Ref. Ares(2025)9511703 - 05/11/2025

PROJECT

POLREC

EURO CLUSTERS

Funded by the European Union

D2.6
Business process innovations adopted in the industrial ecosystem/s



D2.6 – Business process innovations adopted in the industrial ecosystem/s

Document status			
Version	**Date**	**Author**	**Description**
V1.0	12.09.2025	Alexandra Wolf	
V2.0	15.09.2025	Alexandra Wolf	Reviewed by Dorte Baelum

Reviewed	☒	YES	By Ms. Dorte Baelum, Plast Center Danmark
	☐	NO	
Dissemination Level	☒	PU – Public (fully open)	
	☐	SEN – Sensitive (limited under the conditions of the Grant Agreement)	
	☐	CO – Confidential (EU classified under decision)	

Cite As:

If the Deliverable is Public, you retrieve it from the POLREC Project website.

Funded by the European Union

Table of contents

1. Executive Summary 4
2. Introduction 5
3. Business Process Innovations in Chemical Recycling 6
4. Business Process Innovations in Mechanical Recycling 7
5. Cross-Cutting Insights from POLREC Projects 9
6. Key Business Process Innovations 10
7. Embedding Innovations in the Industrial Ecosystem/s 12
8. Discussion and Analysis 15
9. Conclusions and Recommendations 16

Funded by the European Union

Glossary of terms, abbreviations, and acronyms

Partner short name	Partner	Country
POL	Polymeris	FR
CEN	Centro Tecnológico da Indústria de Moldes, Ferramentas Especiais e Plásticos	PT
MAV	Clúster de Materials Avançats de Catalunya	ES
PCD	Plast Center Danmark	DK
WFG	Wirtschaftsförderung Raum Heilbronn GmbH	DE

Table 1 – List of partners

Funded by the European Union

The POLREC project is funded by the European Commission Joint Cluster initiatives for Europe's recovery (Euroclusters) under the Single Market Programme (SMP COSME) grant agreement number 101074434. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EISMEA. Neither the European Union nor the granting authority can be held responsible for them.

1. Executive Summary

The POLREC project has successfully mobilized small and medium-sized enterprises (SMEs) across Europe to pioneer business process innovations that tackle pressing challenges in plastics, rubber, textiles, and composite recycling. By combining chemical and mechanical recycling approaches, SMEs developed novel methods for material recovery, enhanced resource efficiency, and enabled new forms of circularity. These achievements go beyond technical feasibility, demonstrating how strategic business processes—such as supply chain reconfiguration, technology modularization, process optimization, and market-oriented innovation—can foster industrial ecosystems that adopt sustainable and circular models.

Key findings from the POLREC Open Call for Innovation reveal that SMEs introduced innovations across several interconnected domains:

- **Circular supply chain integration:** Many companies implemented closed-loop systems that reintegrate recycled materials into their own production or customer value chains. Initiatives such as José Combalía's polyolefin recycling, RecyOuest's agricultural net valorization, and Gaviplas' de-inking technology illustrate how industrial integration accelerates uptake and ensures reliable use of recycled feedstocks. These approaches minimize reliance on virgin materials, reduce waste, and demonstrate the practical application of circular economy principles.
- **Technology-enabled business models:** SMEs employed advanced technical solutions—including solvent-based separation, selective chemical dissolution, high-performance coatings, pyrolysis optimization, and modular regeneration systems—to improve material quality, operational efficiency, and economic viability. Projects from DLyte, Mälarplast, Earth Protex Portugal, and ECOLLANT exemplify how technical innovation can create new market opportunities, enhance material performance, and enable scalable, industrially relevant processes.
- **Market repositioning and application-specific development:** Companies strategically targeted recycled materials to high-value applications, such as reinforced composites, bioplastics, packaging solutions, automotive components, and eco-designed consumer products. This approach, exemplified by ALTHEORA, SPORTS CARBONE, and Mariton, supports sectoral standards and regulatory compliance while generating new revenue streams. Tailoring recycled materials to specific market needs enhances adoption and demonstrates that sustainability and competitiveness can be mutually reinforcing.
- **Ecosystem collaboration and knowledge sharing:** Strong partnerships with research institutions, technology providers, and industrial customers proved essential for embedding innovations into broader industrial ecosystems. Companies such as Mälarplast, PDC-Plast, and RezyOuest leveraged collaborative networks to enhance technical capacity, accelerate commercialization, and facilitate standardization and regulatory alignment. Ecosystem engagement also fostered shared learning, traceable recycling loops, and the adoption of take-back systems, supporting systemic change beyond individual SMEs.
- **Operational excellence and industrial scalability:** Continuous process optimization—including contamination management, material property standardization, solvent recovery, and automation—was crucial for ensuring the reliability and performance of recycled materials. Scaling pilot projects to industrial levels, as demonstrated by José Combalía, RecyOuest, and

Funded by the European Union

Total Plastic Solution, highlights the importance of combining technical robustness with economic viability. Addressing operational, financial, and regulatory challenges is essential for broad adoption of circular practices.

- **Sustainability impact and new business opportunities:** Mechanical recycling initiatives revealed the value of repair and reuse models, while chemical recycling projects created high-quality outputs suitable for new material markets. Life Cycle Assessments (LCAs) and forward-looking regulatory planning provided additional validation, illustrating how circular processes can generate both environmental benefits and commercial value. The POLREC SMEs demonstrated that embedding circular principles can produce measurable ecological, economic, and social gains.

Despite these successes, challenges remain. Contaminant removal, consistent material quality, financing constraints, and regulatory complexity continue to pose obstacles, particularly for projects transitioning from pilot scale to full industrial implementation. Cross-border collaboration, standardization, and policy alignment are critical enablers for replicating successful innovations and scaling their impact across Europe.

Conclusion:
The POLREC project demonstrates that SMEs can act as catalysts for the European transition toward a circular economy by combining technical innovation, process optimization, and ecosystem-level collaboration. By integrating recycled materials into industrial supply chains, developing high-value applications, and leveraging collaborative networks, these enterprises show that sustainability can drive competitiveness, market diversification, and industrial resilience. The lessons and approaches developed provide a strong foundation for continued progress, offering replicable models for SMEs and industrial ecosystems aiming to scale circular practices and create a sustainable industrial future.

2. Introduction

The POLREC project is a collaborative initiative involving five European clusters, as listed in Table 1. Its primary focus is on promoting sustainable development and the recycling of both high- and low-value polymers, contributing to the goals of the European Green Deal. Specifically, the project supports the ambition of achieving net-zero CO_2 emissions by 2050 and enhancing European strategic autonomy in sourcing raw materials for polymer production.

Over a three-year period, the POLREC consortium investigated how intensified cross-border and cross-sector collaboration among clusters and business networks could help address these environmental challenges. The aim was also to leverage the international business opportunities associated with polymer recycling.

Aim and Scope of the Innovation Open Call

One of the project's central actions was the launch of the POLREC Innovation Open Call, designed to financially support small and medium-sized enterprises (SMEs) with ambitions to reduce the environmental impact of their products. The call specifically targeted companies committed to shifting from traditional disposal methods - such as incineration and landfilling - to more sustainable solutions, including mechanical and chemical recycling of polymer waste.

Funded by the European Union

To further support this transition, the call encouraged the integration of digital tools, as well as the development of improved mold designs and processing aids to optimize the handling and transformation of recycled polymers.

Deliverable 2.3 and 2.5 focus on the outcomes of the Innovation Call and summarize the results of the projects completed by SMEs in the field of mechanical and chemical recycling.

Deliverable D2.6 synthesizes findings from completed SME-led projects, examining their contributions to business process innovation. While technical results are important, this deliverable emphasizes organizational, systemic, and ecosystem-level changes, assessing how SMEs integrate circularity into their processes, engage value-chain partners, and prepare for industrial scalability.

The analysis is based on summaries of 15 SME projects funded under POLREC. Each project was reviewed to extract information on process innovations, ecosystem engagement, and business model impacts. The synthesis focuses on cross-cutting themes rather than duplicating technical details, ensuring a consolidated perspective of industrial adoption.

3. Business Process Innovations in Chemical Recycling

The POLREC project highlights how SMEs across Europe are pioneering business process innovations within chemical recycling, transforming waste streams into high-value materials and enabling circularity across diverse industrial sectors. By combining technical advances with strategic collaborations, flexible business models, and targeted market development, these companies demonstrate how chemical recycling can generate both environmental and economic benefits.

- **Agon A/S – Circular Lifting Slings:** Agon validated a closed-loop system for polyester straps through chemical recycling, enabling high-purity PET recovery. The recovered material is reintegrated into production, reducing reliance on virgin PET. This initiative exemplifies supply chain innovation, converting products that would traditionally be landfilled into high-quality input materials.
- **DLyte Chemicals – Regeneration of Electrolytes:** DLyte transitioned from a single all-in-one regeneration unit to a modular system for dry electrolytes. This redesign improved technical performance while providing a flexible business model, lowering operational costs and enabling incremental adoption by customers. The innovation lies in combining process redesign with commercial scalability.
- **Earth Protex Portugal – Tex2Tex FAASST™:** Earth Protex advanced sustainable textile finishes to reduce microfiber shedding and enhance durability. By integrating bio-based coatings with recycled textiles, the company merged product innovation with environmental value. The project demonstrates how SMEs can reposition themselves by aligning process innovations with emerging sustainable market niches.
- **ECCOLANT – Nylon Tights Recycling:** ECCOLANT developed a roadmap to scale a green chemical process for nylon recovery. Beyond lab-scale validation, the innovation centered on cross-sector partnerships and a structured industrialization plan. Collaboration is framed here as a business process innovation, enabling SMEs to move from isolated experiments to integrated recycling solutions.
- **José Combalía – Polyolefins to Dicarboxylic Acids:** José Combalía converted polyolefins into dicarboxylic acids, generating value-added chemicals for industrial applications. This

Funded by the European Union

represents a business model innovation where recycling pathways are designed for high-value outputs rather than downcycling, demonstrating the potential for premium products derived from post-consumer materials.

- **MACHAON SAS – RePlastify Pyrolysis:** MACHAON explored pyrolysis of mixed plastics, focusing on valorizing waxes as secondary products. By reconceptualizing waste by-products as revenue-generating resources, the company introduced new supply chain and market strategies, showcasing innovation in both material utilization and business modeling.
- **QEV Technologies – Recycling of Competition Cars:** QEV recycled carbon fiber waste from racing cars into luxury automotive parts. By validating non-structural applications for recycled composites, the SME opened high-performance market opportunities. The project demonstrates how chemical recycling can support brand positioning in premium segments while establishing circular production loops.
- **Mariton SA – Recycling Fabric Scraps:** Mariton partnered with Polyloop to recover PVC and fibers from fabric scraps. Beyond technical dissolution, the project built a collaborative recycling pathway between SMEs, converting textile waste into reusable industrial inputs. Business process innovation here centered on inter-firm cooperation, shared logistics, and value recovery from materials that would otherwise be discarded.
- **Imdex – Recycling of end-of-life tires:** Imdex explored recycling waste from end-of-life truck and passenger car tires, converting rubber granules and woven materials into oil and char via pyrolysis. The innovation lies in creating a sustainable waste-to-resource pathway aligned with regulatory developments (2031 ban on rubber granules in artificial turf). Analytical techniques (titrator, ICP, XRF, TGA, FTIR, GC-MS) ensured product quality, and safety protocols addressed potential hazardous emissions. This represents a business process innovation integrating technical, regulatory, and environmental considerations.

Collectively, these projects illustrate that chemical recycling innovations extend well beyond laboratory success. They involve **strategic process redesign, supply chain reconfiguration, modular and scalable technical systems, collaborative partnerships, and targeted market positioning**. By addressing material recovery, industrial feasibility, and application-specific performance, these SMEs demonstrate the transformative potential of chemical recycling to create profitable, environmentally aligned, and scalable business processes.

4. Business Process Innovations in Mechanical Recycling

The POLREC project illustrates how SMEs are driving business process innovations in mechanical recycling, transforming post-consumer and post-industrial waste into high-value products. By combining technical advances with industrial-scale feasibility, regulatory alignment, and strategic market positioning, these companies demonstrate that mechanical recycling can be both environmentally beneficial and commercially viable.

- **Altheora – SMC Cabinet Recycling:** Altheora developed a method to delaminate SMC cabinets, enabling fiber recovery for reuse in composites. This innovation transformed a product category with limited reuse potential into a circular resource loop, reducing dependence on virgin glass fibers while creating new market opportunities.
- **Berbetores Industrial – Additive Manufacturing with Recycled Plastics:** Berbetores tested BAAM with recycled ABS and HDPE. While HDPE proved challenging, successful injection

Funded by the European Union

molding of ABS waste demonstrated technical feasibility. Business innovation was realized by embedding recycling into its "Greendustrial" strategy, linking additive manufacturing with sustainable revenue streams.

- **CAMY SAS – Closed-loop EVA Footwear:** CAMY developed recyclable EVA formulations for medical footwear. Although full reintegration faced technical limits, the eco-design approach aligned product development with circular end-of-life strategies, exemplifying how product-level innovation can drive business process improvements.
- **Earth Protex Portugal – STOMP Elastane Dissolution:** Earth Protex successfully separated elastane from PET textiles, enabling closed-loop recycling. Innovations in solvent recovery and regulatory compliance allowed the company to offer a new circular service to the textile industry, combining technical performance with market-ready business solutions.
- **Gaviplas – Deinking for Food-Grade LDPE:** Gaviplas advanced food-contact safe recycled LDPE through high-precision deinking processes. The business innovation centered on regulatory certification, enabling closed-loop recycling for high-value packaging applications and demonstrating how compliance can unlock market potential.
- **José Combalía – Polyethylene Loop:** José Combalía integrated recycled crown cap liners and shrink films into its own production processes. By creating a circular business model, the SME reduced virgin plastic usage and showcased how in-house recycling can strengthen industrial resilience and operational efficiency.
- **Mälarplast – Tool Coatings for Bioplastics:** Mälarplast applied advanced coatings to tools, enabling molding with recycled bioplastics. The innovation reduced maintenance and scrap rates, changing the economics of recycled material adoption and supporting broader industrial uptake.
- **PDC Plast – Coated Tools for Recycled TPU:** PDC Plast used tool coatings to enable mass production with recycled TPU, achieving significant scrap reduction. The project highlights operational innovation, demonstrating how SMEs can overcome technical barriers and integrate recycled materials into standard manufacturing processes.
- **RecyOuest – Recycling Agro-Nets:** RecyOuest piloted HDPE recycling from agricultural nets, producing yarns with recycled content. The business innovation focused on eco-designed collection schemes and closed-loop agricultural applications, illustrating how SMEs can structure circular value chains.
- **Rezero – Cigarette Filter Recycling:** Rezero mechanically recycled cellulose acetate from cigarette filters into nonwoven materials. The innovation diversified market opportunities, turning a challenging waste stream into inputs for insulation, wipes, and textiles, demonstrating value creation from problematic materials.
- **Sports Carbone – Bicycle Frame Recycling:** Sports Carbone advanced recycling of carbon fiber sports equipment. Business innovation combined repair services with recycled fiber integration, creating a dual revenue model and validating the commercial potential of high-performance recycled materials.
- **Total Plastic Solution – Contaminated Polypropylene:** TPS developed methods to recycle PP contaminated with coolant and water residues. The innovation addressed often-overlooked industrial side-streams by designing scalable, contamination-tolerant recycling workflows.

Funded by the European Union

- **Waste Prevention SL – Open-Loop Urban Products:** Prewaste created blends of mixed plastics for durable urban infrastructure. By turning low-value mixed waste into functional products, the company demonstrated how SMEs can reposition undervalued waste streams into marketable solutions.
- **BIOWRAP – Compostable Film Recycling:** BIOWRAP attempted to recycle its patented compostable stretch film. While the company faced liquidation, early efforts to align bio-based product design with recycling compatibility offer lessons on the risks and challenges of scaling biodegradable solutions.
- **Polymer Alloy Technologies – rPET Composites:** The SME advanced rPET matrix development for utility poles. Business innovation included material blending strategies to enhance properties, positioning recycled PET in structural applications beyond traditional uses, thereby expanding market scope.

Across these projects, mechanical recycling innovations combine **technical process development, eco-design, material standardization, regulatory compliance, and operational integration**. By embedding recycled materials into production loops, SMEs demonstrate how business process innovation can achieve scalable, industrially relevant circularity. These approaches enable industrial ecosystems to adopt more sustainable practices while creating new revenue streams, enhancing competitiveness, and contributing to broader environmental objectives.

5. Cross-Cutting Insights from POLREC Projects

The POLREC projects demonstrate that SMEs across Europe are not only developing technical solutions for recycling but are also pioneering systemic business process innovations that strengthen circularity in plastics and composites. By examining both chemical and mechanical recycling streams, several cross-cutting insights emerge that highlight the drivers, barriers, and potential of these innovations.

- **Integration within industrial ecosystems is crucial:** Companies that link recycling initiatives to established supply chains or strategic partners achieve faster market uptake and more scalable operations. Examples include Gaviplas' de-inking process for food-grade LDPE, Mälarplast's tool coatings for bioplastics, and RecyOuest's closed-loop agricultural net recycling. Conversely, projects lacking sufficient support—financial, regulatory, or technological—face challenges in scaling, as seen with BIOWRAP's compostable film.
- **Material quality and process reliability are central:** Mechanical and chemical recycling alike require consistent, high-quality outputs. Contamination management, solvent recovery, and de-inking are recurring technical challenges, while modular and scalable processes, such as DLyte's electrolyte regeneration or José Combalía's polyolefin loops, illustrate how technical innovation can align with reliable production and market needs.
- **Targeted applications increase adoption and value:** SMEs that adapt recycled materials to specific product categories—ranging from reinforced composites and medical footwear to urban infrastructure and automotive parts—demonstrate higher adoption rates and commercial relevance. These tailored approaches often require additional testing, process validation, and collaboration with research institutes or end-users.
- **Collaboration enhances innovation and commercialization:** Cross-firm partnerships, joint ventures, and engagement with research and technology providers are recurrent themes.

Funded by the European Union

Mariton's collaboration with Polyloop, ECCOLANT's cross-sector industrialization plan, and QEV Technologies' luxury car carbon fibre recycling illustrate how inter-organizational cooperation can create new industrial pathways and revenue streams.

- **Business model innovation complements technical innovation:** Many SMEs have redefined value chains, integrated take-back schemes, or developed dual revenue models that combine repair and recycling. Sports Carbone's repairable bicycle frames, MACHAON's valorisation of waxes from pyrolysis, **BCircular's chemical processes for high-value composite recycling**, and Total Plastic Solution's contamination-tolerant PP recycling exemplify how operational strategies can turn waste streams into profitable, sustainable business opportunities.
- **Regulatory alignment and certification are enablers:** Success often depends on compliance with sector-specific standards or eco-certifications. Gaviplas' food-grade LDPE, José Combalía's closed-loop polyolefins, and CAMY SAS's recyclable EVA footwear show how certification drives both market acceptance and circularity.
- **Scaling remains a complex challenge:** Transitioning from pilot-scale success to industrial implementation requires continued focus on process optimization, material performance, and operational efficiency. Companies like Berbetores Industrial, Earth Protex Portugal, **Imdex with its pyrolysis approach to end-of-life tires**, and RecyOuest illustrate the steps required to move from technical feasibility to robust, industrially embedded solutions.

Collectively, these insights reveal that the POLREC SMEs are advancing circular economy principles not just through technical solutions but via systemic changes in production, collaboration, and market strategies. The lessons learned form a foundation for the subsequent chapters, which explore how these innovations are embedded in industrial ecosystems, scaled across markets, and translated into business opportunities that are both economically viable and environmentally sustainable.

6. Key Business Process Innovations

A range of process-oriented innovations emerged from the POLREC ecosystem. These go beyond technical improvements and represent systemic changes to the way SMEs organize recycling, production, and collaboration. The collective efforts of these companies represent a robust and forward-thinking response to the pressing challenges of sustainability, resource scarcity, and environmental regulation in the industrial and manufacturing sectors. While operating across diverse markets—from plastics and textiles to footwear, construction, and consumer goods—each organization has taken concrete steps towards embedding circular economy principles into their core operations. Their initiatives underscore a clear shift from linear production models to systems that prioritize material recovery, waste reduction, and responsible innovation.

- **Circularity and Resource Efficiency**

  Most companies are investing in closed-loop systems, where production waste is recovered, recycled, and reintegrated into manufacturing. These strategies reduce raw material consumption and lower environmental impact. Projects such as Gaviplas' deinking of LDPE diaper packaging, José Combalía's polyethylene recycling, and Mälarplast's bioplastics recycling with PVD-coated molds exemplify this approach. Chemical recycling initiatives like

Funded by the European Union

AGON A/S Circular Lifting Slings demonstrate how high-purity PET can be recovered and reintroduced into production, emphasizing technical feasibility and material quality.

- **Advanced Material Innovation**

  Companies are exploring high-performance alternatives to conventional materials, which add functional value while maintaining or exceeding performance standards. For example, ALTHEORA developed new composites incorporating recycled glass fibers, CAMY SAS investigated recyclable EVA formulations for footwear, and SPORTS CARBONE focused on carbon fiber recovery for sporting goods. Chemical projects like ECCOLANT and José Combalía demonstrated the recovery of polyamide and polyolefins to produce high-value materials suitable for advanced applications. BCircular added to this trend by validating chemical processes that upgrade composite waste into advanced recycled feedstocks, demonstrating potential for premium applications.

- **High-Potential Recycling Technologies**

  Several companies are developing specialized mechanical and chemical recycling methods, enabling the recovery of materials that would otherwise be difficult to reuse. Earth Protex Portugal and Total Plastic Solution showcased solvent-based separation techniques for textiles and polypropylene, while mechanical recycling projects such as RecyOuest and Rezero focused on filtration, shredding, and extrusion to maximize material recovery. Imdex investigated pyrolysis of end-of-life tires, while MACHAON explored wax valorisation from plastics pyrolysis—both showing how thermal treatment can generate valuable oils, chars, and by-products. QEV Technologies advanced the reuse of carbon fibre waste from high-performance cars into luxury automotive applications, further diversifying recycling pathways.

- **Sector-Specific Applications and Market Expansion**

  Innovations are tailored to sector-specific needs, unlocking new business opportunities. Berbetores Industrial explored additive manufacturing with recycled ABS and HDPE; Rezero targeted hygiene, footwear, and insulation sectors; RecyOuest developed agricultural solutions using recycled HDPE monofilament. Chemical projects like QEV Technologies applied recycled carbon fiber to automotive components, and MARITON SA demonstrated efficient PVC and PE recovery from fabric scraps. **These diverse applications illustrate how SMEs from footwear to composites, including CAMY SAS, ALTHEORA, and BCircular, expand into markets where sustainability is becoming a defining demand.**

- **Collaborative Ecosystems and Partnerships**

  Collaboration across value chains, research institutions, technology providers, and clients has been a critical enabler of business process innovation. PDC-Plast, Mälarplast, and SPORTS CARBONE illustrate how joint ventures and technical partnerships enhance both innovation capacity and commercialization potential. Chemical recycling projects, such as DLyte Chemicals, José Combalía, and **Imdex (through collaborations on safety and pyrolysis process validation)** also highlighted the value of cross-organizational coordination for scaling novel processes.

Funded by the European Union

- **Digitalization and Process Traceability**

  Process traceability and digital integration are increasingly important for scaling circular solutions. Projects like ECCOLANT nylon recycling emphasized the need for tracking material flows, monitoring process efficiency, and ensuring product quality. Mechanical recycling initiatives utilized digital tools for monitoring contamination, assessing material properties, and validating pyrolysis outputs. Such capabilities improve operational efficiency, ensure compliance, build consumer trust, and support data-driven decision-making for industrial circularity.

- **Emerging Business Opportunities**

  Evidence from both mechanical and chemical recycling projects shows clear business potential. Mechanical recycling initiatives demonstrated repair and reuse models as alternatives to traditional recycling, opening new revenue streams. Chemical recycling projects highlighted the opportunity for high-quality materials to enter new markets, supported by life cycle assessments (LCAs) and regulatory foresight. Examples include Imdex and MACHAON's pyrolysis, José Combalía's high-value polyolefins, BCircular's composite valorisation, and QEV's carbon fibre reuse, all of which showcase different but complementary opportunities. Collectively, these efforts create business opportunities that are both profitable and aligned with sustainability demands, reinforcing the strategic value of integrating circular economy principles into SME operations.

Additional evidence from D2.3 and D2.5 shows that business opportunities are closely tied to recycling innovation. Mechanical recycling initiatives highlighted the business case for repair and reuse models as alternatives to pure recycling, opening new revenue streams for SMEs. Chemical recycling projects emphasized the potential for new material markets based on high-quality outputs, supported by Life Cycle Assessments (LCAs) and regulatory foresight. Together, these approaches are creating business opportunities that are both profitable and aligned with sustainability demands.

7. Embedding Innovations in the Industrial Ecosystem/s

A range of process-oriented innovations emerged from the POLREC ecosystem. These go beyond technical improvements and represent systemic changes to the way SMEs organize recycling, production, and collaboration. The collective efforts of these companies represent a robust and forward-thinking response to the pressing challenges of sustainability, resource scarcity, and environmental regulation in the industrial and manufacturing sectors. While operating across diverse markets—from plastics and textiles to footwear, construction, and consumer goods—each organization has taken concrete steps towards embedding circular economy principles into their core operations. Their initiatives underscore a clear shift from linear production models to systems that prioritize material recovery, waste reduction, and responsible innovation.

- **Circularity and Resource Efficiency**

  Most companies are investing in closed-loop systems, where production waste is recovered,

Funded by the European Union

recycled, and reintegrated into manufacturing. These strategies reduce raw material consumption and lower environmental impact. Projects such as Gaviplas' deinking of LDPE diaper packaging, José Combalía's polyethylene recycling, and Mälarplast's bioplastics recycling with PVD-coated molds exemplify this approach. Chemical recycling initiatives like AGON A/S Circular Lifting Slings demonstrate how high-purity PET can be recovered and reintroduced into production, emphasizing technical feasibility and material quality. Imdex, QEV, and BCircular extended these efforts to more challenging waste streams, including end-of-life tires, carbon fiber, and composite residues, showing how circularity can reach beyond plastics into rubber- and fiber-based products.

- **Advanced Material Innovation**

Companies are exploring high-performance alternatives to conventional materials, which add functional value while maintaining or exceeding performance standards. For example, ALTHEORA developed new composites incorporating recycled glass fibers, CAMY SAS investigated recyclable EVA formulations for footwear, and SPORTS CARBONE focused on carbon fiber recovery for sporting goods. Chemical projects like ECOLLANT and José Combalía demonstrated the recovery of polyamide and polyolefins to produce high-value materials suitable for advanced applications. QEV advanced the reuse of recycled carbon fiber for automotive applications, BCircular developed bio-based resin systems to integrate recycled fibers, and Imdex demonstrated how tire-derived materials could be upgraded into industrial feedstocks.

- **High-Potential Recycling Technologies**

Several companies are developing specialized mechanical and chemical recycling methods, enabling the recovery of materials that would otherwise be difficult to reuse. Earth Protex Portugal and Total Plastic Solution showcased solvent-based separation techniques for textiles and polypropylene, while mechanical recycling projects such as RecyOuest and Rezero focused on filtration, shredding, and extrusion to maximize material recovery. Chemical recycling initiatives—including Imdex, Re-Plastify, and BCircular—developed pyrolysis and depolymerization approaches to transform end-of-life tires, composites, and mixed plastics into oils, waxes, and reusable fibers. QEV further demonstrated advanced processing routes for composite carbon materials in the automotive sector.

- **Sector-Specific Applications and Market Expansion**

Innovations are tailored to sector-specific needs, unlocking new business opportunities. Berbetores Industrial explored additive manufacturing with recycled ABS and HDPE; Rezero targeted hygiene, footwear, and insulation sectors; RecyOuest developed agricultural solutions using recycled HDPE monofilament. Chemical projects like QEV Technologies applied recycled carbon fiber to automotive components, and MARITON SA demonstrated efficient PVC and PE recovery from fabric scraps. BCircular explored high-performance resin formulations for construction and sporting applications, while Imdex's tire-derived fractions created opportunities in playground surfaces, flooring, and industrial fillers. Aligning material

Funded by the European Union

innovations with sectoral demands enables companies to expand their portfolios while maintaining relevance in emerging sustainable markets.

- **Collaborative Ecosystems and Partnerships**

Collaboration across value chains, research institutions, technology providers, and clients has been a critical enabler of business process innovation. PDC-Plast, Mälarplast, and SPORTS CARBONE illustrate how joint ventures and technical partnerships enhance both innovation capacity and commercialization potential. Chemical recycling projects, such as DLYTE Chemicals and José Combalía, also highlighted the value of cross-organizational coordination for scaling novel chemical processes. Imdex worked with pyrolysis developers, QEV with automotive manufacturers, and BCircular with resin suppliers, showing how diverse partnerships can accelerate the scaling of difficult-to-recycle material streams.

- **Digitalization and Process Traceability**

Process traceability and digital integration are increasingly important for scaling circular solutions. Projects like ECOLLANT nylon recycling emphasized the need for tracking material flows, monitoring process efficiency, and ensuring product quality. Mechanical recycling initiatives utilized digital tools for monitoring contamination, assessing material properties, and validating pyrolysis outputs. Companies such as Imdex, QEV, and BCircular integrated advanced analytical workflows and digital monitoring to validate the quality of pyrolysis oils, recovered fibers, and resin-fiber composites, ensuring compliance, safety, and performance across recycling streams.

- **Emerging Business Opportunities**

Evidence from both mechanical and chemical recycling projects shows clear business potential. Mechanical recycling initiatives demonstrated repair and reuse models as alternatives to traditional recycling, opening new revenue streams. Chemical recycling projects highlighted the opportunity for high-quality materials to enter new markets, supported by life cycle assessments (LCAs) and regulatory foresight. Imdex's work on tire pyrolysis, QEV's recycled carbon composites, and BCircular's resin-integration technologies all illustrate how SMEs can anticipate regulatory change (such as restrictions on rubber granules in turf by 2031) while simultaneously creating profitable, sustainable product streams.

Additional evidence from D2.3 and D2.5 show that business opportunities are closely tied to recycling innovation. Mechanical recycling initiatives highlighted the business case for repair and reuse models as alternatives to pure recycling, opening new revenue streams for SMEs. Chemical recycling projects emphasized the potential for new material markets based on high-quality outputs, supported by Life Cycle Assessments (LCAs) and regulatory foresight. By diversifying approaches—from tires (Imdex) to composites (QEV), to resin-fiber systems (BCircular)—SMEs collectively illustrate the economic and environmental potential of advanced recycling strategies.

Funded by the European Union

8. Discussion and Analysis

The POLREC project demonstrates that European SMEs are actively advancing circularity in plastics, rubber, textiles, and composites through both mechanical and chemical recycling approaches. Across the diverse range of projects, companies have combined technical innovation, collaborative networks, and value chain integration to create significant impact. The aggregated outcomes reveal a set of cross-cutting insights regarding the drivers, barriers, and transformative potential of business process innovations.

A central finding is that the effectiveness of innovations depends heavily on their integration into established industrial ecosystems. Companies such as Gaviplas, Mälarplast, RecyOuest, QEV Technologies, BCircular, and others illustrate that robust partnerships with suppliers, research institutions, and industrial clients accelerate market uptake, improve operational scalability, and enhance product acceptance. Conversely, initiatives that lack stable financing, regulatory alignment, or technological maturity—such as BIOWRAP and certain experimental recycling streams—struggle to move beyond pilot-scale trials, underscoring the critical role of ecosystem support in converting technical feasibility into sustainable industrial practice.

Another key insight is that technical innovation alone is insufficient to drive circular business models. Process optimization, material quality, and standardization remain decisive factors. Mechanical recycling projects highlighted challenges such as contamination management, de-inking, and achieving consistent material properties, while chemical recycling initiatives emphasized the importance of policy alignment, life cycle assessments (LCAs), eco-friendly alternatives, and stakeholder engagement. Addressing these factors ensures that novel materials and processes are functional, market-ready, and aligned with regulatory and industrial standards. For example, chemical recycling initiatives applied advanced analytical monitoring and process controls to ensure high-quality outputs, while mechanical recyclers implemented improved workflows to stabilize feedstock properties.

Application-specific development has proven to be a major driver of adoption. Projects that tailored recycled materials to targeted product categories—such as reinforced composites (ALTHEORA, SPORTS CARBONE), coated bioplastics for consumer products (Mälarplast), high-value polyesters and polyurethanes (José Combalía), or specialized packaging and textile components (AGON A/S, Earth Protex Portugal)—showed higher adoption rates and stronger market relevance. Similarly, SMEs working on tire and textile recycling (Imdex, BCircular, RecyOuest) demonstrated how outputs can be redirected toward construction, automotive, playground, or footwear applications, highlighting sector-specific adoption of otherwise challenging-to-recycle materials.

The project also reveals the transformative potential of business process innovations for operational and commercial practices. Closed-loop recycling systems, traceable material flows, and collaborative ventures are increasingly feasible, demonstrating a shift from isolated pilot projects to systemic approaches that redefine material recovery and circular production. These innovations enable SMEs to explore new revenue streams, competitive advantages, and market opportunities while simultaneously supporting environmental sustainability and resource efficiency. For example, collaborative models across plastics, textiles, and composites demonstrated that circularity creates industrial synergies that go beyond technical recycling outputs.

Industrial scalability remains a critical focus for future development. Several companies—such as José Combalía, RecyOuest, Total Plastic Solution, and QEV Technologies—have progressed from laboratory or pilot-scale experiments to larger production contexts, addressing process reliability, equipment adaptation, and quality assurance. Scaling also requires integration of process control, solvent

Funded by the European Union

recovery, automation, and mechanical optimization to ensure that recycled materials meet industrial performance and safety standards consistently. SMEs dealing with complex streams (e.g. textiles, tires, or composites) reinforced this point, showing that feedstock variability, process safety, and downstream application compatibility must be addressed through continuous monitoring and adaptive strategies.

Collaboration emerges as a core enabler of these outcomes. POLREC SMEs leveraged joint ventures, technical partnerships, and ecosystem networks to enhance capabilities, accelerate comercialization, and embed circular practices into supply chains. Successful collaborations facilitated knowledge exchange, risk sharing, and alignment with both regulatory frameworks and customer requirements. Conversely, limited partnership engagement was identified as a barrier to full ecosystem integration in some projects, emphasizing the importance of stakeholder networks for long-term sustainability.

Despite the progress achieved, challenges remain in achieving widespread adoption. Variability in feedstock quality, technological limitations, and gaps in policy or standardization frameworks can constrain the scale and consistency of recycled outputs. Future efforts will need to focus on harmonizing industrial practices, enhancing recycling technology reliability, and expanding cross-sector collaborations to support broader market acceptance. Evidence from POLREC indicates that SMEs are actively developing solutions to these challenges but will require supportive ecosystems, financing, and policy clarity to scale their efforts effectively.

In summary, POLREC illustrates that embedding business process innovations in the industrial ecosystem is a multi-dimensional endeavor. Success depends not only on technical excellence in recycling technologies but also on strategic partnerships, process optimization, policy alignment, and targeted product development. By combining these factors, SMEs are laying the foundation for a resilient, circular industrial economy—one that transforms waste into high-value materials, aligns with sustainability objectives, and generates new business opportunities across Europe.

9. Conclusions and Recommendations

The POLREC project has demonstrated the significant potential of SMEs to drive innovation in plastics, rubber, textiles, and composite recycling while actively contributing to the transition toward a circular economy. Across both mechanical and chemical recycling streams, participating companies have implemented business process innovations that enhance material recovery, improve production workflows, and enable sustainable product development. These initiatives not only advance environmental performance but also open new business opportunities, demonstrating that sustainability can act as a driver of competitiveness and economic growth.

A central conclusion is that the successful embedding of innovations relies heavily on integration within industrial ecosystems. Companies that leveraged collaborations with research institutions, technology providers, and industrial partners, including Gaviplas, Mälarplast, RecyOuest, José Combalía, QEV Technologies, BCircular, and Imdex, achieved faster adoption, higher process reliability, and stronger market acceptance. Collaborative approaches, whether through joint ventures, technical partnerships, or multi-stakeholder engagement, proved essential in converting technical feasibility into industrial-scale implementation. Conversely, projects with limited partnerships or insufficient regulatory and financial support, exemplified by BIOWRAP, illustrate the risks of stalled innovation despite promising technical development.

Funded by the European Union

Process optimization, material quality, and application-specific development are crucial for achieving reliable and functional outputs. SMEs improved chemical and structural properties of recycled materials, tailored polymer formulations, or developed high-performance composites to meet industrial standards. Targeted applications, such as reinforced composites produced by ALTHEORA and SPORTS CARBONE, coated bioplastics for consumer products developed by Mälarplast, high-value polyesters and polyurethanes by José Combalía, recycled EVA footwear by CAMY SAS, specialized packaging by AGON A/S, textile components by Earth Protex Portugal, and automotive parts by QEV Technologies, demonstrated higher market relevance and facilitated smoother integration into existing value chains. Similarly, tire and rubber recycling projects led by Imdex and BCircular showed that recovered fractions could be redirected toward construction, playgrounds, and other industrial applications, highlighting sector-specific adoption of materials that are otherwise difficult to recycle.

POLREC also highlights the transformative potential of these innovations for business models and operational practices. Companies increasingly explore take-back systems, traceable recycling loops, and collaborative ventures, reflecting a shift from isolated projects toward systemic approaches to material management. Closed-loop recycling, high-quality feedstock production, and reuse-oriented processes create additional revenue streams while contributing to sustainability goals. Mechanical recycling initiatives demonstrated the business case for repair and reuse, while chemical recycling projects emphasized new high-value material markets supported by life cycle assessments and regulatory foresight. Chemical and pyrolysis projects, including DLyte Chemicals, ECCOLANT, José Combalía, and Imdex, show how novel materials can be industrially viable while opening additional revenue streams.

Industrial scalability remains a key challenge for SMEs. Successful transitions from pilot-scale experiments to full-scale production require robust process control, automation, solvent and contaminant management, and continuous monitoring of material consistency. Scaling is essential not only for meeting market demand but also for ensuring recycled materials achieve performance and safety standards comparable to virgin alternatives. Projects from José Combalía, RecyOuest, Total Plastic Solution, QEV Technologies, and Imdex demonstrate that scaling complex recycling processes requires careful feedstock characterization, adaptive strategies, and quality assurance protocols.

Collaboration emerges as a recurring success factor. Partnerships with suppliers, manufacturers, research organizations, and end-users enhance technical capability, accelerate commercialization, and facilitate integration into supply chains. Ecosystem-wide cooperation also supports standardization, regulatory alignment, and policy compliance, enabling wider adoption of circular practices across regions and sectors. Multi-stakeholder engagement in projects such as Imdex, QEV Technologies, BCircular, and RecyOuest illustrates how cross-organizational collaboration enables practical deployment of complex recycling processes.

Remaining challenges include contamination control, variability in recycled feedstock, industrial scalability, financing limitations, regulatory complexity, and the need for cross-border coordination. Addressing these challenges requires continuous knowledge sharing, investment in advanced recycling technologies, and ecosystem-level support to foster widespread adoption of circular practices. Experiences from Imdex, RezyOuest, and other SMEs indicate that heterogeneous feedstocks necessitate robust monitoring and adaptive strategies to ensure consistent, high-quality outputs.

Funded by the European Union

Based on these insights, several recommendations emerge for SMEs and ecosystem stakeholders. They should continue investing in advanced recycling and material innovation to develop closed-loop systems, high-performance composites, and targeted application-specific solutions that enhance material value and circularity. The Imdex pyrolysis case highlights the importance of developing robust chemical and thermal recycling solutions for complex waste streams. SMEs should prioritize process reliability and industrial scalability by implementing robust process controls, contamination management, and equipment adaptation to support consistent quality at industrial scale. Strengthening collaboration across the value chain with suppliers, manufacturers, end-users, and research organizations will facilitate knowledge transfer, accelerate market readiness, and reduce adoption barriers. Policymakers should provide clear guidelines, incentives for circular practices, and mechanisms to facilitate cross-border collaboration and standardization. Industrial ecosystems should adopt practices that enable monitoring, reporting, and verification of recycled material flows to foster transparency, traceability, and continuous improvement.

In conclusion, the POLREC project illustrates that business process innovations act as a catalyst for the European transition toward a circular economy. By combining technical excellence, strategic collaboration, and ecosystem-level integration, SMEs can develop scalable, sustainable solutions that reduce environmental impact, enhance competitiveness, and create resilient industrial ecosystems. The lessons learned and initiatives implemented through POLREC provide a robust foundation for continued progress, demonstrating that the green transition is not only feasible but actively underway across Europe. Experiences from all participating SMEs, including Imdex, QEV Technologies, BCircular, Gaviplas, Mälarplast, RecyOuest, José Combalía, and others, show that even complex and traditionally difficult-to-recycle materials can be transformed into commercially viable, circular inputs through process innovation, collaboration, and ecosystem embedding.

Funded by the European Union

PROJECT INFORMATION

Grant Agreement	Project 101074434 — POLREC
Programme	Single Market Programme (SMP COSME)
Call	SMP-COSME-2021-CLUSTER
Topic	SMP-COSME-2021-CLUSTER-01
Type of action	SMP Grants for Financial Support
Project Title	Supporting a green and resilient Europe through POLymer RECycling
Project starting date	1st September 2022
Project end date	31st August 2025
Project duration	36 months

PROJECT CONSORTIUM

Funded by the European Union

PROJECT

POLREC

Funded by
the European Union

