIOVA Project's growth has been characterized by a strategic balance between innovation, collaboration, and sustainability.

Challenges and solutions

While BIOVA has successfully implemented several iS initiatives, it has encountered key challenges along the way and developed strategies to overcome them.

Challenge 1: Need for better understanding of regulatory and legal frameworks. Solution: At the start of its operations, BIOVA conducted an in-depth legal analysis and consulted with food safety authorities (ASL) to ensure compliance. Operating under the framework of the 2016 "Legge Gadda" on food recovery in Italy, BIOVA purchases surplus food at a symbolic price. This approach ensures compliance with the regulation, which requires that only legally acquired food products can be transformed and resold.

Challenge 2: Difficulties with legal aspects, as there is no clear regulatory framework for circular initiatives. Solution: While the solution mentioned above is effective in Italy, international expansion requires additional legal adaptation, which represents an ongoing challenge. The absence of a harmonized European framework means that BIOVA must assess regulations on a country-by-country basis for international expansion, requiring continuous legal adaptation and strategic partnerships.

Challenge 3: Difficulties in coordinating multistakeholder participation. Solution: Coordinating different sectors and stakeholders, each with their own pace of innovation and regulatory constraints, created challenges in aligning objectives and operational standards. To address this, BIOVA developed tailored engagement strategies for each partner type, fostering knowledge-sharing, providing technical support and ensuring adaptable collaboration models that accommodate different levels of readiness for CE adoption.

Potential of replication

BIOVA project's IS model offers significant potential for replication across various industries and geographical contexts. By leveraging waste streams and

transforming them into value-added products, the core principles of BIOVA's approach can be adapted to numerous sectors aiming to implement CE strategies.

One of the most promising areas for replication is the broader food and beverage industry. Many food sectors generate by-products that, like bread and brewing grains, are often discarded but retain nutritional and functional properties. For example, unsold fruits and vegetables can be repurposed for juice production or plant-based ingredients, while dairy industry by-products can be transformed into protein-rich food alternatives. The concept of upcycling surplus raw materials can be widely applied to reduce food waste and generate new revenue streams. The scalability of BIOVA's approach is also supported by its adaptability to different business models and regulatory environments. In regions where food waste management is a priority, companies can implement similar recovery and valorisation strategies with local adaptations. Public policies promoting CE practices can further accelerate adoption, making it easier for businesses to integrate IS into their operations.

To facilitate widespread replication, BIOVA can act as a knowledge-sharing hub, collaborating with research institutions and policymakers to develop best practices and guidelines. By fostering education and advocacy CE principles, the company can inspire other businesses to rethink waste as a valuable resource, amplifying its environmental and economic impact on a larger scale.

2.3. Interview with best practices

To gain deeper insights into the successful implementation of Industrial Symbiosis (IS), this section features exclusive interviews with the owners and key stakeholders behind the showcased best practices. These interviews offer a unique opportunity to explore the human perspective behind the numbers, uncovering the motivations, challenges and strategic decisions that drove these initiatives.

By hearing directly from those who spearheaded these transformative projects, stakeholders can better understand the practical realities of implementing IS, including the collaborative efforts required, the hurdles encountered, and the innovative solutions devised. Furthermore, these firsthand accounts illuminate the broader vision and long-term goals of IS practitioners, inspiring others to act and replicate success in their own contexts.

This section is structured to cover the journey of these IS pioneers, focusing on their motivations, approaches, and lessons learned. It emphasizes not only the technical and operational aspects of IS but also the social, economic and environmental dimensions that make it a cornerstone of sustainable development.

Through these narratives, we aim to inspire a broader audience to adopt and adapt IS principles, creating a ripple effect of innovation, efficiency and sustainability across diverse sectors and communities.

Best Practice 1. ITC-AICE (Spain)

Role in the organisation and expertise related to Industrial Symbiosis

As researcher at ITC-AICE (Instituto de Tecnología Cerámica - Asociación de Investigación de las Industrias Cerámicas), I work on fostering sustainable industrial practices through resource efficiency, CE principles and waste valorisation. Our work in IS focuses on developing strategies to reuse waste materials from one industry as raw materials for another, thereby reducing environmental impact and improving cost efficiency.

ITC-AICE collaborates with companies and research institutions to implement innovative solutions that enhance sustainability within the ceramic industry and related sectors. Their expertise includes:

- Process optimisation for waste minimisation.
- Valorisation of industrial by-products for ceramic applications.
- Implementation of CE models.

Motivation to pursue Industrial Symbiosis

The reason was our participation in the European project 'SHAREBOX', which compiled the IS practices that the ceramics sector was currently carrying out and others that could be put into practice.

We also participated in other regional projects such as SIMVAL and CIRCER and in other European initiatives such as CIRCLEAN, which allowed us to develop a methodology for implementing symbiosis in industrial areas.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

One of the most widespread and best-known IS processes among companies in the industry is the reuse of sludge from the glazing process in the preparation of ceramic bodies. This action emerged due to technical and legal necessities and was developed at first by drawing up point agreements between companies due to the significant economic savings obtained. These point actions became generalised and were formalised by the signing of a collaboration agreement between the tile manufacturers' association ASCER and the Autonomous Government of Valencia in January 2002. As a result, the spray-dried powder producers received sludge from the glazing departments of ceramic tile manufacturers, as well as the waste materials generated before the firing stage. When these agreements do not exist, these materials are handled as waste.

There are several reasons why the synergy of using sludge from the ceramic process was consolidated: on the one hand, these were practices that were already being carried out by some companies; on the other, there was a change in the legislation on waste management; and finally, there was the large amount of this type of waste that is generated.

Key objectives at the start of the IS initiative

The main objective was to reduce costs and simplify waste management. An easy and simple way to do this was to introduce them into the process of producing raw materials for the substrate.

Key steps taken to implement the IS system

In the case of ceramic sludge there were two key processes, as the recipient of the sludge, in this case the spray dried granules manufacturer, had to register as a

waste manager to be able to reuse it. On the other hand, the agreement signed by the manufacturers 'association and the public authority, which committed the manufacturers' association to keep a record of all sludge and aqueous suspension transactions carried out in the sector.

Critical resources for a successful implementation

Human resources were fundamental, followed by technological resources, mainly to be able to keep a computerised record of the flows and quantities of waste managed through this agreement.

Role of partnership or external support in the process

The support of the association of tile and ceramic flooring manufacturers was fundamental and necessary; without it, this practice would not have been carried out. In addition, the participation of public institutions was also necessary, which, through the agreement, favoured the implementation of this IS action.

Specific technologies, processes or innovations adopted to facilitate IS

No specific technologies were adopted, although an attempt was made to channel this type of waste, avoiding transport costs. In the case of nearby facilities, this has been successfully implemented.

Measurement of the success of the Is initiative

The success of the sludge utilisation initiative lies in two key points:

- The reduction of industrial water discharge into public waterways, which means economic savings and a reduction in the environmental impact.
- The reduction in the consumption of raw materials, mainly water in a process that consumes large amounts of it.

Specific mistakes or missteps to be avoid in future IS initiatives

It is essential that any project on IS has a long-term, ongoing nature. It is also necessary that all parties involved participate actively. That is why the figure of a facilitator is essential to keep the initiatives that are carried out active and consolidated.

Key lessons learned

The active attitude of the participants and the collaboration of public institutions that facilitate and promote this type of practice is key.

Future potential of Industrial Symbiosis

The potential of IS lies in the efficient use of resources. As the cost of raw materials increases, IS will make headway and serve as a tool for strengthening industrial ecosystems.

Putting IS into practice means understanding the needs of each company and recognising that the world is a finite resource. For this reason, training and communication are necessary skills for putting it into practice.

Best Practice 2. Tire Industrial Park (Türkiye)

Role in the organisation and expertise related to Industrial Symbiosis

I represent the Tire Industrial Park. The Tire district of İzmir contributes 9% of Türkiye's raw milk production and is in the Küçük Menderes Basin. The region has facilities for utilizing its milk production to support the national economy, including agriculture and large and small livestock farming, which form the backbone of milk production. The dairy and dairy product companies implementing IS within the Tire Industrial Park (TOSBİ) provides economic benefits both to the region and the country. The IS project, addressing wastewater generated during milk and dairy production, is the first of its kind in the region. Moving forward, projects related to whey, a by-product from these factories, are being considered for further evaluation.

Motivation to pursue Industrial Symbiosis

The reduction of discharge limits for dairy factories (with values reaching at least five times higher in the dairy industry), the increasing operational costs associated with this, and the inability to meet discharge standards due to the continuous operation of these systems have been key motivating factors. The primary goal is to ensure that milk production, which is the main livelihood of the region, continues to contribute to the national economy through the factories in the Tire Industrial Park. Additionally, by converting waste generated during production into by-products, a new economy is created. This approach prioritizes environmental safety at the highest level, ensuring long-term economic sustainability.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

Efforts are being made to prevent environmental harm from waste products such as whey and wastewater, which could negatively impact the production of agricultural products (barley, wheat, silage, etc.)—the key requirement for large and small livestock farming in the Küçük Menderes Basin. No feasibility study was conducted beforehand.

Key objectives at the start of the IS initiative

Reducing production costs, creating alternative revenue streams and ensuring the long-term sustainability of the existing system.

Key steps taken to implement the IS system

Within our region, SÜTAŞ A.Ş. has completed its symbiosis project. The region includes 4 feed factories, 10 dairy processing plants, 1 whey powder production unit, 1 wastewater treatment plant and 1 energy production facility utilizing organic waste as a raw material.

Critical resources for a successful implementation

Financial resources and environmental awareness have played a role.

Role of partnership or external support in the process

The process was entirely funded by the financial contributions of the 11 production facilities, established using their own equity. Contributions were made according to the companies' individual plans and a VAT incentive was obtained during the installation phase.

Specific technologies, processes or innovations adopted to facilitate IS

We use of updated technological equipment, the goal of reducing processing costs has been achieved.

Measurement of the success of the Is initiative

For the effluent water to be discharged into the Küçük Menderes Basin, the COD level must be reduced to 160 COD. Achieving these values is considered a measure of success.

Specific mistakes or missteps to be avoid in future IS initiatives

Investments should focus on establishing facilities with capacities suitable for raw materials and ensuring that these facilities are located close to raw material sources to avoid transportation costs.

Key lessons learned

According to TOSS, the most crucial aspect of sustainability is the revalorization of waste generated during production and the added value it brings to the national economy.

Future potential of Industrial Symbiosis

We believe that the potential for IS is high. The goal should be to establish new production facilities that utilize by-products generated from waste during the main production processes of all manufacturing companies and industries across Türkiye. This would contribute to the national economy while ensuring the continuation of environmental awareness.

Best Practice 3. Manresa in Simbiosi (Spain)

Role in the organisation and expertise related to Industrial Symbiosis

I am the manager of the Bufalvent Business and Industrial Estates Association in Manresa. My first experience with IS began with the pilot project promoted by Simbiosy consultancy in Manresa.

Motivation to pursue Industrial Symbiosis

Our motivation came from over 25 years of resource-sharing experience within our association, such as street lighting and signage, which are common in industrial estates. Having collaborated successfully for so long, we saw an opportunity to enhance our cooperation through an IS project. We aimed to take our collaboration to the next level and showcase the benefits of IS as the first initiative of its kind in the region of Catalonia (Spain), potentially serving as a model for future projects.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

The main challenge was raising awareness about IS and demonstrating its benefits. However, the driving force behind this decision was the opportunity to strengthen our existing cooperation and maximize the advantages of resource sharing.

Key objectives at the start of the IS initiative

Our primary objective was to prove that collaboration enables projects that would be unfeasible individually. We aimed to demonstrate the benefits of IS and unlock new business opportunities through cooperative efforts.

Key steps taken to implement the IS system

The process began with an ecosystem analysis to identify the companies involved, their activities, the types of waste they generated, and how these were managed. We then identified key opportunities within the territory, which required extensive consensus-building. We started with a pilot project, and after its success, we expanded the initiative to the entire Manresa area.

Critical resources for a successful implementation

The social dimension was crucial for success, as the project's success depended on everyone's involvement and collaboration.

Role of partnership or external support in the process

The project was made possible through funding from public entities, including the government and the Barcelona Deputy. The pilot project led by Simbiosy was fully funded, covering all expert costs. Additionally, the tools and methodologies developed can now be replicated in other regions.

Specific technologies, processes or innovations adopted to facilitate IS

No advanced technologies were involved since the project focused more on governance structures and territorial collaboration rather than technological solutions.

Measurement of the success of the Is initiative

Simbiosy developed a set of indicators (KPIs) to be monitored annually to assess the project's impact and success.

Specific mistakes or missteps to be avoid in future IS initiatives

We did not encounter any significant mistakes, as IS is an evolving process where each step offers valuable learning experiences.

Key lessons learned

The key to our success was initiating the IS project within an existing association, where trust was already established among members. Gaining companies' trust is one of the biggest challenges in IS projects, so starting within a trusted network greatly facilitates participation. Additionally, educating stakeholders about IS and how it works was crucial, so I recommend incorporating educational initiatives from the start.

Future potential of Industrial Symbiosis

I see great potential for IS, as it has proven successful in Manresa. I would encourage others to learn more about it and consider the benefits it can bring to their own communities.

Best Practice 4. Chihuahua Green (Mexico)

Role in the organisation and expertise related to Industrial Symbiosis

I lead and drive the Chihuahua Green initiative, which was promoted by COPARMEX, the Employers' Confederation of the Mexican Republic. My background was not directly related to IS before the pilot project we carried out in Chihuahua City, in collaboration with both public and private sectors. The idea to implement this project came from my participation in a congress where I saw a clear opportunity to introduce this model to my region.

Motivation to pursue Industrial Symbiosis

In Mexico, and specifically in Chihuahua, there was a lot of talk about the CE, but very little action had been taken. The first time I encountered the concept of IS was at a CE seminar for Northern Mexico organized by the European Union in Mexico. During this event, Veronica Kuchinow from the consultancy Simbiosy, who works on IS projects in Spain, presented examples from Europe. This inspired us to reach out to experts, and with the support of the European Union, we launched a project in Chihuahua, following the success of similar initiatives in Mexico City.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

The most significant challenge at the outset was raising awareness of IS within the region, as it was an unfamiliar concept. As I mentioned earlier, the main motivation was the success of the Chihuahua Green City pilot and the opportunity to scale it up using the knowledge gained from the project.

Key objectives at the start of the IS initiative

Our primary goal was simply to launch the project and get people talking about IS, making the concept more widely understood. A key aspect was learning from the European experience to ensure the pilot project's scalability. The aim was to transition from a municipal pilot in Chihuahua City to a state-level initiative.

Key steps taken to implement the IS system

We began with a territorial analysis in Chihuahua City, identifying opportunities for implementing IS. After launching Chihuahua Green City and developing the business models, the final phase of the pilot focused on ensuring the project's sustainability beyond the European funding. We succeeded in securing a commitment from the state of Chihuahua, which pledged to extend the project to other cities in the state, drawing on the experience gained from the initial city-based initiative.

Critical resources for a successful implementation

European Union's financial support and the expertise provided by Simbiosy were essential for the pilot phase.

Role of partnership or external support in the process

Partnerships and external support played a crucial role in the success of the initiative. We engaged with key stakeholders across all sectors of the territory, including industry clusters, universities, and non-profit organizations, all of which contributed to the project's development and alignment with territorial and environmental goals. The collaboration with these various entities helped foster an approach that involved the entire economic landscape of the region. Additionally, the support from the European Union, both in terms of funding and expertise, was instrumental in the project's initiation and scaling.

Specific technologies, processes or innovations adopted to facilitate IS

While the project primarily focused on territorial governance, we incorporated key technological tools like SYNER and Symtrack, which were essential for mapping and tracking IS opportunities. Additionally, we developed a guide for implementing IS projects in Mexico. This project not only facilitated the adoption of these tools but also helped establish a framework that can guide future IS initiatives across the country.

Measurement of the success of the Is initiative

We measured success using various Key Performance Indicators (KPIs), focusing on economic benefits (e.g., funding opportunities, CAPEX-OPEX), environmental impact (e.g., CO2 emissions reductions, water usage), and social outcomes (e.g., number of people trained, companies created through the project). The most important indicators were those related to economic impact, as companies needed to see the tangible benefits of participating in the project.

Specific mistakes or missteps to be avoid in future IS initiatives

The key lesson is perseverance – you may face setbacks, but failure is part of the process. Communication is critical, and learning from mistakes is an essential part of developing IS projects. Even when things go wrong, you don't lose time, as long as you adapt and keep going.

Key lessons learned

The key to our success was initiating the IS project within an existing association, where trust was already established among members. Gaining companies' trust is one of the biggest challenges in IS projects, so starting within a trusted network greatly facilitates participation. Additionally, educating stakeholders about IS and

how it works was crucial, so I recommend incorporating educational initiatives from the start.

Future potential of Industrial Symbiosis

The future of IS in Mexico is promising, and it has the potential to expand significantly due to the groundwork we've laid. IS projects require specialized knowledge, and even though I've been involved since 2020, I am only now beginning to feel confident in leading such initiatives in other regions. The learning process is substantial, and what we've learned in Chihuahua should serve as a valuable resource for others. I encourage others to consider the lessons learned from successful projects and incorporate them into their own initiatives to ensure the best possible outcomes.

Best Practice 5. CLES initiative (France)

Role in the organisation and expertise related to Industrial Symbiosis

Two persons were involved in this interview:

- As project manager at the Port Autonome de Strasbourg, my role is to coordinate the port's ecological transition initiatives, working alongside the other project managers in our division. Until 2024, I also animated the GUP (Groupement des Usagers des Ports (=Group of Port Users of Strasbourg), which supports the IS approach by representing the port's businesses. My work involved managing the administrative aspects of the initiative, such as the following contributions and members, as well as defining and evaluating the project's objectives and actions. Although I am trained as a geographer and not as an engineer, my knowledge of the port sector and the local economic ecosystem has enabled me to bring stakeholders together and highlight synergies between port projects and businesses. My expertise lies in managing collective ecological transition projects and connecting the goals of businesses with those of public initiatives.
- As a project manager in CE, my role involves facilitating industrial and territorial ecology (= Écologie industrielle et territoriale (EIT)) initiatives within various projects. My expertise is based on my background in environmental law, specializing in liability and insurance, with a thesis focusing on technological risk management around the Port of Strasbourg Oil Terminal. Additionally, I completed a University Diploma in pollution and nuisances. My professional experience includes project management as well as team coordination.

Motivation to pursue Industrial Symbiosis

Launched in 2013, the CLES initiative aims to integrate sustainability into the operations of the Port de Strasbourg by applying the principles of industrial and territorial ecology. The objective is to optimize resource use, reduce waste, and improve the environmental and economic performance of port businesses. The success of CLES is based on the collaboration of stakeholders such as the Port de Strasbourg, the Eurométropole de Strasbourg, ADEME, the Région Grand Est, and the Climaxion program, with the support of the Groupement des Usagers des Ports (GUP) and the association Initiatives Durables. Initially, Initiatives Durables was a network of businesses focused on advancing CSR starting in 2004. The association later expanded its expertise to environmental issues, particularly CE.

The initiative promotes synergies among businesses by encouraging them to collaborate on shared services, waste recovery, and energy optimization. This allows businesses to reduce operational costs and their carbon footprint. CLES has also set up workshops and working groups to identify best practices and solutions tailored to the needs of the port industry. By integrating inclusive decision-making processes and developing a collaborative network of stakeholders, CLES ensures alignment of goals and the effectiveness of its actions. Supported financially by regional and national organizations, the initiative has become a national model for CE, demonstrating that businesses can reconcile economic profitability with environmental sustainability.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

The CLES initiative faces several major challenges, such as business engagement, external risks (like rising energy prices), and cooperation between public and private stakeholders. To overcome these obstacles, the strategy relies on

demonstrating tangible benefits for businesses, flexibility in the face of economic crises, and the implementation of participatory governance.

Any regulation strengthening the obligations of businesses serves as a lever to justify the need for action. The context, particularly the energy crisis, has been especially influential. It highlighted the need to rethink local energy supply autonomy and the securing of production and logistics conditions, which also include the transportation of goods.

When an external event, whether climatic, geopolitical, economic, or financial, disrupts the system, it raises awareness of the importance of acting collectively. This is an opportunity to anticipate and define frameworks to prepare for similar situations in the future. Although it is never ideal, it is often one of the drivers for emphasizing the fragility of the system and the need to plan for these risks.

Key objectives at the start of the IS initiative

The main objectives of the CLES initiative were as follows: integrating sustainability into the operations of the Port of Strasbourg by applying the principles of industrial and territorial ecology. This aimed to optimize resource use, reduce waste, improve the environmental and economic performance of port businesses, and reduce their carbon footprint. The objectives also included:

- The social acceptability of industries,
- Environmental benefits,
- Economic outcomes,
- Meeting regulatory requirements, such as carbon footprint assessments, sorting, composting, etc.

Key steps taken to implement the IS system

The implementation is based on funded facilitation that ensures continuous presence and fosters cooperation between public and private stakeholders.

The key steps for developing the different phases of the approach:

1. Planning and financing: defining agreements between partners, securing funding.
2. Implementation and facilitation: raising awareness (workshops, murals), detecting synergies, quick and structural actions to engage companies sustainably. Facilitation through newsletters, strategic monitoring, and working groups.
3. Monitoring and evaluation: governance meetings and regular assessments to adjust actions.

The approach evolves by strengthening collaboration and adapting solutions to the industrial and environmental challenges of the territory.

Critical resources for a successful implementation

The success of the CLES initiative relies on three essential pillars of industrial and territorial ecology:

- Financial: Initial funding is 100% public (Eurométropole de Strasbourg, Région Grand Est, ADEME, Climaxion), progressively supplemented by contributions from companies (50%). In the long term, it is crucial to diversify funding sources to ensure the project's sustainability.
- Organizational: A structured cooperation between companies, public institutions, and Initiatives Durables, which facilitates and oversees the approach. Shared governance and themed working groups (waste, water, energy, human resources) ensure stakeholder engagement.

- Operational: Concrete actions such as resource pooling, logistical optimization, and waste reduction. Technological tools (flow modelling, energy monitoring, collaborations with laboratories) help identify and assess synergies.

This robust approach guarantees the resilience to mitigate external shocks, and the adaptability needed to maintain the project's relevance over time.

Role of partnership or external support in the process

The external support from public institutions, such as the Eurométropole de Strasbourg, ADEME, the Région Grand Est, Climaxion, etc., played a very important role as they provided public funding from the launch of the initiative.

Very interesting academic collaborations also emerged, notably with the eco-advisor cohorts from the Éco Conseils training program, to detect and develop synergies. Work was also conducted with the University of Strasbourg, particularly on the biodiversity aspect within the territory.
Consulting companies were also involved to complement the technical aspects of some synergies.

Specific technologies, processes or innovations adopted to facilitate IS

To facilitate IS, several technologies, processes, and methodologies have been adopted:

- Flow modelling to identify opportunities for resource pooling.
- Monitoring of energy consumption and CO_2 emissions to optimize environmental impact.
- Collaboration with laboratories and consulting firms to assess the feasibility of synergies.

- Resource pooling tools: resource exchanges, group purchasing, logistics optimization, and sustainable mobility.
- A heating network operated by the R-PAS entity, bringing together R-CUA, PAS and the various companies that produce waste heat, enabling better energy recovery.
- Animation and structuring of the network by Initiatives Durables, through working groups and action plans over 1 to 2 years.

These innovations have helped to sustainably structure industrial ecology and adapt solutions to the needs of the territory.

Measurement of the success of the Is initiative

The success of the initiative is primarily measured through its sustainability and the expansion of the number of stakeholders involved. Since its launch in 2013 with 15 companies, the network has significantly grown to reach 32 stakeholders in 2024, doubling in just over 10 years. This momentum demonstrates the attractiveness and relevance of the approach, reinforced by the recognition of the economic, environmental, and social benefits it generates. Monitoring the number of engaged companies and the evolution of the synergies created are key indicators to assess the project's impact and effectiveness.

To measure the results, the approach relies on standard indicators such as waste reduction, CO_2 emissions, energy and cost savings, comparing them to the baseline indicators and those of the year under study. Additionally, the initiative is part of the Réseau SYNAPSE, where it exchanges and compares with other projects and initiatives. This facilitates collaborative benchmarking, enriching the approach and allowing performance tracking against other similar initiatives.

Specific mistakes or missteps to be avoid in future IS initiatives

When implementing IS initiatives, it is crucial to find a balance between the time spent exploring and searching for new synergies, and the time needed to effectively implement projects. This balance can sometimes be difficult to maintain, as the lifespan of initiatives may be shorter than expected, and economic conditions may be less favourable than before. One pitfall to avoid is underestimating the time and resources required to mature a project.

It is also important to highlight that, while companies may withdraw from the initiative if they no longer find it beneficial, project facilitation requires sustained engagement from stakeholders to ensure its effectiveness and continuity. Attention must also be paid to the legitimacy of the project, especially to public actors, who must be regularly convinced of the value and impact of the actions taken. It is essential to be able to provide strong justification for the time and effort invested, ensuring that the initiatives implemented have a real long-term impact.

Another mistake to avoid is limiting oneself to established practices. One must be ready to test different techniques (facilitation, technology, etc.) and explore new synergies, stepping out of their comfort zone and continuously seeking new ideas.

Therefore, balancing funding, company involvement, and an innovative approach are essential to ensuring the sustainability of such initiatives.

Key lessons learned

A thorough listening approach is at the heart of facilitating these initiatives. The strength of facilitation lies in the ability to identify connection opportunities between different organizations. This subtle approach is based on anticipation,

allowing the identification of future issues that will become structural for businesses.

A delicate balance must be struck between covering a broad range of topics and having in-depth expertise on specific subjects. In summary, the foundation lies in the ability to listen to businesses' needs, characterize them precisely, and connect them with tailored solutions, localized within a nearby area.

It is also crucial to be attentive to businesses' receptiveness. When a new business is invited to join the initiative, it may hesitate or prefer to wait and observe the actions of neighbouring companies. It is not a failure if immediate engagement is not achieved; the key is to establish a foundation of trust. Businesses must first learn to know each other and build solid relationships.

Moreover, it is essential to adapt to the existing situation. If structures or working groups are already in place, it is important not to disrupt businesses' established practices, as this could undermine their engagement. The goal is to maintain the commitment of the businesses already involved. This does not mean that new ideas cannot be introduced, but it is important to nurture these ideas within the existing team, discuss them, and evaluate the possibilities together. When a majority of members agrees, votes can be organized to validate the proposals.

Future potential of Industrial Symbiosis

In France, industrial and territorial ecology is an obligation for local authorities as part of the TETE (Territoire Engagé dans la Transition Écologique (= Territory Committed to Ecological Transition) reference system. Territories wishing to earn more points must implement an industrial and territorial ecology approach.

Although this is an obligation, it encourages other regions to adopt this approach, given that it will become increasingly difficult to draw on natural resources in Europe in the long term. This shows that the adoption of industrial and territorial ecology will gradually become inevitable for territories. This transition, although initially restrictive, represents an opportunity for innovation and collaboration, encouraging a rethinking of practices in terms of sustainability, both environmentally and economically. Collective action and exchanges between companies facilitate this transition, as each can draw inspiration from the good practices of others, even if the commitments are specific and vary according to the needs and priorities of each company.

This reflects a deeper commitment than simply complying with regulatory obligations: collective intelligence within companies makes it possible to draw inspiration, test different approaches, and put in place concrete solutions tailored to local challenges.

Best Practice 6. Nuove Tecnologie Arredamenti (Italy)

Role in the organisation and expertise related to Industrial Symbiosis

At Nuove Tecnologie Arredamenti (NTA), we are a family-owned company based in Sardinia, Italy, and we have been deeply committed to sustainability for decades. While our company was originally founded in 1957, we have spent the last 30 years refining our expertise in bio-environmental consulting, sustainable furniture production, and material recovery.

My role within the company revolves around managing sustainability projects, overseeing IS initiatives, and ensuring our products align with ecological standards. Our expertise primarily focuses on eco-friendly furniture design, with a particular emphasis on low-emission products, natural wood, and ecological varnishes. But beyond just designing sustainable furniture, we also actively engage in raw material recovery projects, working closely with researchers and industries to repurpose waste into valuable materials.

Over the years, our experience in eco-design and material science has allowed us to develop innovative ways to extend the life cycle of products, reduce industrial waste, and integrate CE principles into our business model. IS has been a natural extension of this philosophy—it allows us to build networks, collaborate with different industries, and create value from materials that would otherwise be discarded.

Motivation to pursue Industrial Symbiosis

Our motivation for embracing IS is deeply rooted in our philosophy of sustainability and resource conservation. We have always believed that waste is not an end-

product, but rather an opportunity—a potential resource that can be reintegrated into production cycles rather than being discarded.

In Sardinia, where our company is based, there is a long tradition of craftsmanship and respect for natural materials, but at the same time, we've seen the environmental impact of industrial waste. One striking example is sheep wool, which is abundant in Sardinia yet often classified as industrial waste. This realization pushed us to find a way to repurpose wool, not just as a niche product but as part of a larger CE strategy.

We also saw a shift in consumer awareness—as more people started looking for sustainable alternatives, we recognized the need to evolve beyond just selling eco-friendly furniture. This led us to explore IS initiatives that go beyond our own company, such as collaborating with textile industries, agricultural suppliers and research centres to establish new, sustainable material streams.

Additionally, external factors like rising production costs, raw material shortages, and evolving environmental regulations reinforced our decision to invest in IS. We understood that sustainability is not just an ethical choice—it is a business strategy that ensures long-term resilience.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

When we first started integrating IS into our production process, we encountered both challenges and opportunities that shaped our approach.

One of the biggest challenges was low consumer demand for sustainable products. While awareness of sustainability has been growing, many consumers

still prioritize price and convenience over eco-friendly alternatives. Competing with mass-produced, low-cost furniture has been difficult, as sustainable materials and ethical production often come at a higher cost.

Another challenge was financial constraints. As a small business, accessing funding for sustainability initiatives has not always been easy. While we received support from the European Regional Development Fund (ERDF) in the past, institutional support for CE businesses remains inconsistent.

Regulatory barriers also presented difficulties. Sustainable manufacturing practices are still not fully standardized, and navigating bureaucratic processes can be complex. For example, when we developed wool insulation panels, we faced unexpected restrictions due to contamination risks, which impacted our ability to market the product for construction use.

Despite these challenges, we also saw major opportunities in adopting IS. By repurposing discarded wool and other natural materials, we were able to reduce production costs while also contributing to waste reduction and sustainable resource use. This approach also allowed us to differentiate our brand, attracting eco-conscious consumers and businesses that prioritize sustainability.

Furthermore, partnerships with local and international stakeholders opened new opportunities for innovation. Collaborating with Sardegna Ricerche and Cravolu helped us refine our wool processing techniques, while our participation in European sustainability networks provided valuable knowledge-sharing and industry connections.

In the end, our decision to implement IS was driven by a commitment to making sustainability practical and economically viable. It hasn't always been easy, but by focusing on education, partnerships, and continuous innovation, we've been able to navigate challenges and seize opportunities for long-term impact.

Key objectives at the start of the IS initiative

From the very beginning, our main objective was to integrate CE principles into our production process, making our business model more sustainable, efficient and resource conscious.

One of our first goals was waste reduction. Sardinia has an abundance of sheep, yet the wool industry was not fully utilizing this resource. Instead of letting this material degrade as waste, we saw the opportunity to repurpose it into high-quality products, such as textiles, cushions, mattresses and insulation panels. This objective aligned with our broader mission of reducing environmental impact while promoting local craftsmanship.

Another key goal was to develop partnerships that would enable cross-sector collaboration. We wanted to bring together businesses, researchers, and policymakers to create a network of shared resources. This led to our participation in Sardinia Green Synergy (local cooperative among companies), where we worked alongside agricultural suppliers, textile producers, and eco-construction specialists to exchange materials and expertise.

Additionally, we aimed to increase consumer awareness about sustainable furniture and eco-friendly materials. Many people do not realize that choosing sustainably made furniture can have a positive impact on both the environment and their health. Through education initiatives, marketing strategies and

participation in sustainability events, we sought to engage more consumers and demonstrate the value of choosing locally produced, sustainable alternatives.

Finally, we wanted to establish long-term economic resilience. Sustainability is not just about doing what is right for the planet—it also needs to be financially viable.

By creating a business model that reduces dependency on imported raw materials and focuses on upcycling, we hoped to position ourselves as a leader in eco-friendly furniture production while ensuring long-term financial sustainability.

Key steps taken to implement the IS system

Implementing IS at Nuove Tecnologie Arredamenti has been a gradual process, built on both technical improvements and strong collaborations over the years.

Everything starts with waste recovery and material sourcing. In Sardinia, one of the biggest environmental issues is the waste of local sheep wool. Despite the island having a high sheep-to-human ratio, the wool produced often ends up being discarded or burned, classified as industrial waste instead of a valuable raw material. Recognizing this, we established a partnership with Cravolu, a wool processing facility in Nule, to recover, clean, and repurpose this wool into useful products. This was a major step forward in aligning our company with CE principles.

Once the wool and other materials are collected, they go through cleaning and processing to prepare them for reuse. Wool requires careful treatment to ensure it is free from contaminants like moth larvae, which could compromise its usability.
By working with Cravolu's textile experts, we refined natural cleaning and treatment processes, allowing us to turn the wool into high-quality yarns, textiles, carpets, mattresses and insulation panels.

The manufacturing process follows, where recovered materials are integrated into our eco-friendly furniture production. Sustainability is at the core of everything we do—our furniture is designed to have a low environmental footprint, using non-toxic varnishes, locally sourced wood, and minimal synthetic components. In recent years, we have also experimented with hemp fibres, seeking new ways to diversify our sustainable material portfolio.

Another crucial aspect of IS in our company is quality control and certification. We pursued ISO 14,001 certification, a standard that validates our closed-loop production system and ensures that our processes meet strict environmental sustainability criteria. This certification not only helps improve market credibility but also strengthens consumer trust in our brand.

Finally, we focus on distribution and consumer engagement. Our products are primarily sold directly to consumers, which allows us to communicate our sustainability values more effectively. We also integrate educational components into our sales strategy, ensuring that buyers understand the long-term environmental benefits of choosing sustainable furniture.

Throughout this journey, we have also integrated water and energy efficiency measures in our facility. We use rainwater collection systems to reduce reliance on municipal water supplies and photovoltaic panels to lower our energy consumption. This allows us to operate more sustainably, even as a small company with limited resources.

Implementing IS at NTA has required constant innovation, but it has shown us that even in a resource-limited setting, small businesses can make a big impact with the right approach.

Critical resources for a successful implementation

The success of our IS system has been made possible by a combination of technological innovations, financial support and dedicated human resources.

From a technological perspective, the biggest challenge was developing a viable process for transforming wool waste into high-quality materials. Wool is naturally biodegradable, but to make it suitable for eco-construction, textiles, and furniture applications, it requires proper cleaning, treatment and processing. We worked closely with Cravolu, a company specializing in wool processing, to develop methods that ensure the wool is free from contaminants while maintaining its natural properties.

Additionally, our production facility integrates renewable energy solutions, which have been crucial in reducing operating costs and improving environmental efficiency. Our photovoltaic panels provide a significant portion of our energy needs, and our rainwater collection system helps minimize water waste. These innovations have demonstrated that even small companies can adopt CE strategies without excessive financial strain.

On the financial side, our journey has been both challenging and rewarding. We received funding from the ERDF, which was instrumental in establishing our eco-friendly woodworking facility. However, consistent financial support for IS initiatives remains a challenge, especially for small businesses. While we have successfully

financed parts of our operations through private investments and sustainability grants, securing long-term funding is an ongoing effort.

Finally, human resources have played a fundamental role in our success. We have a dedicated team of artisans, designers and sustainability specialists who bring their expertise to every aspect of production. Additionally, we have partnered with local universities and training programs to educate young professionals about sustainable material use. Over 50 participants have attended our training sessions, ensuring that the next generation of furniture makers is well-equipped with knowledge of IS principles.

Ultimately, our IS model would not have been possible without the right mix of technology, financial support and skilled professionals. By continually investing in these areas, we have been able to develop a scalable, sustainable business model that aligns with CE goals.

Role of partnership or external support in the process

Partnerships and external support have been essential in making our IS approach feasible. Without strong collaborations, it would have been impossible to develop sustainable supply chains, access financial resources and scale our initiatives.

One of our key research partners has been Sardegna Ricerche, which has provided technical expertise and support in developing material recovery solutions. Their input has been crucial in improving our wool processing system and optimizing material reuse techniques.

Another major partner has been Cravolu, the wool processing facility we worked with to transform sheep wool waste into textile and construction materials. Their

expertise in cleaning, treating, and spinning wool has been a key factor in our ability to produce sustainable mattresses, carpets and textile products.

In terms of financial support, we received funding from the ERDF. This funding enabled us to establish an eco-friendly woodworking facility, allowing us to expand our production capacity and material recovery efforts. However, we have also faced challenges—institutional support for IS initiatives is not always consistent, and we are actively seeking private investment and new financial models to ensure long-term stability.

Additionally, we collaborated with local universities and training programs, offering educational sessions on sustainable material use. Over 50 participants have attended our training programs, helping to raise awareness of IS principles and build industry expertise.

We were also involved in Sardinia Green Synergy, a cooperative that aimed to create a network of businesses committed to IS. The cooperative initially facilitated resource exchange and cross-sector collaboration, but due to financial instability, it was eventually dissolved. Despite this setback, its core principles continue to influence our sustainability approach today.

Specific technologies, processes or innovations adopted to facilitate IS

Our IS model is based on a structured process that integrates waste recovery, sustainable material processing, and eco-friendly production techniques.

One of the core processes we adopted is the recovery and transformation of waste wool. Sardinia has a large sheep population, but much of the wool is classified as industrial waste and left to degrade in the environment. Instead of letting this

resource go unused, we partnered with Cravolu, a wool processing facility in Nule, to create a closed-loop wool recovery system. The wool is cleaned and processed into yarns, carpets, mattresses, and insulation panels, giving it a second life in sustainable applications.

The wool processing system is constantly evolving to overcome technical challenges. One issue we faced was wool contamination by moth larvae, which made it unsuitable for bioconstruction. However, this setback led us to explore alternative uses, such as high-quality textiles and natural dye applications, attracting interest from artists and designers.

Our eco-friendly furniture production is also supported by waste recovery from the wood industry. We incorporate recycled textiles and natural construction materials into our product line, ensuring that our designs follow eco-design principles and have an extended life cycle. We also experimented with hemp fibres as an alternative raw material, but commercial viability remains a challenge due to processing costs and market barriers.

In terms of sustainable facility management, we integrate photovoltaic solar panels into our production site, which reduces our reliance on non-renewable energy sources. Additionally, we implemented rainwater collection systems, allowing us to reduce water waste in material processing.

To validate our CE approach, we pursued ISO 14,001 certification, which confirms that our waste recovery and closed-loop production systems meet international environmental standards.

Measurement of the success of the Is initiative

At Nuove Tecnologie Arredamenti, we define success in three main dimensions: environmental benefits, economic impact, and social engagement. Each of these aspects helps us measure how effectively IS is integrated into our production model.

From an environmental perspective, one of our key success metrics is waste reduction. By implementing IS, we have achieved a 50% reduction in waste, primarily through wool recovery and repurposing efforts. Instead of being discarded or left to degrade, wool is processed into textiles, mattresses, carpets, and insulation panels. This has helped reduce the environmental impact of waste disposal in Sardinia, where sheep wool is often treated as an unwanted by-product.

Another major sustainability metric is CO_2 emissions reduction. Our production facility has an energy system with a capacity of 19.50 kW, and we meet a portion of our energy needs through photovoltaic panels. This has helped lower our carbon footprint, reducing CO_2 emissions by approximately 3.75 kg per hour.

In terms of energy efficiency, we track energy savings through our use of renewable energy sources. Our solar panel system has allowed us to reduce energy consumption by 30%, decreasing reliance on non-renewable power sources.

Similarly, our rainwater collection system has helped cut down on municipal water usage, supporting more sustainable resource management.

From an economic standpoint, IS has helped us reduce raw material costs by at least 5%. This figure accounts for the expenses associated with treating and processing recovered materials before introducing them into the production cycle.

By minimizing dependence on newly sourced raw materials, we have increased financial efficiency while maintaining sustainable production standards.

Our annual revenue is approximately €400,000, with a portion of this generated from secondary markets, where we sell upcycled wool-based products and eco-friendly furniture. This diversification of revenue sources contributes to long-term financial resilience and allows us to continue investing in sustainability initiatives.

Beyond financial and environmental success, social impact is a major measurement of IS effectiveness. Currently, 10 workers are employed at Nuove Tecnologie Arredamenti, but our IS efforts also support job creation across the supply chain, particularly in wool processing, recycling and sustainable manufacturing. We have also prioritized knowledge sharing, hosting training sessions that have engaged over 50 participants, including students, professionals and industry partners.

Additionally, cross-sector collaboration is an essential success metric. To date, we have established over 10 partnerships with key stakeholders, including research institutions, local suppliers, and industry associations. These collaborations ensure that IS remains an active and evolving part of our operations.

Specific mistakes or missteps to be avoid in future IS initiatives

Through our experience with IS, we have encountered several challenges and setbacks, and I believe there are valuable lessons that other businesses can learn from.

One of the main mistakes that businesses make when adopting IS is underestimating market demand for sustainable products. Many consumers say they want eco-friendly options, but when it comes to purchasing, they often choose cheaper, mass-produced alternatives instead. This is something we have faced in the sustainable furniture sector, where the cost of producing high-quality, eco-friendly products can be higher than that of traditional furniture. Because of this, we had to rethink our marketing and consumer education strategies, ensuring that customers understand the long-term benefits of sustainable choices.

Another challenge is financial constraints and unstable access to funding. IS initiatives often require investment in material recovery processes, infrastructure, and product development, but funding for SMEs in the CE sector is often inconsistent. While we have benefited from European funding programs like the ERDF, institutional support has been sporadic. Many businesses make the mistake of relying only on public funding, which is not always sustainable in the long term. A better approach is to diversify funding sources, exploring private investments, crowdfunding, and long-term financial partnerships to ensure financial resilience.

Regulatory barriers can also create unexpected challenges. A major lesson we learned was that navigating bureaucratic processes in sustainable material use is not always straightforward. For example, when we developed wool insulation panels for eco-construction, we faced strict regulations due to contamination risks, which forced us to redirect the material toward textiles instead. Businesses should anticipate potential regulatory hurdles early on and engage with policymakers and industry associations to ensure that there IS initiatives align with legal and safety requirements.

Another issue that can arise is technical setbacks in material processing. In our case, wool contamination by moth larvae created difficulties in repurposing wool for construction. Many businesses assume that once a material is identified for recovery, the process will be straightforward, but technical adjustments and process innovations are often needed. Partnering with research institutions and industry experts can help companies find solutions faster and optimize their IS processes.

Finally, maintaining long-term partnerships is often more difficult than forming them. While Sardinia Green Synergy was a promising cooperative that brought together businesses from different sectors to exchange resources and materials, financial instability led to its eventual dissolution. A key lesson here is that for IS networks to be sustainable, they need clear long-term financial strategies and commitment from all partners. Businesses should ensure that roles, contributions and financial responsibilities are clearly defined when forming IS collaborations.

Key lessons learned

One of the biggest lessons we've learned is that IS
is not just about waste recovery—it is about creating a new way of thinking about production and sustainability.

A key takeaway is that consumer education is crucial. Even the best IS initiatives will struggle if consumers do not understand the value of sustainable products. We've found that storytelling and transparency—explaining where materials come from and how they are repurposed—help build consumer trust and willingness to invest in sustainable alternatives.

Another important lesson is the power of partnerships. IS does not work in isolation—it requires collaboration across industries. By working with wool processors like Cravolu, research institutions like Sardegna Ricerche, and local suppliers, we have been able to develop innovative solutions that would not have been possible alone. Businesses considering IS should focus on building strong, strategic partnerships with organizations that share their sustainability vision.

We have also learned that IS must be financially viable to be sustainable. While environmental impact is a priority, businesses need to ensure that their IS model generates revenue. This is why we track cost savings from raw material recovery and new revenue streams from secondary markets, such as selling wool-based products. Companies implementing IS should develop clear financial strategies to ensure long-term success.

Additionally, we have seen that policy advocacy plays a big role. Many regulatory frameworks are not yet designed to fully support CE models. By working with policymakers and industry associations, businesses can help shape regulations that make IS more accessible. Our experience with regulatory barriers in the wool sector has shown us that engaging in policy discussions early on can prevent delays and ensure that IS initiatives align with legal standards.

Finally, a critical lesson is that IS is a continuous process of improvement. Even when an IS model is working, new challenges and opportunities will arise. We constantly reassess our waste recovery strategies, explore new materials like hemp fibres and look for ways to improve efficiency. Businesses should embrace flexibility and innovation, understanding that IS is not a one-time implementation, but an evolving strategy.

Future potential of Industrial Symbiosis

IS has the potential to fundamentally change how businesses operate, especially in sectors like furniture production, textiles, and construction. The idea that one industry's waste can become another's resource is gaining traction and as sustainability regulations tighten across Europe, businesses will have no choice but to adapt and integrate CE principles.

One of the key areas of growth we see is cross-industry collaboration. Right now, IS is often implemented on a small scale, but by developing stronger regional and national networks, businesses can exchange materials more efficiently, reduce costs and optimize waste recovery. We have already seen how collaborations between furniture makers, textile producers and wool processors can create valuable circular supply chains, and this model can be replicated in other sectors. Policy and funding will also play a major role in shaping the future of IS adoption. While we have received financial support from European funds such as ERDF, there is still a need for more structured incentives for SMEs. Governments should focus on subsidies for industrial waste recovery, tax incentives for circular businesses, and simplified regulations for sustainable materials. If these support mechanisms improve, we will see a major acceleration in IS implementation across Europe.

Another important factor is consumer awareness. Many people still do not realize the impact of their purchasing choices, and while sustainability is growing in popularity, it is often seen as a niche market rather than a mainstream expectation.

One of our goals at Nuove Tecnologie Arredamenti is to educate customers about the benefits of choosing furniture made from recovered materials and low-emission natural products. If businesses across all industries make transparency

and consumer engagement a priority, demand for sustainable alternatives will grow.

Finally, for companies that are hesitant to adopt IS, I would say: start small but think long-term. Implementing IS doesn't have to mean immediate large-scale changes. Companies can begin by identifying waste streams in their operations and exploring potential reuse opportunities. The key is to build strong partnerships, whether with research institutions, material suppliers, or other businesses in the value chain. The more companies collaborate, the easier it becomes to scale IS initiatives and create a truly CE.

Best Practice 7. ProSeed (Switzerland)

Role in the organisation and expertise related to Industrial Symbiosis

I am the co-founder and CEO of ProSeed, a Swiss startup established in 2023. My background is in food technology, and I studied at HES-SO (University of Applied Sciences and Arts of Western Switzerland), where my master's thesis focused on the valorisation of wet by-products in the food industry.

At ProSeed, we specialize in IS, developing sustainable supply chain solutions by repurposing food industry by-products, particularly brewer's spent grain. Our goal is to convert what was previously considered waste into high-value food ingredients, reducing environmental impact while creating economic benefits for businesses.

Our approach is based on two key elements: sourcing raw materials from industrial by-product streams and using innovative processing technology to extend their usability. We have developed a modular drying system that allows breweries and other food manufacturers to process their by-products on-site, transforming them into stable ingredients for the food industry. With our proprietary stabilization technology, we have the capability to process up to 200 tonnes of barley flakes per year, which is equivalent to the waste produced by 5 million litters of beer.

Motivation to pursue Industrial Symbiosis

The motivation came from identifying a major inefficiency in the food industry. Breweries and other food processors generate large volumes of wet by-products that spoil quickly and are discarded as waste. At the same time, ingredient manufacturers require sustainable raw materials but face shortages in supply.

This gap presented an opportunity: if we could extend the shelf life of wet by-products, they could become a viable ingredient source instead of waste. Our proprietary drying technology achieves exactly that, transforming short-lived waste materials into valuable food-grade ingredients with a shelf life of up to 18 months.

By acting as an intermediary between breweries and ingredient manufacturers, we created a closed-loop IS model, where waste from one sector becomes a resource for another. This not only improves sustainability but also helps breweries turn a disposal cost into a revenue stream.

Additionally, we saw the potential to scale this model beyond breweries, applying it to soy production, coffee processing, and other industries with wet by-products. IS offers a way to bridge sustainability with economic incentives, making it attractive for businesses to adopt.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

The biggest challenge was that wet by-products spoil within hours—typically between 4 and 8 hours—making them unsuitable for reuse in traditional supply chains. Additionally, breweries and food manufacturers have limited space to install large-scale drying or processing equipment, which discouraged many from considering upcycling solutions.

The opportunity was clear: If we could develop a compact, energy-efficient, and easy-to-install drying solution, we could solve these barriers and unlock IS potential.

To tackle this, we designed a plug-and-play modular drying system housed within a standardized shipping container. This allows breweries and other producers to process by-products on-site without major infrastructure changes. The system uses 50% less energy than conventional drying technologies and can fully operate on renewable energy, making it an environmentally and economically sustainable solution.

Another key opportunity was the rise of sustainability-driven regulations and consumer demand for CE solutions. Companies increasingly recognize the importance of reducing waste and securing alternative raw materials. Our model helps them achieve both while remaining cost-effective.

Key objectives at the start of the IS initiative

From the outset, our main objectives were to create a sustainable solution that could repurpose wet by-products, turning them into high-value food ingredients.

Our focus was to help breweries and food processors reduce waste, all while creating an additional revenue stream for them. The environmental aspect was key but so was ensuring that companies adopting our technology saw clear economic benefits.

A major goal was also to develop a highly energy-efficient system. Traditional drying technologies consume vast amounts of energy, making them unsustainable for large-scale industrial adoption. We aimed to cut energy consumption in half while making our drying system modular and easy to install.

Additionally, we wanted to ensure compliance with European food safety regulations so that the upcycled ingredients could seamlessly enter the market. To

further drive adoption, we launched the ProSeed Upcycling Link Program (PULP), a networking initiative aimed at fostering cross-sector collaboration in IS. By creating a support structure for businesses interested in upcycling solutions, we hoped to make sustainable practices more accessible and financially viable for the industry.

Key steps taken to implement the IS system

The first step in our implementation was installing our containerized drying unit directly at breweries and food processors. These drying systems are designed to be modular, allowing for easy integration into existing production sites without requiring significant infrastructure modifications. Once the system is in place, the process begins with a mechanical dehydration phase, which removes excess moisture from the wet by-products. This step is crucial, as it significantly improves the energy efficiency of the drying process.

The drying process itself is at the heart of our technology. We use a low-energy drying technique that consumes 50% less energy than conventional drying methods. This not only reduces operational costs for breweries but also aligns with sustainability goals. Throughout the process, rigorous quality control measures are in place to ensure that the dried material meets strict European food safety standards.

Once the by-product has been dried and stabilized, it is packaged in bulk and transported to ingredient manufacturers, such as flour mills and protein processors, who further refine it into high-value food ingredients like fibre concentrates and protein powders. The key to our system's success is that the final product is designed to be easily integrated into existing food production infrastructures. By ensuring compatibility with standard milling and ingredient

manufacturing processes, we make IS a seamless, scalable, and cost-effective solution.

Critical resources for a successful implementation

The success of ProSeed's IS model relied on a combination of technological innovation, skilled human resources, and strong financial support.

On the technological side, the most critical element was developing our proprietary drying system, which is designed to extend the shelf life of wet by-products from a few hours to 18 months. This required extensive research and engineering expertise, particularly in optimizing energy efficiency—our system consumes 50% less energy than traditional drying methods and can run on 100% renewable energy.

Developing this level of technology required not only scientific research but also close collaboration with equipment manufacturers to ensure that the system could be scaled and adapted for different industrial contexts.

From a human resources perspective, our team had to be multidisciplinary to handle the different aspects of implementation. We combined expertise in food technology, engineering, and business strategy to bring our solution to market. Our founding team consists of specialists in microengineering, business development, and food science, which helped us bridge the gap between technical feasibility and commercial viability. Additionally, we expanded our workforce to include marketing and business development experts, as educating potential adopters about the benefits of IS was just as important as perfecting the technology.

Financial resources were another key factor. The transition from academic research to industrial-scale application required significant investment. We were

able to secure €1 million in grants from public and private institutions, including Innosuisse, The Ark Incubator, and the Swiss National Science Foundation (FNS). Without this funding, scaling our model would have been significantly more difficult.

Beyond direct investment in technology, financial resources were also necessary to fund pilot projects with industrial partners, particularly breweries and food manufacturers. This allowed us to demonstrate real-world feasibility and create a business case that encouraged wider adoption.

In summary, the combination of cutting-edge technology, a skilled interdisciplinary team, and strong financial backing was essential to the successful implementation of our IS model.

Role of partnership or external support in the process

We started with strong academic collaboration, as ProSeed was originally developed as part of my master's thesis at HES-SO (University of Applied Sciences and Arts of Western Switzerland). Working within an academic setting helped us conduct feasibility studies, optimize our process, and validate our concept before transitioning into a business.

On the financial side, public and private funding partnerships played a major role. We received grants and funding from Innosuisse, The Ark Incubator, and FNS, which helped us scale from prototype to full-scale implementation. This was essential because many startups struggle to secure funding for the transition from research to industrial deployment.

Industry partnerships were just as critical. We worked closely with breweries, soy product manufacturers, and ingredient processors—the key stakeholders in our IS

model. Breweries provided us with the raw material stream (spent grain), while flour mills and ingredient manufacturers helped refine and integrate our upcycled products into their supply chains.

A major milestone was securing our first pilot brewery partner, which allowed us to test and refine our drying system under real-world conditions. This successful pilot provided us with industrial validation, demonstrating that our technology was both technically and commercially viable.

Additionally, we launched the ProSeed Upcycling Link Program (PULP) to facilitate industry-wide collaboration and knowledge-sharing on upcycling solutions. Through PULP, we aim to expand IS networks across multiple sectors and increase adoption rates across the food industry.

Specific technologies, processes or innovations adopted to facilitate IS

The core of our IS approach is based on technological innovation and process optimization.

At the heart of our solution is our proprietary drying technology, which stabilizes wet by-products and extends their shelf life from 4-8 hours to 18 months. This was a critical breakthrough because wet by-products spoil extremely quickly, making it nearly impossible for companies to repurpose them efficiently.

To solve this, we designed a plug-and-play modular drying system housed in a standardized shipping container. This makes installation easy and cost-effective, as companies do not need to invest in large-scale facility modifications. Instead, our drying system can be placed directly at breweries or food production sites, where by-products are generated.

The drying process itself is highly energy-efficient, consuming 50% less energy than conventional drying methods. It consists of two key phases:

1. Mechanical dehydration – Excess moisture is removed from the wet by-products before drying. This step is crucial because it reduces energy consumption in the drying phase.
2. Low-energy drying – Our system processes the material at a carefully controlled temperature to preserve nutritional integrity while ensuring food safety compliance.

One of the key innovations is that our system can fully operate on renewable energy sources, making it sustainable and scalable for a variety of industries.

The dried by-products, such as barley flakes, are then sold to ingredient manufacturers, who further process them into flour, protein concentrates, or fibre supplements. The major advantage of our approach is that it creates a seamless link between waste producers (breweries) and ingredient manufacturers, making IS a practical and profitable solution.

Measurement of the success of the Is initiative

We measure success through three main dimensions: environmental impact, economic benefits and industry adoption.

First, we track waste reduction. Our system diverts large volumes of spent grain and other wet by-products from disposal, transforming them into valuable food-grade ingredients. Instead of being discarded or used in low-value applications like animal feed, these materials are reintegrated into the human food supply chain, supporting CE principles.

Second, we measure energy efficiency and carbon footprint reduction. Compared to conventional drying technologies, our system uses 50% less energy, leading to significant CO_2 savings. By calculating energy use per ton of processed material, we ensure our process is not only economically viable but also environmentally responsible.

From an economic perspective, success is defined by cost savings and revenue generation for our partners. Breweries that use our technology can turn a disposal cost into a new revenue stream by selling dried by-products to ingredient manufacturers. Meanwhile, the buyers of these materials gain access to a sustainable, high-quality raw material that can replace conventional ingredients at a competitive price.

Finally, industry adoption is a key indicator of success. We track:

- The number of breweries and food manufacturers adopting our system
- The growth of our ProSeed Upcycling Link Program (PULP)
- The expansion of our Industrial Symbiosis model to other sectors

Ultimately, success for us means that more companies recognize the economic and environmental benefits of upcycling, leading to widespread adoption of sustainable practices across the industry.

Specific mistakes or missteps to be avoid in future IS initiatives

One of the biggest mistakes that companies often make when trying to implement IS is assuming that large industrial partners will drive the initiative for them. Many startups or smaller companies expect that major players in the industry—whether they are food processors, ingredient manufacturers, or government agencies—will actively seek out and adopt sustainable solutions. It doesn't work that way.

If you have an IS idea, you need to take the lead. Big companies are not necessarily looking for change; they are looking for efficiency and reliability. So rather than waiting for them to take the first step, you must proactively engage with them, demonstrate the economic and operational benefits of your solution, and show that it integrates seamlessly into their existing processes.

Another common misstep is underestimating the time and effort needed to develop an industrial-scale solution. There is a huge difference between proving a concept in a research environment and making it work at a commercial level. It is essential to anticipate long development cycles, extensive regulatory compliance work, and real-world testing phases before expecting companies to adopt your model.

Additionally, many businesses underestimate the importance of financial planning and funding for scaling. While securing grants for research and early development is often feasible, the real financial challenge comes when moving from prototype to industrial-scale production. Many IS initiatives fail because they struggle to secure investment for industrial implementation, even after proving their concept.

To avoid this, it's crucial to diversify funding sources—combining public grants, private investments, and industry partnerships. This approach helped us secure €1 million in funding, allowing us to move beyond lab-scale research and deploy our technology in a real-world industrial setting.

Key lessons learned

One of the most important lessons we've learned is that IS is not just about technology—it's about collaboration and mindset shift. Even if you develop the most innovative process, it will not succeed unless the companies involved understand and accept the benefits of adopting it.

A key takeaway is that communication and education are essential. Many companies still do not see by-products as potential revenue streams. Instead, they see them as waste that needs to be managed. Changing this mindset requires engaging directly with businesses, explaining how upcycling adds value, and showing them real-world case studies that demonstrate the financial and environmental benefits.

Another major lesson is that modularity and adaptability are crucial. Industrial partners are far more likely to adopt IS solutions if they do not require major changes to their existing operations. This is why we designed our drying system as a modular, plug-and-play unit that can be easily installed at production sites. The less friction you create for adoption, the higher the chances of success.

Additionally, we learned that IS works best when multiple industries collaborate. While we started with breweries, we quickly saw that other food sectors faced similar challenges—such as soy production, coffee processing, and fruit pulp industries. By adapting our model to different sectors, we expanded our potential market and created a network of interconnected industries that benefit from upcycling.

Finally, government and policy support matter more than people realize. Many businesses want to adopt IS solutions but hesitate because of financial and regulatory uncertainties. Stronger policy incentives, subsidies, and regulatory

frameworks can accelerate IS adoption dramatically. We believe that advocating for better financial support for first industrial pilots is key to making IS more accessible to a wider range of businesses.

Future potential of Industrial Symbiosis

The future of IS is incredibly promising, but its success depends on scaling adoption across industries and increasing government support. We see a growing recognition that waste is a valuable resource, and companies that integrate IS principles will gain a competitive advantage by reducing costs, improving supply chain resilience, and aligning with sustainability goals.

One of the key areas for future growth is policy support and financial incentives. Many companies understand the benefits of IS but hesitate due to high initial investment costs and regulatory uncertainties. Governments need to play a more active role by offering financial incentives, subsidies, and tax benefits for businesses that adopt IS models. In our experience, there is substantial funding for research and development, but far less for scaling up industrial pilots. This gap needs to be addressed to ensure that innovative IS solutions reach industrial scale.

We also see cross-sector collaboration as a major driver for the future of IS. While our initial focus has been on breweries, we are already expanding into other sectors, such as soy production, coffee processing, and fruit pulp industries. Many industries generate high-moisture by-products, and with the right technology, these materials can be stabilized and upcycled into valuable ingredients. The more industries that adopt IS solutions, the greater the environmental and economic impact.

Another important area is consumer awareness and market demand. As sustainability becomes a priority for both regulators and consumers, companies

that integrate IS into their production processes will have a stronger market position. We believe that brands will increasingly use upcycled ingredients in their products, further driving demand for sustainable supply chain solutions.

To encourage businesses to embrace IS, we focus on education, networking, and real-world case studies. Many companies hesitate to adopt IS solutions because they lack clear information about its economic benefits. This is why we launched the ProSeed Upcycling Link Program (PULP)—a platform where businesses can connect, share knowledge, and see practical examples of successful IS implementation. By demonstrating that IS is financially viable, scalable, and easy to implement, we can accelerate its adoption across industries.

Best Practice 8. Industrial Zone Tezno (Slovenia)

Role in the organisation and expertise related to Industrial Symbiosis

I am a project manager at our institute. I've started by offering the interpretation of the underground production lines from World War II in the industrial complex but got quickly involved with other projects of the institute dedicated to operating the industrial zone. This way I was always aware of how the zone was set up, how it used to function as one unit and how they managed all their resource flows.

Motivation to pursue Industrial Symbiosis

As the institute we are managing the industrial site of a former industrial giant. This meant that different parts were already cooperating in the past, but were no longer owned by the same owner, and were no longer complementing each other's production. Instead, they adopted the facilities to their production, so some of the potential for symbiosis was gone. Still, as we always strive to provide added values for the companies at our location, we always look for projects that can help us do just that.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

Cost reduction is the main aspect, which is also a part of waste management, as waste is also connected to costs, while byproducts and secondary raw materials are a resource.

This is why we joined the Smart Street project. It was the concept of the University of Maribor – the Faculties for Logistics; Electrical Engineering and Computer sciences; and Criminal Justice and Security that started developing ways to smarten up the city. We became part of the Smart cities and communities and now

have the smart waste collection and disposal system, which reduces the costs for waste management.

Key objectives at the start of the IS initiative

Apart from waste management and reduction of its costs, our companies are also large consumers of electricity, so we started reducing the dependency on buying electricity by producing our own, while also reducing the electricity costs through smart lightning.

Key steps taken to implement the IS system

As I have said, this used to be one unit, under one management, where different parts of the industrial facilities worked together. People were rotating from one part to another, to get to know the processes and material flows, looking for ways to optimise them.

For example, the water used for cooling the machines was used for heat for the swimming pool the industry set up for the city as an open-air swimming pool. It was a rather simple, but very effective way of reusing excess heat, with a very popular effect on the local population as the pool was very popular until the early nineties, when investments in its infrastructure were needed, while the industry was collapsing.

The idea behind our institute was that although there would be no single owner, the site would still be managed by one unit, which could offer better services to individual companies, so the maintenance of the site was part of the synergy and we are the facilitators of IS in the Zone Tezno.

Critical resources for a successful implementation

Initially there was a political decision to have an entity which would manage the entire site, so this really prevented the complete deterioration of the zone, when different parts fell under different ownership. However, that would not be enough.

We needed to provide added value for the companies, which was always our mission. From joint energy supply to joint maintenance services, on one hand lowered the costs for individual companies, while also optimised the service, as instead of having many individual contractors (for example for winter road maintenance), there was a single service. This meant the companies did not have to deal with such logistic aspects of operating within the zone. But it also opened the door of individual companies, so we were able to closely work with them, knew their industrial processes, and were able to gain their trust. With waste management we also learned about their material flows and were able to suggest optimisation or start project, for which we try to get financing as well, to implement symbiosis.

Role of partnership or external support in the process

In this specific case of the Smart Street, the partnership with the university, but also the Waste manager services were crucial, as we are basically only the pilot site, where the activity takes place, but through this activity we are also fostering IS as the companies are reducing their waste and are better with reuse of byproducts which are produced within the industry zone.

Specific technologies, processes or innovations adopted to facilitate IS

We have an ongoing process of fostering the companies within our industrial zone, which was used to communicate with the companies, and they all supported the

idea and were willing to share their waste – byproducts, which is reducing their costs, and contributes to waste validation that consequently fosters IS.

For technological solutions, it was the university that developed a smart city platform, which allows for a reduction of 14 tons of CO_2 exhaust per year.

Measurement of the success of the Is initiative

From our side it was the indicator of companies that are involved in the joint waste management but are also using the waste / byproducts of other companies, reducing the waste that goes out of the zone. However, it's the University that is measuring the overall impact on the environment, as we are mostly the pilot location for their developed smart city solution.

Specific mistakes or missteps to be avoid in future IS initiatives

Do not try to force people into symbiosis. Just because you see the potential, does not mean the companies are willing to implement it. Start with those, who share the commitment to reduce environmental impact, and once this results also in the economic indicators, then others will want to join. Do not convince them to do something, show them, how it's beneficial for them.

Key lessons learned

You need to be open for collaboration. This is difficult for small or medium companies, as they often don't have enough resources to take care of research and development, or are strictly limited to their internal processes, so it's no wonder they cannot think about additional options, unless they are forced into them. So, it's up to you, if you want to foster symbiosis to get to know their processes and material flows and see what could be done… and then look for ways how to show them the benefits if they would try this.

Future potential of Industrial Symbiosis

There should be more support for facilitation of IS and incentives for those who agree to try and implement new ways of working together and achieving symbiosis.

Best Practice 9. Kooperativa 103 (Slovenia)

Role in the organisation and expertise related to Industrial Symbiosis

I am the founder of the company. A self though entrepreneur, who was always fascinated with global analysis. This is also how I learned about corn-based snacks replacing potato-based snacks on the global market, as corn is more resilient as a plant.

Motivation to pursue Industrial Symbiosis

Upon starting my company, I faced several challenges, mostly how to get high quality and steady supply of ingredients. I started cooperating with my suppliers.

As corn growing was more in the field of agriculture and I was mostly in food preparation, there wasn't all that much cooperation possible. However, with my suppliers of flavours for different popcorns, I found people who were thinking along the same lines as I did. We all wanted to reduce food waste. So, we pulled our knowledge and resources together and started a joined coop, which ensures the symbiosis between us. Above all, we started looking for new products where we could start processing food that would otherwise be wasted.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

As we are all small enterprises, our main goal was to optimise our own production, while at the same time staying true to our goals of sustainability in which we all firmly believe in. So, by having shared production lines, we were able to reduce investment costs. However, joint production facility also enables us to learn from each other's processes.

We were all looking for ways to prolong the life cycle of food products, especially with huge quantities of fruit that was wasted. We all had ideas of how to make smoothies from bananas that couldn't be sold on the market, how to make marmalade from raspberries that would rotten away… but it is one thing to have the idea but another to scale it up and have a product that would sell well, to cover the costs and make profits. And especially, even with this processing, you'd still get waste, which we were able to further use.

Key objectives at the start of the IS initiative

Reduction of costs was crucial, because if you are unable to be financially successful, your company won't survive. But this sharing of the production lines and storage capacity started further synergies as we started to share human resources as well. We were learning from each other and saw that byproducts of one company can become ingredients for products of another company. This was especially true, with processing for berries, where we were able to make the flavour for fruit ice-creams out of the fruit paste that was left over when producing marmalade.

So, our objective was to cut costs, which we did, by ensuring optimal atmospheric conditions in our process lines, which allowed for other activities – you need a certain temperature and low humidity for production and storage, so joining the two was very helpful and reduced the need for energy consumption.

Key steps taken to implement the IS system

It grew organically. We started collaborating, as I needed flavouring for popcorn, and others provided it, we realized that we could use same equipment for many of our processes. So, we invested in shared equipment, which we saw was not fully used, so we started offering it to others.

This started our collaboration; however, we were looking for a legal format which would suit us best and it turned out that forming a cooperative was the best solution for us.

Upon establishing the cooperation, we started working together at the shared facilities, which first enhanced the human resource development as we were able to learn from each other and better understand each other's needs and material flows. This then led to new ideas, how we could improve our production and further synergies were born out of it.

Critical resources for a successful implementation

The key to our success was the mindset we had. We were all doing what we liked and were highly motivated to learn more, to see how each other are doing something, to help each other, and open to outside companies, if they'd want to join as well.

So, yes, human resources would be the crucial factor, as they provided both the knowledge to find and implement the technological solutions, but most importantly, it was our commitment that made us want to do this, even if there were some investments that didn't directly contribute to our narrow production process, but we all looked beyond this and it paid off.

Role of partnership or external support in the process

We did not get direct government grants, and we were not big enough to be interesting for the academic sphere. However, we were part of the Start Up programme, which apart from helping our primary production line also helped us connect with people who thought the same, which – as I've said – is the basis for any such cooperation, people with the right mind set.

Specific technologies, processes or innovations adopted to facilitate IS

We were just optimising the complementing the equipment we had, as well as packaging or distribution channels, so that we achieved symbiosis in an organic way.

For technological solutions, it was the university that developed a smart city platform, which allows for a reduction of 14 tons of CO2 exhaust per year.

Measurement of the success of the Is initiative

The best case where we saw this was when a large shipment of bananas would be wasted, and instead we were able to make smoothies from it and placed them on the market.

So, we measure success by reduction of food waste, where we start new products that use the waste – or better said, byproducts – from our primary production.

Specific mistakes or missteps to be avoid in future IS initiatives

What you really need is balance. On one hand, you shouldn't be afraid to try something new, but you also must have reasonable and realistic ideas. It is always good to have people around you who can complement you with knowledge and experience but have the same mindset of wanting to progress and don't only look through the financial prism.

Key lessons learned

You need to know the material flows and working processes of the companies you work with if you want to find a way to collaborate and optimise your processes. With large companies, it is simpler. They already know what waste they produce and if

any of it could be reused, resold... but with small companies, you really need to be connected, to identify the opportunities.

Future potential of Industrial Symbiosis

There was always the possibility of symbiosis, as leftovers or waste from one production line was usually used in other processes. We just need to look at households from the past, where they did not waste anything, utilising each resource to the maximum, making them self-sustainable. With specialization of production and the scale of mass production, this old mentality was lost, but we can see that the old knowledge and experience is making a renaissance.

Best Practice 10. BIOVA (Italy)

Role in the organisation and expertise related to Industrial Symbiosis

At BIOVA, we focus on reducing food waste through innovative CE solutions, and my role is centred on developing industrial partnerships and optimizing our waste recovery model. Since our founding in Turin in 2019, we have worked to transform unsold bread into craft beer, turning what would otherwise be discarded into a valuable, marketable product.

BIOVA has evolved from a small neighbourhood initiative into a food innovation hub, creating a closed-loop system that integrates bakeries, supermarkets and breweries. We collect unsold bread from retailers, deliver it to partner breweries, and then redistribute the beer through the same retailers, reinforcing a sustainable and circular model.

Over time, we have expanded beyond bread-to-beer conversion, incorporating pasta waste and spent brewing grains into our product line. Today, we are exploring new ways to upcycle by-products into protein-rich snacks, reinforcing our commitment to maximizing resource efficiency in the food industry.

Motivation to pursue Industrial Symbiosis

Our motivation came from recognizing the massive amount of food waste generated daily—particularly bread. In Italy, thousands of tons of perfectly good bread go unsold and end up being discarded. We saw an opportunity to rethink food waste, moving away from a linear model of consumption and instead creating a sustainable, circular process.

The key motivation was the realization that waste has value. Bread contains fermentable sugars, making it an ideal substitute for malted barley in brewing.

Instead of throwing it away, we could use it as a resource to create something new. This insight drove us to develop our IS model, where food waste is not an endpoint but a starting point for something valuable.

Additionally, we wanted to address the economic inefficiencies in food retail. Bakeries and supermarkets incur costs for unsold goods, so creating a model where waste is collected and repurposed into a new product not only reduces disposal costs but creates financial value. It's a win-win: businesses reduce waste, consumers get sustainable products, and we contribute to a circular food system.

Finally, we were inspired by the potential for community engagement. IS is most powerful when it brings stakeholders together, and at BIOVA, we've developed a collaborative model where bakeries, breweries, and retailers all play an active role in creating a closed-loop food system.

Specific challenges or opportunities (e.g., waste management issues, rising costs, regulatory pressures) that drove this decision

One of the biggest challenges has been navigating unclear regulations. CE initiatives, especially in food production, often lack clear regulatory frameworks. Unlike traditional brewing, where raw materials are well-defined, using recovered bread or pasta waste introduces legal uncertainties. Understanding how these materials can be classified and processed safely required a lot of research and collaboration with food safety authorities.

Another challenge has been coordinating multiple stakeholders. IS is about integration, and that means aligning bakeries, supermarkets, logistics partners, breweries and distributors under one system. Each partner operates with different

priorities and business models, so creating a system that works efficiently for everyone required constant communication and adaptability.

However, these challenges also presented opportunities. Consumer demand for sustainable products is growing, and we've been able to leverage this shift in awareness to create a brand that is not just about reducing waste but also about innovation in the food industry. The growing trend of co-branded sustainable products has helped us expand our partnerships with major retailers like COOP Nord-Ovest, Carrefour and Eataly, making our IS model scalable and replicable.

Another opportunity came from repurposing our own by-products. Initially, we focused solely on bread-to-beer conversion, but as we looked deeper into our production process, we saw that brewing itself generates by-products—specifically spent grain. Instead of discarding this material, we have now developed protein-rich snacks that require 40% less raw material than conventional chips, further reducing resource consumption and reinforcing our closed-loop production system.

Key objectives at the start of the IS initiative

Our primary objective was clear: to transform food waste into valuable products while creating a sustainable business model.

At first, we focused on establishing the logistics—building a reliable system for collecting unsold bread from retailers and efficiently delivering it to breweries for beer production. This required developing strong partnerships with bakeries, supermarkets and logistics providers to ensure seamless coordination.

Another key goal was to ensure food safety compliance. Using recovered food waste as raw material is not as straightforward as traditional sourcing, so we had to work closely with food safety experts and regulatory bodies to ensure our process met all legal and quality standards.

As the project evolved, we expanded our objectives to maximize resource efficiency. This led us to explore new applications for by-products, such as transforming spent brewing grains into snacks, further closing the loop in our supply chain.

Additionally, we wanted to make sustainability accessible to consumers. Many eco-friendly initiatives fail because they are too expensive or niche. Our goal was to integrate sustainability into everyday consumer choices, offering products that are not only environmentally responsible but also affordable and widely available.

Finally, we aimed to scale and replicate our IS model. The success of our partnerships with COOP, Carrefour and Eataly showed that this approach could be expanded beyond bread and beer. By incorporating pasta, rice, and other food waste streams, we continue to explore new applications of IS in the food sector.

In the end, our IS initiative is about demonstrating that sustainability and profitability can go hand in hand. By creating a model that benefits businesses, consumers, and the environment, we believe IS can become a standard practice in the food industry.

Key steps taken to implement the IS system

The implementation of our IS model has been a process of constant adaptation and optimization, starting from a simple idea and evolving into a structured, scalable system.

The first step was to establish the supply chain for unsold bread collection. This required working closely with bakeries, supermarkets, and logistics providers to create an efficient system where bread that would otherwise be discarded could be collected safely, transported quickly, and stored properly before being used in brewing. We had to ensure that the bread retained its quality for fermentation, which meant developing specific handling and storage guidelines.

Once we had a steady supply of raw materials, the next challenge was integrating the bread into the brewing process. Working with our partner breweries, we refined our method so that up to 30% of the malted barley could be replaced with recovered bread, maintaining the flavour and quality of the beer while reducing the environmental footprint of traditional brewing.

Scaling up required us to optimize logistics and expand our network. Initially, we worked with a limited number of local retailers, but as demand grew, we partnered with major supermarket chains like COOP, Carrefour and Eataly, allowing us to integrate into existing food distribution systems. This shift was crucial in making our circular model commercially viable, as it provided a steady market for us upcycled beer.

Beyond bread-to-beer conversion, we looked at ways to further close the loop. We identified new waste streams—such as pasta and rice waste—that could be repurposed in a similar way. At the same time, we started developing snacks made from spent grain, which is a by-product of brewing. Instead of discarding this

valuable material, we transformed it into high-protein, fibre-rich snacks, reinforcing our commitment to full resource utilization.

Critical resources for a successful implementation

Our success has been built on a combination of human expertise, financial support and technological refinement—each playing a crucial role in scaling our IS model. From a human resources perspective, having the right partnerships has been fundamental. Collaborating with breweries, logistics companies, and food retailers allowed us to build a seamless operational model. Each partner brought specific expertise: bakeries and supermarkets ensured proper bread collection, breweries adapted their brewing processes, and retailers helped distribute the final product back into the market. This interconnected network made IS not just a concept, but a practical business reality.

Financially, we secured funding through private investment and collaborative projects, which allowed us to scale our operations and invest in process optimization. Access to funding for CE initiatives can be challenging, but demonstrating the economic potential of food upcycling helped us attract partners willing to invest in sustainable innovation.

Technologically, the biggest challenge was adapting the brewing process to incorporate unsold bread without compromising beer quality. Our partner breweries played a key role in developing and testing different formulations, ensuring that replacing part of the barley with bread would still result in a high-quality product. Additionally, developing snack production from spent grain required investment in food processing technology, allowing us to turn what was previously considered waste into a marketable product.

Role of partnership or external support in the process

We didn't get direct government grants, and we were not big enough to be interesting for the academic sphere. However, we were part of the Start Up programme, which apart from helping our primary production line also helped us connect with people who thought the same, which – as I've said – is the basis for any such cooperation, people with the right mind set.

Specific technologies, processes or innovations adopted to facilitate IS

The success of our Industrial Symbiosis (IS) model has been closely tied to technological adaptations and process innovations, particularly in the way we recover and integrate food waste into brewing and snack production.

One of the most critical technological challenges was adapting the brewing process to incorporate unsold bread as a partial substitute for malted barley. Bread contains fermentable sugars but using it in brewing requires adjustments to the milling and mashing stages to ensure proper starch conversion. Working closely with our partner breweries, we refined a method that allows us to replace up to 30% of the malted barley with bread, maintaining the flavour, consistency, and quality of the beer while reducing the need for new raw materials.

Another key innovation has been developing new applications for brewing by-products, particularly spent grain. This material, which is rich in fibre and protein, was previously discarded or used as animal feed. However, by processing and drying the spent grain, we have been able to repurpose it into high-protein snacks, reducing food waste at multiple points in the supply chain.

Logistics also plays a crucial role in IS, so we have optimized collection and distribution systems to ensure the efficient movement of unsold bread from

retailers to breweries. We designed a streamlined supply chain, where bakeries and supermarkets participate directly in the circular process, making food waste recovery a standard part of operations rather than an added burden.
Technology in IS doesn't always mean high-tech solutions—sometimes, it's about refining existing processes to make them more efficient and scalable. Our innovations have focused on making circular food production commercially viable, proving that sustainability can be integrated into business models without compromising quality or profitability.

Measurement of the success of the Is initiative

Success for us has always been about impact—both environmental and economic. From the very beginning, we set clear objectives to measure how effectively we could reduce food waste, optimize resource efficiency, and create a financially viable circular model.

One of the most important success indicators is the amount of food waste we recover and upcycle. Every year, we prevent thousands of kilograms of unsold bread from being discarded, turning it into a valuable raw material for brewing. By integrating waste recovery into the supply chain, we have managed to substitute up to 30% of malted barley with recovered bread, significantly reducing the environmental impact of beer production.

Another key metric is CO_2 emissions reduction. Since producing malted barley requires large amounts of water, land, and energy, using bread instead helps lower the carbon footprint of each batch of beer. Our IS initiative directly contributes to cutting down resource consumption, making brewing more sustainable and efficient.

Beyond environmental impact, we measure success in terms of economic benefits for our partners. Supermarkets and bakeries not only reduce disposal costs but also benefit from selling our upcycled beer in their own stores, creating a CE within the retail sector. By keeping food waste within the value chain, we turn what was once a liability into an asset, benefiting all stakeholders involved.

Finally, consumer engagement plays a huge role in defining success. The fact that our products are now available in major retailers like COOP, Carrefour and Eataly shows that there is a growing demand for sustainable alternatives. Seeing consumers actively choosing products made through IS reinforces our belief that circular production models can become mainstream.

Specific mistakes or missteps to be avoid in future IS initiatives

IS is a powerful tool for sustainability, but it comes with challenges that can easily be underestimated. Looking back at our journey, there are several key missteps that other businesses should try to avoid.

One of the biggest mistakes is assuming that regulations will be clear and straightforward. CE initiatives—especially those related to food waste recovery—fall into grey areas of legislation. When we started integrating unsold bread into beer production, we quickly realized that existing food safety laws were not designed for upcycled ingredients. Navigating the regulatory framework took time and required us to work closely with food safety authorities to ensure compliance. Companies entering the IS space should anticipate legal complexities early on and proactively seek expert guidance to avoid delays.

Another challenge we faced was underestimating the complexity of coordinating multiple stakeholders. IS is not a standalone operation—it requires seamless

collaboration between different businesses, each with its own priorities, schedules and operational constraints. At first, aligning bakeries, supermarkets, breweries and logistics partners was difficult because everyone had different expectations. We quickly learned that clear communication and structured agreements are essential to keep things running smoothly. Businesses adopting IS should ensure that roles and responsibilities are well-defined to avoid inefficiencies.

Financial planning is another area where businesses must be realistic and strategic. Many IS projects start with grant funding or public support, but long-term success depends on building a financially sustainable business model. Early on, we relied heavily on external funding, but we realized that for IS to work at scale, it must be profitable on its own. That is why we focused on commercializing our beer and snack products through major retailers, ensuring that our circular system could generate revenue while staying true to its sustainability goals.

Finally, one of the most underappreciated challenges is changing consumer perceptions. People like the idea of sustainability, but they do not always understand the value of upcycled products. Some consumers hesitate to buy products made from recovered materials because they associate them with lower quality or food safety concerns. Overcoming this requires effective storytelling and education. We had to communicate why using recovered bread is both safe and beneficial, turning sustainability into a selling point rather than a concern. Any business entering IS should invest in clear, positive messaging to help consumers see waste-derived products as premium and innovative rather than second-rate.

IS is a fantastic opportunity, but anticipating regulatory, logistical, financial and consumer-related challenges early on can make the process much smoother.

Key lessons learned

If there's one thing we have learned, it is that IS is not just about waste recovery—it's about rethinking entire business models. Successfully implementing IS requires innovation, adaptability and strong partnerships.

One of the most important lessons is that collaboration is everything. IS is not something a business can do alone—it thrives on strong networks and cross-sector cooperation. Finding the right partners, whether they are suppliers, manufacturers, retailers, or policymakers, is what turns an idea into a fully functional circular system. The more aligned your stakeholders are, the easier it is to integrate IS into everyday operations.

Another key takeaway is that scalability should be built into the model from the start. Many IS projects begin as small pilot initiatives, but for them to have a long-term impact, they need to be financially viable and capable of growing beyond their initial scope. When we started, we focused only on bread-to-beer conversion, but by keeping scalability in mind, we were able to expand into other food waste streams, like pasta and spent grain. Any company adopting IS should think about how their model can evolve over time.

Regulatory engagement is also critical. Instead of waiting for policy frameworks to adapt, businesses should be proactive in working with regulators. Engaging with food safety authorities and policymakers early on helps shape discussions around waste recovery, food safety standards, and sustainable production. Companies that take an active role in advocating for supportive policies will find it easier to navigate legal challenges.

Perhaps the most valuable lesson is that IS is not just a sustainability initiative—it's a market opportunity. When implemented well, IS does not just reduce waste; it creates new revenue streams, lowers costs, and enhances brand value. Companies that embrace IS as part of their core business strategy—rather than just as an environmental effort—will have the greatest success.

At the end of the day, IS is about changing mindsets—within businesses, among consumers, and across industries. If more companies recognize the value in waste and integrate IS into their operations, we can completely transform the way industries interact with resources, making circularity the norm rather than the exception.

Future potential of Industrial Symbiosis

The future of IS is huge, especially in the food industry. We are only scratching the surface of what's possible when we start rethinking waste as a resource. The global food system generates massive amounts of by-products, and IS offers a clear, practical solution to reduce waste, cut costs, and create new market opportunities.

One of the biggest areas for growth is cross-industry collaboration. Right now, we're focused on bread and brewing, but there are countless possibilities in sectors like dairy, coffee production, fruit processing and plant-based foods. By connecting different industries, we can create even more efficient closed-loop systems, where waste from one process becomes the raw material for another.

Policy support will also play a key role. While sustainability is gaining traction, we still see regulatory barriers that make IS projects more complex than they should be. Governments need to simplify regulations around food waste recovery and offer financial incentives for businesses that adopt CE principles. More funding, tax

incentives, and grants for IS initiatives could help businesses transition faster and more effectively.

For companies considering IS, my biggest piece of advice is just start. It doesn't have to be a perfectly structured model from day one—what's important is to experiment, find partners, and build solutions step by step. Many companies hesitate because they fear the complexity of integrating circular processes, but once you establish the right partnerships and refine your supply chain, IS becomes a natural part of business operations.

3. Conclusions

The analysis of the selected Industrial Symbiosis (IS) best practices highlights the remarkable potential of IS to drive both environmental and economic benefits through innovative resource-sharing strategies. By applying comprehensive criteria that assess innovation, sustainability impact, replicability, industry relevance and collaboration, this report has identified outstanding examples that demonstrate how IS can effectively support CE principles.

These showcased practices illustrate diverse approaches—ranging from advanced technological solutions to strategic partnerships—that contribute to waste reduction, energy efficiency, and carbon footprint minimization. Notably, the successful implementation of IS initiatives requires active cooperation between businesses, municipalities and other stakeholders, emphasizing the importance of multi-level collaboration.

Several common factors have contributed to the success of these initiatives. Strong public-private collaboration has been central, facilitating regulatory support, infrastructure development, and access to funding. Equally crucial is the engagement of local actors and SMEs, whose participation ensures the relevance, adaptability, and long-term viability of the symbiosis networks. Dedicated coordination bodies or facilitators have also played an essential role in building trust, aligning objectives, and managing logistics between partners.

However, these initiatives have also faced common challenges. One of the most persistent obstacles is the initial reluctance of companies to participate, often due to a lack of awareness, perceived risks or uncertainty about economic returns. Overcoming siloed thinking and fostering a culture of collaboration requires time,

transparency, and clear demonstration of mutual benefits. Regulatory and administrative hurdles can further complicate implementation, especially in cases where cross-sectoral coordination is needed.

A key lesson emerging from these practices is the importance of measuring and communicating both qualitative and quantitative impacts. The ability to track resource savings, emission reductions, economic gains, and social value is vital not only for continuous improvement but also for justifying investments and scaling efforts. Success stories supported by data serve as powerful tools for advocacy and replication.

By presenting these exemplary cases, this report aims to inspire policymakers, industry leaders and practitioners to adopt similar strategies, recognizing IS as a powerful tool for achieving sustainability goals. As industries face increasing environmental regulations and resource constraints, embracing IS offers a viable path toward enhancing competitiveness, fostering innovation, and building resilient ecosystems. The proven scalability of these practices further underscores IS's role as a key driver in promoting sustainable industrial development across regions and sectors.

Annex I. Best practices selection

Best Practice	Location of the best practice	Degree of innovation	Impact on sustainability	Replicability and Adaptability	Industry relevance	Level of collaboration
1. Industrial Symbiosis in the ceramic sector	Castellón (Spain)	The IS in a traditional sector such as the ceramic one demonstrated a high degree of innovation in the sector through the integration of advanced technologies, processes and novel business models.	This solution reduce waste, carbon emissions and energy consumption. It is also encouraging resource efficiency.	Ceramic production is prevalent globally, also in other regions of Southern Europe, South America and Asia. It could be adapted to other ecosystems.	This IS solution not only meets industry-specific needs (material efficiency, energy optimization or wate management) but also enhances the sector's competitivenes s and resilience in the face of resource scarcity and	This multi-stakeholder approach drives shared value, fostering systemic change within the ceramic sector and promoting Industrial Symbiosis as a mainstream practice.

					regulatory pressures.	
2. Industrial Park of Izmir	Izmir (Türkiye)	By implementing cutting-edge technology for large-scale wastewater treatment, this facility offers a pioneering solution for improving water quality and restoring marine ecosystems.	The project plays a central role in achieving long-term water sustainability goals for the region and enhancing the resilience of local water systems.	The project demonstrates how infrastructure investments can address localized environmental issues while serving as a template for sustainable urban water management globally.	This project highlights the role of municipal facilities in tackling urban water challenges while driving long-term environmental and economic benefits.	This project serves as a model for effective municipal, technical, and community collaboration, driving sustainable urban water solutions through shared responsibility.
3. Manresa in Symbiosis	Manresa (Spain)	The project demonstrated a pioneering approach to Circular Economy principles within	The project achieved significant reductions in waste sent to landfills, increased	The project began at the city level in Manresa as a pilot initiative, demonstrating the feasibility of	The initiative addresses critical industry needs, including waste management, energy	The project showcases how multi-stakeholder collaboration can scale from city-level to

		an industrial ecosystem.	energy recovery from biogas and biomass, and optimized resource use.	Industrial Symbiosis within a single industrial park. Its success paved the way for expansion to the regional level, encompassing the entire Bages region.	efficiency, and cost reduction, while fostering competitiveness and sustainability. Its relevance spans various sectors, such as plastics, metals, and energy generation.	regional-level, driving 30+ synergies, energy networks, and centralized resource hubs. Its structured framework ensures adaptability to similar industrial ecosystems.
4. Chihuahua Green City	Chihuahua (Mexico)	The project's innovation lies in positioning companies as the primary drivers of collaboration. Unlike many initiatives led by public authorities, Chihuahua	The project has significantly reduced waste, improved energy efficiency, and supported the integration of renewable energy, fostering long-term	The project evolved from a city-level initiative (Chihuahua Green City) to a state-level program (Chihuahua Green Project), showcasing the scalability of a	The project has relevance across various sectors, including manufacturing, energy, and waste management, enhancing resource	The leadership of local companies drove the initiative's success, fostering collaboration with public entities and research institutions. This

		Green City relies on private-sector leadership to identify and implement synergies.	environmental and economic benefits for the region.	company-driven collaboration model. It serves as a replicable framework for other regions with strong industrial ecosystems.	efficiency and sustainability.	synergy created a scalable, impactful model for Industrial Symbiosis and sustainability.
5. CLES (Coopérations Locales et Environnementales en Synergies / Local and Environmental Cooperation in Synergies)	Strasbourg (France)	The CLES initiative is innovative in its integration of Industrial and Territorial Ecology principles, fostering synergies among businesses while engaging institutional partners. Its replicable	The CLES initiative advances sustainability by reducing CO_2 emissions, recovering waste, and optimizing shared resources at the Port of Strasbourg. Its focus on Circular Economy	Since 2013, the CLES initiative has become a model for Circular Economy practices at the Port of Strasbourg, demonstrating replicability and adaptability to other industrial contexts. Initially focused on a few	The CLES initiative directly addresses key industry challenges such as waste management, material efficiency, and energy optimization. By fostering collaboration among businesses at	The CLES initiative excels in fostering high levels of collaboration, involving a wide range of stakeholders from both the private and public sectors. It encourages partnerships between companies such as

		model for mutualization and resource sharing addresses environmental and economic challenges, positioning it as a leader in sustainable industrial practices.	practices and long-term collaboration strengthens both environmental stewardship and local economic resilience, serving as a model for sustainable industrial ecosystems.	businesses, it expanded significantly with support from the Groupement des Usagers des Ports (GUP), Initiatives Durables, and funding from entities like the Eurométropole de Strasbourg, the Région Grand Est and the ADEME. CLES's collaborative and flexible approach, promoting shared resource management and waste	the Port of Strasbourg, it enables shared resources and synergies, which help reduce waste, improve resource use, and lower energy consumption. This approach is highly relevant to the industrial sectors, providing sustainable solutions that align with their operational needs while driving long-term environmental	manufacturers and waste management organizations to optimize resource use and reduce waste. Additionally, it engages local governments, environmental agencies, and associations like Initiatives Durables, creating a multi-layered cooperation framework. This broad collaboration ensures the success of the initiative, offering a

				recovery, positions it as a transferable framework for industrial zones, adaptable to local needs while aligning with sustainability goals.	and economic benefits.	model for other regions to adopt sustainable practices.
6. Distretto agrumi di Sicilia	ITALY					
7. Nuove Tecnologie e Arredamenti	Italy	IS practice being innovative in converting industrial waste into value-added products, having integrated eco-design principles that	In an area with other sheep production, the project recovers processing waste and regenerates economic and cultural value, reviving local cultural and	By demonstrating how SMEs can integrate IS principles, the company provides a framework that can be applied across regions with similar	This project notes the importance of innovation in the furniture and green building sector and confirms the work of the production chain as a qualifying	This project demonstrates how extending multistakeholder collaboration on the IS project is not only desirable, to ensure essential support for SMEs to

		extend the life cycle of products.	heritage values, activates research into new materials for green building	sustainability challenges.	element of the IS concept.	experiment with new business models, but necessary to ensure sustainability over time
8. PROSEED	Switzerland	Food and Beverage production, waste upcycling, and Circular Economy solutions.	Environmental: ProSeed reduces food waste by upcycling wet byproducts into reusable raw materials, cutting CO2 emissions by up to 142,500 tons annually in EU targeted breweries alone. • Economic: ProSeed's business model	drying units are scalable, modular, and adaptable to various wet by-products beyond brewing, including soy pulp and oat residue	ProSeed's solution holds high relevance for two key industries: • Food & Beverage Processors: o Provides a low-CAPEX solution for managing wet by-products that are otherwise wasted or disposed of at a cost.	ProSeed actively creates local ecosystems by connecting beverage processors and ingredient manufacturers, such as millers and fermentation companies.

			transforms waste management costs into revenue streams for beverage producers while providing ingredient manufacturers with sustainable raw materials. • Social: By contributing to a circular food system, ProSeed aligns with global goals for reducing hunger, promoting health, and supporting		o Enables processors to turn waste into a revenue stream by selling upcycled materials. o Seamlessly integrates with existing infrastructure, minimizing disruption and additional investment. • Ingredient Manufacturers:	

			sustainable consumption practices.			
9. Industrial zone symbiosis	District Tezno, Maribor, Slovenia	The Industrial zone is developing the so-called smart street in the zone as part of "Digitalization of Energy Infrastructure Management and Control System" (DUEISVEzaCT) project.	Impact on sustainability is high because of the implementation of advanced systems for monitoring and managing energy consumption, battery energy storage systems, and infrastructure management within the zone.	Replicability is possible within all industrial zones and/or individual companies to optimize for e.g. the control of energy consumption.	The industrial zone addresses key challenges in larger areas of industrial companies.	The level of collaboration is among all companies in the industrial zone. And the companies are interested in active role of optimization of the zone.

10. Symbiosis in production sector (Kooperativa 103)	Maribor, Slovenia	Cooperative 103 is joining small companies and start-ups in innovative way of collaboration: one production space, with the purpose of reducing costs (rent, delivery, machinery, etc.). In this way also new ideas and cooperations on other levels emerge.	With sharing production facilities and equipment, as well as other goods, the impact on sustainability is high because of lower and optimized energy and water consumption, reduction of packaging and delivery, etc.	The practice of shared facilities and equipment between companies is largely replicable and has an open way of adaptation from small to large companies and throughout many different sectors.	Cooperative addresses challenges of beginner companies starting on a similar field by bringing together, sharing and reducing high costs.	Collaboration is not only in sharing facilities and equipment, but also in sharing knowledge and ideas, which can bring new products, optimized packaging and much more.
11. BIOVA	Turin, Italy	BIOVA's innovation lies in creating a multidirectional	BIOVA's closed-loop supply chain with retailers,	Their approach has already proven adaptable to	BIOVA's Industrial Symbiosis model	BIOVA exemplifies multi-stakeholder

		Industrial Symbiosis model that transforms food waste into premium products through novel conversion processes	HoReCa businesses, and manufacturers creates economic sustainability by generating value from waste while reducing disposal costs for partners	different waste streams (bread, pasta, rice) and different product categories (beer, snacks).	addresses critical challenges facing the food industry, including waste reduction, resource efficiency, and sustainable supply chains.	collaboration through partnerships spanning the entire food supply chain. Their co-branding strategy further strengthens collaborative relationships by sharing visibility and market recognition.