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Cradle-ALP

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Sectoral Cradle2Cradle industrial transformation roadmaps

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1. Summary

This report introduces the Transformation Roadmap activities and results elaborated in the frame of the Cradle−ALP project, which aims to integrate cradle−to−cradle (C2C) approaches, circular design, and circular substitutions in various industries, especially in the Alpine region. To promote this shift toward circularity to the 5 industrial sectors identified as key sectors within the Alpin Space, the Cradle−ALP partners worked on conducting a roadmapping process involving the different stakeholders along the value−chain of the 5 main sectors. The output of this process was analyzed and summed up into 5 Circular Transformation Roadmaps for the Polymer/Composites, Chemistry/Materials, Textiles, Packaging and Wood/Furniture industrial sectors in the Alpin Space

This document focuses on the process and results for the Circular Transformation Roadmap of the Polymer−based composites sector, conducted by Polymeris with the support of Chemie Cluster Baryern, Technology Center Horb Innonet Kunststoff and School of Engineering and Architecture of Fribourg as members of the Transnational Sectoral Working Group on Polymer−based composites. The roadmap includes a detailed approach to achieving these goals, encompassing technologies, business models, and legal and political frameworks. It offers short−, mid−, and long−term activities to promote circularity within the sector.

2. Introduction to Cradle-ALP project

Cradle−ALP aims for mainstreaming cradle to cradle (C2C) approaches, circular design, and circular substitutions (from the alpine region) for linear products in industrial processes, in different industrial sectors. The Alpine Space is abundant in natural resources and possesses the technology necessary to replace fossil raw materials and toxic substances in production with sustainable, eco−friendly alternatives. This transformation facilitates the reintegration of materials and products into a healthy, closed−loop cycle after use. The focus of this project shall be on the substitution of chemical and fossil based/unsustainable materials with more circular, sustainable, and bio−degradable ones.

First, the partners will build a broad awareness and understanding in the public, the relevant industries as well as among stakeholders from policy and innovation intermediaries, for the opportunities, barriers, and mechanisms of the transformation of industrial products towards higher circularity by means of C2C approaches, circular design and circular substitutions. Business support providers shall be trained to accompany the transformation of businesses along more circular value chains.

In a second step, the partners will explore in details and test opportunities for implementing C2C approaches, circular design, and circular substitutions along specific value chains in the chemistry/plastics and wood/forestry sectors supported by digital technologies. Building on a thorough multidimensional (technology, policy, economy, etc.) roadmapping exercise, transnational groupings of stakeholders – including businesses – will be installed, with the aim to transfer the C2C roadmaps into industrial practice along exemplary value chains.

Finally, the partners will work towards ensuring a transnational policy convergence towards transnational S4 strategies in the priority sectors of the project and initiate common cross border funding instruments for the industrial C2C transformation.

3. Objectives and scope of the Transformation Roadmap for the Polymer-based composites sector

The objective was the development of a transformation roadmap in the Polymers−based composites sector to show existing and upcoming technologies (digital and engineering) and legal and normative requirements which can foster the transformation of industrial practices towards circular economy. This includes the substitution of materials with bio−based and/or recyclable alternatives.

The overall objective of the transformation roadmap for the Polymer−based composites sector is to guide the industry toward a more sustainable future by reducing landfill disposal of composites waste to just 10% of total waste by 2035, in alignment with the EU Landfill Directive. The focus is on promoting circularity and sustainability within the industry, focusing on Materials & resources, circular product design and end−of−life management & valorization of composites waste.

4. Roadmapping procedure & participating organisations

A workshop with an external expert support group was carried out to identify gaps, barriers, drivers, and potentials for sector of Polymer−based composites.

To elaborate possible future solutions as content for the roadmap three online workshops were designed using a Mural whiteboard following the same procedure and engaging the participants in three exercises:

1) Identifying potential gaps and barriers in knowledge, technology limitations, market structural barriers, regulatory limitations, public acceptance or other gaps and barriers preventing the industry to achieve the vision set out following the experts' workshop.
2) Defining solutions and key activities to implement to overcome the gaps and barriers previously identified. Those key activities must concern each component of the industrial sector, including technology development and deployment, development of business models and market opportunities, development of regulations and standards, policy formulation, creation of financing mechanisms, and public engagement.
3) Assigning the solutions and key activities according to their field (Technology, Business Model, legal/political) and their timeframe (short−term, mid−term, long−term) and voting on the activities that are the most important to implement and achieve.

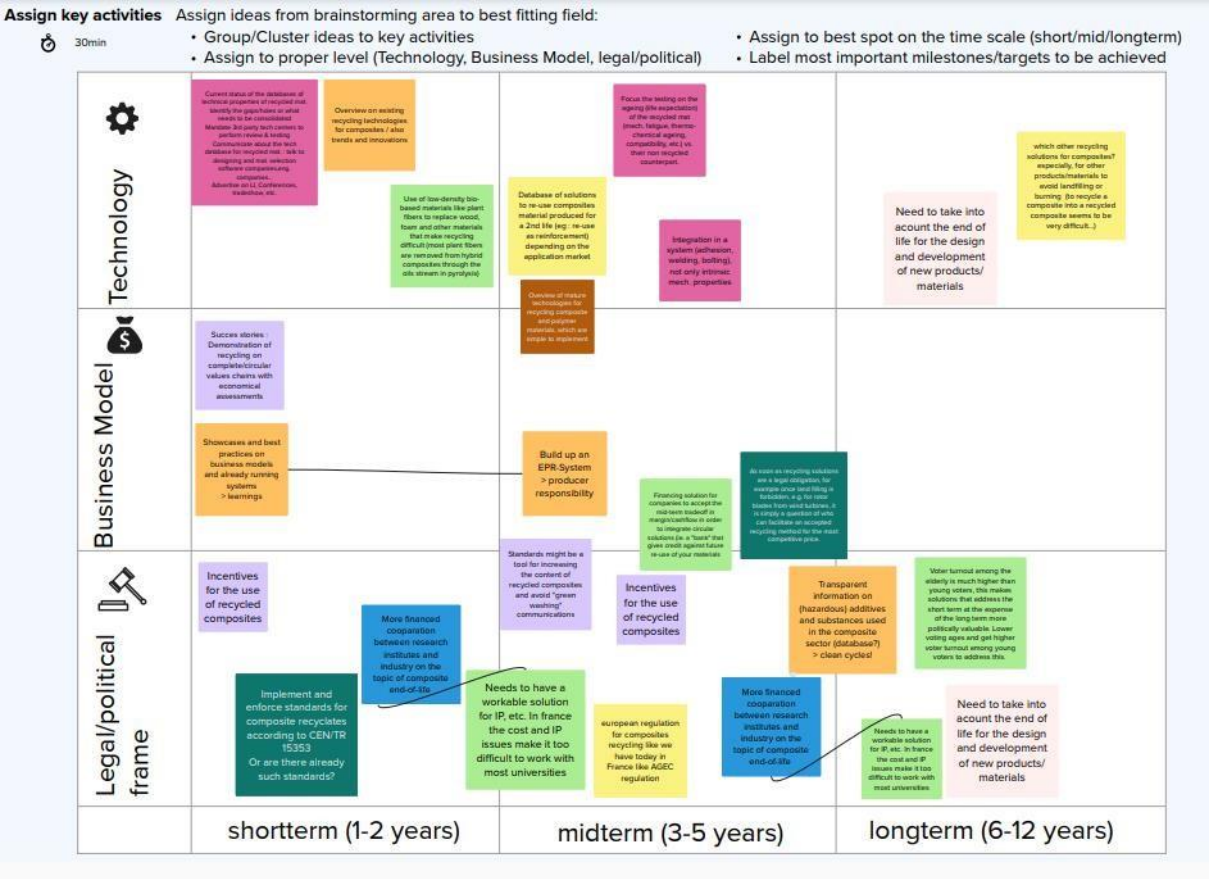

FIGURE 1 : SCREENSHOT FROM THE MURAL TOOL USED FOR THE ROADMAPPING PROCEDURE DURING WORKSHOP 1 OF THE TSWG COMPOSITES

All information were combined and sorted to be visualized on a timeline.

The Polymer−based composites TSWG is composed of :

- Polymeris PP08
- Chemie Cluster Bayern PP03
- Technology Center Horb Innonet Kunststoff PP02
- School of Engineering and Architecture of Fribourg PP09

Through the 4 partners, the Polymers/composites TSWG covers the Auvergne−Rhône−Alpes (FR), Bourgogne−Franche−Comté (FR), Bavaria (DE), Karlsruhe (DE) and Swiss region in the Alpin Space.

The general roadmapping process for the Polymer−based composites sector, as developed in line with the WP2−Act2.1 methodology, involved a structured approach to envision the future of the industry and promote a more sustainable and circular economy.

Before the workshops, a MURAL template was designed by CCB to guide the roadmap exercises. A training session was held on January 31, 2024, where partners were introduced to the template and the roadmap methodology. This session was recorded and made available to partners via the project's internal collaborative tool, Trello.

The promotion for the workshops began on January 12, 2024, with articles on the TSWG partner's website, email campaigns, newsletters, and social media posts. The goal was to engage a diverse audience from various sectors, including automotive, furniture, renewable/bio−based materials, and technology platforms.

- **Workshop 1:**

Held on February 7, 2024, from 14:00 to 16:30, this workshop focused on Materials & Resources analysis for a more circular composites industry. It had 33 registered participants from Germany, France, and Switzerland, with 20 actual participants. The discussion centred on identifying gaps and barriers in achieving circularity, followed by brainstorming solutions.

- **Workshop 2:**

Organized on February 20, 2024, from 14:00 to 16:30, this workshop addressed Circular Product Design in the composites industry. It had 23 registered participants, with 12 attending. Participants brainstormed on gaps and barriers related to circular design and discussed potential solutions.

- **Workshop 3:**

Conducted on March 14, 2024, from 14:00 to 16:30, this workshop explored Value Recovery (Collecting, Sorting, Recycling) of Polymer−based composites. It had 36 registered participants, with 15 attending. Participants discussed solutions for improving value recovery and the circular economy in the sector.

- **Lessons Learned:**

Moderation and the scope of the workshops needed adjustments. There was a need for more focused guidance during brainstorming sessions and smaller group discussions for deeper engagement. Defining the scope and boundaries more clearly during communication and promotion was also identified as an area for improvement.

Overall, the roadmapping process for the Polymer−based composites sector provided a platform for stakeholders to explore, discuss, and contribute to a sustainable and circular future. The workshops helped identify gaps and propose solutions to achieve the goals of the transformation roadmap.

5. Challenges in the Polymer-based composites sector - gaps & barriers analysis

The gaps and barriers analysis were the starting point of the roadmapping process. It was conducted by each partner member of the TSWG Polymer−based composites and further detailed with the input of the experts during the experts' workshop. Below is the summary of this analysis.

Gaps: What is missing from our regional ecosystems to achieve circularity in the Polymer/plastics industry?

- Lack of clear legal requirements/better understanding of the requirements
- Lack of acceptance from customer
- Lack of enough funding for scaling up advanced technologies
- Lack of cooperation between competitors working on the same sector
- Lack of mature technologies to sort & recycle complex materials.
- Lack of implementation/expertise on eco−design from the businesses
- Lack of expertise on circular business models

Barriers: What are the current obstacles that prevent the actors from our regional ecosystems to achieve circularity in the Polymer/Plastic industry?

- High price of bio−based materials & fluctuant price of recycled material
- Regulatory hurdles
- Negatives stereotypes toward sustainable plastics properties
- Material/products specifications are unpredictable.
- High investment cost with a limited growth potential
- Fragmented value−chains
- Mismanagement of waste
- Difficulties to identify waste streams/composition.

Drivers/Potential: What are the main challenges to focus on in the future to allow our regional ecosystems to achieve circularity in the Polymer/Plastics industry?

- Public awareness towards environmental issues/ growing market demand
- Up−coming legal requirements (strong focus on polymer industries)
- Corporate identity
- Common resources available for SMEs (i.e.: Recycling pilot platforms to prepare for recyclability)
- Reduce CO2 food print for incineration.
- Reduce use of natural resources

6. Vision of the Transformation Roadmap Polymer-based composites

The first step of the Cradle−ALP roadmapping process was to define a vision that guides the involved stakeholders and experts (businesses, public authorities, academics etc.) in each industrial sector on a joint understanding of what is the ideal future scenario in the specific industrial sector. It refers to a clear and inspirational description of the future state that an industry aims to achieve. The vision formulates an hypothetic objective or, generally speaking, an idea of how the future is imagined.

To provide such a frame for discussion the project partners discussed with external expert's ideas for the sectoral visions.

Based on the input of the experts, for the polymer−based composites sector the following vision was elaborated: to reduce landfill disposal of composites waste to just 10% of total waste by 2035, in alignment with the EU Landfill Directive. This vision was selected as the key challenges for Europe's polymer−based composites industries, including automotive, railway, aerospace, maritime, aeronautics, and sports equipment, in achieving a significant reduction in landfill disposal by 2035 are multifaceted. These industries often rely on complex composite materials that are difficult to recycle due to their heterogeneous nature and strong bonding agents. Current recycling infrastructure may not support advanced processes, leading to high costs and limited recovery. Additionally, the industries face regulatory and technical barriers that inhibit large−scale adoption of circular practices. Achieving the 10% landfill disposal target requires innovative recycling technologies, circular product design, and consistent regulatory frameworks that are explored throughout the roadmapping process.

7. Roadmap structure – topics, levels, time scale

The roadmap's vision encompasses three key topics for discussion on how to achieve circularity in the Polymer−based composites sector, encompassing the 3 main different levels in the value−chain of the sector:

- **Circularity in Materials & Resources**: This focus area seeks to promote the use of bio−based and biodegradable polymers, reducing reliance on non−renewable

resources. It aligns with the EU Landfill Directive's emphasis on waste prevention, encouraging a shift toward sustainable raw materials and reducing the generation of waste at the source.

- **Circular Product Design:** This aspect highlights the importance of designing products with end−of−life considerations in mind. By incorporating recyclability and reuse into the design process, the industry can reduce waste and increase the lifespan of products, which aligns with the directive's goal of reducing landfill use.
- **End-of-Life Management and Valorisation of Waste**: This focus area involves developing effective methods for identifying, collecting, sorting, and recycling composite waste. It supports the directive's intent to minimize the environmental impact of waste disposal and promote the use of advanced recycling technologies to recover value from waste.

The roadmap focuses on providing main activities to implement on three different aspects encompassing the key stakeholders from this industrial sector:

- **Technologies and research & development activities**: Technologies drive innovation and efficiency in production, recycling, and waste management. Focusing on technological solutions allows an industry to find new methods for recycling, reusing, reducing waste and improve resource consumption.
- **Business Models approaches:** Business models play a significant role in creating economic incentives for companies to adopt circular practices and building markets for industrial circular practices that can be usually less profitable or economically viable than linear practices. It also includes on solutions encouraging collaboration among stakeholders, including manufacturers, suppliers, and recyclers to foster a more integrated approach to circularity, with shared goals and resources. This is essential to ensure long−term industry commitment to circular practices.
- **Legal and Political Framework:** The impact of legal and political framework is strong in supporting an industry to become more circular. Legal frameworks can offer financial incentives, tax reliefs, and grants to encourage businesses to adopt circular practices. A clear legal and political framework ensures regulatory compliance and establishes a level playing field for all industry players. It also can help harmonize regulations across regions, reducing fragmentation and promoting standardization. This consistency is crucial for industries such as the European composites industry operating across multiple jurisdictions and ensures a coherent approach to circularity.

The roadmap's timeframe spans from 2024 to 2034, with short−term, mid−term, and long−term goals. This structure provides a strategic approach to achieving circularity:

- **Short-Term (2024–2026):** The short−term goals aim to establish the foundational elements of the roadmap, such as developing public databases, implementing Extended Producer Responsibility (EPR) schemes, and identifying suitable plant fibers for composites. These activities are designed to kickstart the circular transition by addressing immediate challenges and creating a knowledge base.

- **Mid-Term (2026–2029):** The mid−term goals build on the short−term initiatives by introducing more complex solutions, like implementing ISO standards, promoting financial cooperation, and advocating for bio−sourced materials. This timeframe allows for the development of infrastructure, business models, and standards to support circularity.
- **Long-Term (2029–2034):** The long−term goals focus on deeper structural changes, such as aligning EU regulations, banning landfilling of high−value composites, and implementing design−for−circularity practices. This timeframe enables the industry to transition into a sustainable future with a consistent legal and business framework.

This distribution among short−, mid−, and long−term goals is beneficial because it allows for gradual progress, accommodating the industry's complexities while ensuring sustained momentum toward circularity.

8. Transformation Roadmap Polymer-based composites

	2024-2026	2026-2029	2029-2034
Public & reliable data through standardisation and transparency	Public database of mature recycling technologies and second-life solutions available to all		Public database of technical properties of recycled materials available
	Implementation of standards for composites recycled materials according to CEN/TE 15353	Implementation of ISO standards for certifying recycling & second-life solutions	
	Populate LCA databases with reliable data based on ISO14 040 standards	Implement design practices prioritizing modularity & easy disassembly through industry collaboration and knowledge sharing.	
			Available and transparent information on hazardous additives and substances used in composites
Incentives to lower the cost and foster the uptake of eco–design, dismantlability, second life and recycling by the industry.	Implement Extended Producer Responsibility schemes on composites industries in each European country & align European regulations based on standards for composites end-of-life management		Ban landfilling of specific composites waste (i.e.: high-value composites)
			Implement EU regulations to include a minimum amount of recycled materials in new composites products
	Salex tax incentives for investments in recycling machinery	Developing new public funding scheme to cover significant upfront cost of circularity integration in products (i.e. bank offers credit on value of future re-use of material/component)	Harmonized Design for circularity guidelines for stakeholders along the value-chain
	Foster a culture of sustainability through education and training on eco-design		
	Promotion of success stories and successful business cases for circularity in composites.		
Improvement of identification, collection, logistics models of composites waste.	Identification of steady waste streams of composites	Reinforced financed cooperation between research institutes & industries to develop & upscale end-of-life solutions for the main waste streams	
	Encourage public-private partnerships (PPPs) to establish collection and logistics models for composite waste.		Implement pilot projects and models for composite waste collection in major industrial areas, focusing on ease of collection and transportation
Increase use if bio–sources materials in composites products for easier dismantling and energy recovery.	Collaboration industries & academics to identify plant fibers for composites & optimal processing techniques	Development of infrastructures for Waste-to-Energye recovery of biomaterials	
	Establishment of a strong bio-based composites supply-chain through collaboration between manufacturers, suppliers & research institutions		Creation of a market for bio-based composites by encouraging adoption among manufacturers & increasing consumer demand.
	Advocating for Waste-to-Energy recovery of biomaterials with support to development of structures and regulations		
	Materials difficult to remove (glass or carbon fibers, thermosetting resins, synthetic core materials) are replaced by low-density biobased materials for easier dismantling		
Monitor and extend lifespan of composites to reduce waste.		Extend use of smart and structural health monitoring system in the industry	Mature technologies available to assess condition & performance of composite materials at their end-of-life

a. Technologies, Research & Development

Outcomes	Activities		
	short-term (2024 - 2026)	**Mid-term (2026 - 2029)**	**long-term (2029-2034)**
Comprehensive public resource on second life and end-of-life solutions	Development of public database of existing mature technologies for recycling composites	Development of public database of second−life solutions for composites materials with information regarding upcycling and reprocessing/recycling of polymer−based composites products and insights from original producers.	Development of a public database of technical properties of recycled composite materials.
Extend use of bio-sourced materials	Identify suitable plant fibers for composites and determine the optimal processing techniques for these fibers in composite manufacturing.	Infrastructure is developed for waste−to−energy recovery of biomaterials.	Low−density biobased materials like plant fibers replaced other materials like wood or foam difficult to remove in composites products, allowing more advanced design practices for easy dismantling and value recovery through incineration
Implementation of circular design practices	LCA databases are populated with reliable data based on ISO14 040 standards	Implement design practices that prioritize modularity, easy disassembly, and material separation through industry collaboration and knowledge sharing.	Each composite product produced is dismantlable by design
Monitoring & enhancing composites aging for longer-lasting products		Smart and structural health monitoring system for real time detection of polymer aging to extend the composites lifespan.	Mature and economically viable technologies are available to assess the condition and performance of composite materials at their end−of−life to determine their suitability for reuse

Comprehensive Public Resource on Second Life and End-of-Life Solutions

Developing comprehensive public resources, public databases of existing mature recycling technologies, and public databases of second−life solutions for composites are crucial steps in fostering a more circular composites industry. This allows stakeholders to access critical information on sustainable practices and tackles the challenge of uncertainty about the best practices for recycling and reusing composites. It can include case studies, industry guidelines, and expert insights on circularity, which can guide businesses in their efforts to reduce waste.

On the short−term, the first step is the development of a public database for mature recycling technologies to overcome the lack of transparency in the composites recycling process. This database should centralize information about various recycling methods, detailing their advantages, disadvantages, and specific applications. By having this information readily available, companies can make informed decisions about which recycling techniques to adopt.

On the mid−term, a public database of second−life solutions for composites materials should be developed to address the challenge of limited knowledge about the potential reuse of composite materials. This database can contain information on upcycling and reprocessing/recycling of polymer−based composites, along with insights from original producers, fostering creativity in finding new applications for these materials.

On the long−term, having a public database of the technical properties of recycled composites will be crucial for ensuring the safety and quality of recycled materials. This database provides data on the characteristics of recycled composites, indicator on the margin for variation in the quality and characteristics of the recycled material according to the configuration of the recycling technology, the structure and type of fiber−reinforced polymer input material. This database would allow businesses to understand their properties and comply with industry standards.

Extend use of bio-sourced materials

Identifying suitable plant fibers for composites and determining optimal processing techniques is the first step on a short−term. Plant fibers like flax and hemp are renewable and biodegradable, offering an eco−friendlier alternative to synthetic fibers. They are also strong and flexible, but integrating them into composites requires new processing methods, such as resin infusion or weaving.

Developing infrastructure for waste−to−energy recovery provides a solution for end−of−life composites. Waste−to−energy facilities convert biomaterials into energy through high−temperature incineration, reducing landfill waste while generating electricity or heat. This approach contributes to a circular economy by reclaiming energy from otherwise discarded composites, with a lower energy consumption than for petroleum composites waste.

Replacing difficult−to−remove materials like wood or foam with low−density biobased materials is another crucial step. By using plant fibers and other lightweight biobased materials, manufacturers can design composites for easy disassembly and recycling. This shift simplifies end−of−life processes, allowing for easier separation and recovery of valuable

materials through incineration. The key challenge is redesigning composite products to incorporate these new materials without compromising performance.

Implementation of circular design practices

By 2025, having Life Cycle Assessment (LCA) databases populated with reliable data based on ISO 14040 standards could significantly reduce the landfill disposal of composite waste. This projection is grounded in the need for consistent, credible data to inform sustainable practices in the composites industry. ISO 14040 provides a rigorous framework for conducting LCAs, ensuring that environmental impacts are assessed accurately and consistently. When LCA databases adhere to these standards, they offer reliable data on material sourcing, manufacturing processes, product lifecycles, and end−of−life scenarios. With reliable LCA data, manufacturers can pinpoint stages of production where waste generation is high and implement measures to reduce it. This might include optimizing material usage, promoting recycling, or designing products with easier end−of−life disassembly.

Making every composite product produced by 2033 dismantlable by design is an ambitious goal due to several challenges. Composite materials are complex, often combining various fibres and matrices, complicating disassembly. The legacy of current designs, which typically don't prioritize end−of−life considerations, adds to the challenge. Regulatory constraints across European countries create inconsistent frameworks, and high costs discourage the investment in new dismantling technologies. Solutions to these challenges from a technological point of view include on the mid−term to implement design−for−circularity principles, focusing on modularity, material separation and easy disassembly through industry collaboration and knowledge sharing between the different stakeholders of the value−chain. Harmonizing regulations across Europe to standardize dismantling requirements, investment in new technologies, extended Producer Responsibility (EPR) schemes are also important steps that are further explained in the business models and political framework.

Monitoring & enhancing composites aging for longer lasting products.

By 2033, advanced technologies should be available to assess the condition and performance of composite materials at their end−of−life, aiming to determine their suitability for reuse. These technologies help identify whether a composite product can be reused in its existing form or requires further processing. By enabling effective risk assessment, this solution can reduce waste by repurposing materials that still have utility and enable less manufacturing new products, providing an economically viable approach to circularity. Examples of advanced technologies to further develop are non−destructive testing (NDT) methods, such as ultrasonic or X−ray techniques, that can evaluate the internal structure of composites without causing damage or thermographic and acoustic emission monitoring that can detect internal defects and provide early indicators of material degradation.

Smart and Structural Health Monitoring Systems for Real−Time Detection of Polymer Aging by 2028 encompasses technologies and systems that monitor the condition of composites in real−time to detect signs of polymer aging and structural degradation. Its main goal is to ensure the ongoing safety and performance of composite products, allowing early detection of wear, damage, or degradation, and enabling proactive maintenance or repair. This involves embedded sensors, like fiber−optic or piezoelectric sensors, and wireless monitoring systems,

providing continuous data on factors such as strain, temperature, and stress. This technology is useful in maintaining the health and longevity of composites during their use phase.

b. Business Model approaches

Outcomes	Activities		
	short term (2024 - 2026)	**midterm (2026 - 2029)**	**long term (2029-2034)**
Business models to extend the use of biosourced materials	Encourage collaboration between manufacturers, plant fiber suppliers, and research institutions to establish a strong supply chain for biobased composites	Market created for biobased composites by encouraging adoption among manufacturers and increasing consumer demand.	
Training and harmonization of eco-design practices		Foster a culture of sustainability within the composites industry through education and training programs focusing on eco−design	Create harmonized Design for Circularity Guidelines for stakeholders along the value−chain
Financial support for managing end-of-life composite waste	Increase tax relieve for investment in recycling machinery to support the enterprises in investing more in this to produce the recycled material	Encourage public investment in new dismantling technologies by developing financial solutions covering the significant upfront costs caused by integration of circularity in products (ie: bank credit against future re−use of the product)	
Promotion and support of business case and models for collecting, managing, and recycling waste composites	Promotion of success stories and successful business cases for circularity in composites.	Encourage public−private partnerships (PPPs) to establish collection and logistics models for composite waste.	Implement pilot projects and models for composite waste collection in major industrial areas, focusing on ease of collection and transportation

Business Models to Extend the Use of Bio-Sourced Materials

A key driver for circularity in the composites industry is the increased use of bio−sourced materials. By collaborating with plant fiber suppliers, manufacturers, and research institutions, the industry can create a sustainable supply chain. This collaboration allows for the development of composites with reduced environmental impact. In the mid−term, creating a market for biobased composites requires engaging stakeholders, raising awareness, and demonstrating the benefits of these materials. By showcasing the positive outcomes and promoting biobased composites, manufacturers can attract new customers and stimulate demand.

Training and Harmonization of Eco-Design Practices

A culture of sustainability is fundamental for achieving circularity. Eco−design training programs help educate industry professionals on the importance of modularity, easy disassembly, and material separation. By aligning industry practices with these principles, manufacturers can streamline recycling and reduce waste. Harmonized Design for Circularity guidelines ensure that everyone in the value chain understands and adopts consistent eco−design practices. These guidelines also should support compliance with EU regulations, facilitating the industry's transition to a circular model.

Financial Support for Managing End-of-Life Composite Waste

Financial incentives play a crucial role in encouraging businesses to invest in recycling technologies. Tax relief for recycling machinery is a powerful motivator, reducing the financial burden on companies seeking to adopt circular practices. In the mid−term, innovative financial solutions such as bank credit against future reuse help companies cover the significant upfront costs associated with integrating circularity into their products. This financial support promotes wider industry participation, leading to a more sustainable composite sector.

Promotion and Support of Business Cases for Collecting, Managing, and Recycling Composites Waste

Promoting successful business cases for collecting, managing, and recycling composite waste is essential to drive industry−wide adoption of circular practices. This first step easy to implement on the European level by leveraging existing EU platforms, networks and events enable showcasing of real−world examples of how composite waste can be collected, managed, and recycled efficiently, businesses are more likely to adopt similar practices. Sharing success stories and promoting these cases through industry events, publications, and online platforms can create a ripple effect, encouraging broader participation in circular practices.

Promoting successful business cases is a proven method to encourage industry adoption of circular practices. Public−private partnerships (PPPs) play a vital role in establishing collection and logistics models for composite waste by fostering collaboration among stakeholders. By involving multiple sectors, including manufacturing, transportation, and recycling, PPPs can develop a more integrated approach to managing composite waste. This collaboration ensures that different industry players work together to create a seamless waste collection and recycling process. In the long term, pilot projects in industrial areas can provide valuable insights into efficient collection and transportation. These pilot projects are designed to test

and refine methods for collecting composite waste from various sources, such as manufacturing plants, construction sites, and end−of−life products. The data collected from these projects can help optimize collection routes, reduce transportation costs, and improve overall waste management efficiency.

c. Legal and political framework & general aspects

Outcomes	Activities		
	shortterm (2024 – 2025)	midterm (2026 – 2028)	longterm (2029−2033)
Harmonization of EU regulation for dismantling and end-of-life management.	Implement Extended Producer Responsibility schemes on composites industries in each European country to make manufacturers responsible for their products at end−of−life, promoting the adoption of dismantling−friendly designs.	Aligned European regulations across countries based on standards, creating a consistent framework for composite product dismantling	Ban landfilling for certain types of composites waste (high−value waste) to ensure development of a market for secondary materials and recycling solutions.
Develop comprehensive and transparent standards to ensure safe and sustainable practices.	Implement and enforce standards for composites recycled materials according to CEN/TR 15353.	Develop and implement ISO standards that certify what is recycling, reusing.	Transparent information on hazardous additives and substances used in the composites sector.
Implementation of a market for recycled composites	Identification of steady composites waste streams for creation of adapted recycling structures. Sales tax relieve for investment in recycling machinery.	Reinforced financed cooperation between research institutes and industry to develop and upscale end−of−life/recycling solutions	Implement EU regulations requiring to include recycled content in new composites products.
Extend use of bio-sourced materials		Advocate for Waste−to−energy recovery for biomaterials on a policy level as incineration of bio−based material is less energy−demanding	

Harmonization of EU regulation for dismantling and end-of-life management.

Harmonizing regulations across EU countries involves navigating diverse legal systems and compliance requirements. It also requires extensive collaboration between governments, industries, and regulatory bodies to develop unified standards. The first solution to be implemented in the short−term is to implement Extended Producer Responsibility (EPR) schemes in Europe, to place the responsibility for end−of−life management on manufacturers, incentivizing them to design dismantling−friendly products and invest in recycling infrastructure. Manufacturers may resist these schemes due to the added costs and administrative burdens, necessitating a careful balance between regulation and industry buy−in. On the mid−term, a consistent EU regulations framework makes it easier for manufacturers to design composite products with a clear understanding of the regulations they must meet throughout Europe. This harmonization also simplifies compliance, reducing the administrative burden on businesses that operate in multiple countries.
On the long−term, banning landfilling for specific high−value composites waste creates a market for secondary materials and drives the development of second−life or recycling solutions and investment in eco−design.

Develop comprehensive and transparent standards to ensure safe and sustainable practices.

The first step, in the short term, focuses on implementing and enforcing standards for composites recycled materials according to CEN/TR 15353. The challenge here is ensuring consistent application across various industries and regions, as quality of recycled materials can vary widely. The mid−term step involves developing and implementing ISO standards to certify what constitutes recycling and reusing in the composites sector. The challenge is defining clear and universally accepted criteria for these processes, given the complex nature of composites recycling. The expected impact is a more structured approach to recycling, which encourages businesses to comply with these standards, reducing ambiguity and promoting best practices. The long−term step aims to ensure transparency about hazardous additives and substances used in the composites sector. The challenge lies in obtaining and sharing information on these substances, as manufacturers might be reluctant to disclose proprietary formulations. The impact of this step is significant, providing consumers and industry stakeholders with crucial information to make informed decisions, thereby promoting safer composites production, and enhancing industry accountability.

Implementation of a market for recycled composites

The ambitious goal of creating a market for recycled composites begins with identifying steady waste streams to ensure a consistent flow of material for recycling facilities. This process can be challenging in the short term, requiring extensive tracking, and quantifying of composite waste. A key step to encourage investment in recycling machinery is implementing sales tax relief, reducing the financial burden for businesses investing in recycling equipment.

In the mid−term, fostering financial cooperation between research institutes and industry can support the development and scaling up of recycling solutions. Coordination among stakeholders is essential to direct funding toward innovative technologies that enhance recycling efficiency and reduce costs.

The long−term approach involves implementing EU regulations that require a specific percentage of recycled content in new composite products. While this step has transformative potential, it also presents challenges in ensuring compliance across various industries and countries. Manufacturers may resist such regulations due to concerns about product quality and additional costs. Overcoming these concerns requires developing industry−wide standards to maintain quality, implementing rigorous quality control processes, and ensuring transparency through certification schemes. Another critical long−term solution is incentivizing manufacturers to collaborate and increase the volume of recycled content, leading to economies of scale that reduce costs.

Extend use of bio-sourced materials by advocating for Waste-To-Energy recovery solutions

The impact of advocating for this policy is substantial. By promoting waste−to−energy recovery, the composites industry can reduce the amount of waste sent to landfills, making the process more sustainable. This approach can also generate energy from the incineration of bio−based materials, contributing to renewable energy sources and reducing reliance on fossil fuels. Furthermore, this policy can encourage the use of bio−based composites in manufacturing, aligning with broader sustainability goals and reducing the industry's carbon footprint. While waste−to−energy recovery can be less energy−demanding for bio−based materials, strict regulations are necessary to control emissions and ensure that the process does not contribute to air pollution or other environmental issue.

9. Annex

Sources :

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