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Sectoral Cradle2Cradle industrial transformation roadmaps

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1. Summary

The EU Interreg project Cradle-ALP intends to support small and medium-sized enterprises (SMEs) of the alpine region to adopt cradle to cradle approaches and circular business models in five different industrial sectors: chemistry and materials, polymers, packaging, textile and wood/furniture.

European SMEs are confronted with numerous challenges in their efforts to transform their manufacturing processes and business models to more sustainable and circular concepts. To discuss and identify possible solutions, interested stakeholders and experts were invited to contribute to the development of a transformation roadmap. For each addressed sector, an individual transformation roadmap was developed that outlines proposed activities on a technological, business, and legal/political level. For the roadmap on chemistry and material, stakeholders and experts from industry, academia and business support organizations were invited, mainly coming from Austria, Slovenia, Switzerland, Bavaria, and Baden-Württemberg.

The transformation roadmap for chemistry and materials originally aimed to focus on the use of chemicals as additives including adhesives, coating, inks/pigments etc. During three separate online workshops, participants developed a large number of possible solutions to address current challenges. The resulting activities were grouped into specific categories and assigned on a time frame (short-, mid- and long-term) regarding priority and expected realization.

The resulting roadmap demonstrates to SMEs the ideas and suggestions of participants and experts on how to overcome current challenges on the way to a circular economy. Furthermore, it will serve as a means for the consortium partners to provide direct support to interested SMEs in identifying technology partners and establishing circular business models.

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 five 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 among the public, the relevant industries as well as stakeholders from policy and innovation intermediaries. Opportunities, barriers and mechanisms of the transformation of industrial products towards higher circularity by means of C2C approaches, circular design and circular substitutions will be focused. 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 Chemistry/Materials

The objective was the development of a transformation roadmap in the chemistry and materials 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.

During the preparatory discussion the transnational sectoral working groups (TSWG) for the chemistry and materials sector decided to focus on the subtopic of chemical additives applied in different materials to narrow down the topic and not to interfere with the other four sectors (polymers, textile, packaging, wood/furniture) during the roadmapping process.

Therefore, the overall objective of the transformation roadmap was to identify measures and activities to support the transition of the chemical and material industry towards a more circular economy. The focus included chemicals as additives:

- Adhesives
- Fillers, lubricants, colorants, inks, pigments
- Coatings, powder-coating, wet coatings
- Additives (plasticizer, UV protection, flame retardant, catalysts, …)
- Additives in/for recyclable materials and compostable materials

Additionally, this included:

- Substitutes for ‘Substances of Concern’ according to REACH
- Chemicals for green transition
- Chemicals made by carbon capture & utilization (CCU)

The roadmap is not supposed to focus on bulk chemicals and platform chemicals to avoid a potential overlap to the other sectoral roadmaps, especially polymers.

4. Roadmapping Procedure & Participating Organisations

Initially, a workshop with the external expert support group was conducted to identify gaps, barriers, drivers and potentials for the sector of chemistry and materials. In a second step, to elaborate possible, future solutions 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 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 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.

The collected information of all three workshops were combined and sorted to be visualized on a timeline.

Figure 1: Exemplary screenshot showing results of discussions of one workshop assigned on the time scale.

All three workshops had the objective to collect information on technologies, business models and the legal/political framework from the participating industry and research experts through brainstorming activities and discussions. The procedure of each of the three workshops followed the same step by step approach. After a brief introduction to the Cradle-ALP project, the general objective of the roadmapping process and the workshop agenda, participants were invited to briefly introduce themselves.

A first step comprised the findings and discussion of gaps and barriers on all three levels (technology, business model, legal/political framework) impeding and preventing the transformation from a linear to a circular value chain as seen from the industry perspective of the participants. These gaps and barriers served as a basis for the brainstorming process to find necessary measures and novel solutions that help to establish circular processes along the value chain. Subsequently, the collected ideas and suggestions were consolidated where meaningful and assigned to different time periods (short-, mid-, long term). Afterwards, the participants voted for the most important activities/measures to be taken.

The first workshop focused on the aspects of resources, raw materials and materials needed in the chemicals/materials sector. In the second workshop the participants were asked to discuss critical issues regarding design for recycling and circular product design in the context of chemicals used as additives. The third workshop comprised the topic of value recovery and especially collecting, sorting and recycling facets.

The TSWG Chemistry/Materials invited a total of 51 experts for the Chemistry/Materials topic from the Cradle-ALP consortium partner regions of Bavaria, Baden-Wuerttemberg, Slovenia, Austria and Switzerland. The topics of the three separate workshops were as follows:

- **Workshop 1: (raw) materials/resources**
  Organized on February 5th, 2024 the workshop focused on raw materials and resources needed for more circular and biobased additives.

- **Workshop 2: product design/design for recycling**
  This second workshop on February 28th, 2024 addressed the topic of design for recycling regarding additives.

- **Workshop 3: value recovery (collecting, sorting, recycling)**
  In the last workshop on March 5th, 2024 participants discussed solutions for collecting, sorting and improving recycling processes.

5. Challenges in the Industrial Sector - Gaps & Barriers Analysis

The chemical industry is one of the most important industry sectors in Europe. In 2022, Europe was still the second largest producer of chemicals in the world, providing bulk, specialty and consumer chemicals and supplying many downstream industry sectors with raw materials. Most of the chemical products are vital for Europe's economy, not only today but also for the transition to greener production drastically reducing carbon dioxide emissions to become climate-neutral by 2050. The sector can contribute to finding solutions for urgent challenges of our modern society such as material and waste recycling, capture and utilization of CO2 as a feedstock, delivering products for e-mobility or renewable power generation, developing safer chemicals, less harmful to the environment and building new, resilient value networks to establish a functional circular economy.

Nevertheless, the chemical industry faces several challenges on its transition pathway towards a more circular and sustainable economy. First, the chemistry sector is one of the largest industrial energy consumers and the third largest sector regarding CO2-emissions. Decarbonization of the high energy consuming processes by use of renewable energy is one major task. In addition, fossil resources such as crude oil and natural gas are also the raw materials which are converted to chemical products such as monomers and polymers for various industries.

According to Cefic, the European Chemical Industry Council, the chemical industry is aware of its crucial role in Europe's industry transition and the necessary support of the EU Green Deal to reach the ambitious goal of climate neutrality by 2050.

Most additives are products of the chemical industry. They give functionality to almost all kind of products as UV-absorbers, antioxidants, solvents, flame retardants etc. Whereas for many bulk chemicals such as plastic polymers different more sustainable, biobased and/or recyclable solutions exist or are being developed, there is not a sufficient number of suitable additives yet. For that reason, manufacturers tend to use fossil-based additives for their sustainable products.

As the Cradle-ALP consortium works on the sectors of polymers, packaging, textiles and wood/furniture it was decided to focus on additives in more detail. As described in

section 3 this includes adhesives, fillers coating etc. for which often no sustainable alternatives are currently available.

During an expert workshop at the beginning of the process as well as during the roadmapping workshops, gaps and barriers were collected and discussed to serve as a basis for further identification of putative solutions. Gaps and barriers are for example factors that negatively affect or hinder the buildup of circular value chains, complicate the access to technological solutions and knowledge or impede novel developments and innovations on the way towards a cradle to cradle-based circular economy. The gaps identified by the experts and participants can be sorted in various categories.

Identified Gaps

According to the experts a major challenge for SMEs are insufficient alternatives to conventional fossil-based chemicals. Often only a small choice of green/recyclable alternatives is available and ready to use in sufficient quantities on the market. This has an effect on the prices, which usually means that low cost or cost-competitive alternatives are lacking. Even more for additives there is only a limited number of circular/ biobased products available.

Company representatives also raised concerns on the insufficient knowledge on the behavior of additives during product lifetime and recycling processes. The lack of material data sheets and specifications with sufficient information and the absence of precise analytics to determine type and quality of the additives and/or compound composition prevents companies to switch to 'recyclable' alternatives. This is accompanied by the need for an information system using structured data models, and standard metrics to track the sustainability of materials along a value chain.

In addition, it was mentioned that companies need better contacts to organizations providing knowledge and support with solutions for recycling infrastructure such as specialized recycling infrastructure for chemicals.

Summary of Identified Gaps:

- Lack of alternatives to fossil materials
- Small pool of green alternatives ready to use → lack of low-cost alternatives
- Lack of suitable additives for circular/ biobased products
- Limited availability of feedstock

- Lack of precise analysis of compounds and additives in recycled materials
- Insufficient knowledge on behavior of additives during lifetime or recycling
- Composite-based products made from recyclable mono-material
- Lack of material data sheets and specification of recycled/biobased materials
- Lack of information system to track the sustainability of materials along value chain (structured data models, and standard metrics)

- Need of knowledge & solution providers for recycling infrastructure (specialized recycling infrastructure for certain chemicals)

- Lack of comprehensive LCA proving the positive impact of a material
- Insufficient sustainability data on alternative feedstocks

- Lack of comprehensive regulatory status for alternative feedstocks
- Lack of obligatory design specifications and guidelines for recycling methods
- Lack of guidelines for sustainable chemical design → design standards
- No binding targets/requirements for circular products

- Need for incentives for companies to develop more sustainable chemical products
- Missing financial support for purchase and use of green materials and recyclates
- Low acceptance by customers

Table 1: Summary displaying the gaps identified during discussions with experts and participants

A major drawback is the insufficient availability of sustainability data on alternative feedstocks and the lack of comprehensive, standardized Life Cycle Assessments (LCA) proving the positive climate and environmental impact of circular chemicals/materials.

The lack of a comprehensive regulatory status for alternative feedstocks, the lack of obligatory design specifications and guidelines for recycling as well as missing binding targets and/or requirements for circular products add up to the uncertainty of organizations preventing them to undertake further steps towards a circular economy model.

Finally, there are insufficient incentives for companies to develop more sustainable chemical products. Consequently, companies otherwise willing to transform their business miss adequate financial support. Finally, there is the impression that acceptance of cradle to cradle and more sustainable products by the customers is too low.

Identified Barriers

Next to missing factors that influence the development of circular economy concepts, participants and experts identified various obstacles for SMEs impeding the uptake of cradle-to-cradle approaches.

The consistent supply and quality of resources, particularly carbon-neutral or biobased raw materials like chemical monomers, is one of the biggest barriers. In addition, identification and procurement of appropriate additives for circular and biobased products is a challenging and tedious process.

The adoption of a circular business model is further complicated by the fact that the use of virgin, fossil-based materials is still less expensive whereas the costs for new production lines and testing for novel material developments are high. In conclusion, for most companies the profitability of circular economy/bioeconomy business models is still too low.

Another barrier for SMEs is the challenge of scaling up production processes for novel chemicals. The high level of product diversity and complexity makes it even more challenging. In addition, established value chains are complex, and often based on long-lasting customer-supplier relationships. The complexity of the value chains makes it difficult to address traceability issues, too.

Finally, there are significant challenges to overcome, including the uncertainty surrounding legal obligations regarding the declaration of recycled material, regulatory barriers during the installation of new production lines or technologies and existing waste regulations that limit the use of residual materials.

Summary of Identified Barriers:

- Limited resource availability and quality
- Insufficient availability of carbon neutral or biobased starting monomers
- Difficulty to identify suitable additives for circular/biobased products

- High cost expenditures for testing (from regulatory to performance)
- High cost expenditures for new production lines
- Low costs of fossil-based virgin material (low profitability)
- Missing economic incentives for reuse of chemicals

- Lack of scalability for some technologies
- Difficulty of scale-up process for novel (biobased) chemicals

- Complexity and diversity of products
- Complexity of value chains
- Challenge of addressing traceability issues of value chains

- Uncertainty about legal requirements for declaration of recycled material
- Restricted use of residual materials through existing waste regulations
- Regulatory hurdles for new production lines and technologies
- Restrictions due to REACH regulation

Table 2: Summary displaying the barriers identified during discussions with experts and participants.

Potentials and Drivers

Next to the gaps and barriers analysis the experts recognized drivers and potentials for the future of circular economy.

According to the experts the enforcement of waste regulations and laws, mandatory recycling quotas and increasing the costs for undesirable economic practices are drivers to accelerate the transition to a circular economy. The improvement of funding opportunities and financial incentives may also positively impact this transition. Technological innovations that improve sustainability and progress in chemical recycling are considered to be beneficial.

The experts also see potential in better waste separation procedures, a domestic recycling market in Europe, modifying waste regulations to view waste as a valuable resource, lowering carbon dioxide emissions, and using CO2 as a feedstock.

6. Vision for the Transformation Roadmap Chemistry/Materials

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 an 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 experts' ideas for sectoral visions.

The final vision statement for the chemistry and material transformation roadmap was: ***'Clean material cycles by sustainable chemicals available at scale in the Alpine Space by 2035'***.

7. Structure of the Roadmap

The transformation roadmap for the chemistry and materials sector is structured into three layers, summarizing activities in

- **Technologies, Research & Development, (Raw) Materials**:
  Novel technologies allow to exploit new resources and to develop methods to reuse and recycle materials, products, waste and side streams to establish closed recycling loops, reduce resource consumption and carbon dioxide emissions.
- **Business Model Approaches**:
  Today linear economy models are still more profitable for companies than circular approaches. To support SMEs in adopting circular practices it is essential to show advantages of circular business models and to encourage to look into new opportunities and markets to reach a commitment.
- **Legal and Political Framework**:
  A transparent legal and political framework ensures regulatory compliance and establishes a level playing field for all industry players. It provides a

coherent basis for companies to undertake the necessary steps for the transformation of the industry. Harmonization of regional regulations and standards will increase the willingness of companies to actively engage with the transformation.

The outcomes and activities are described in the subsections of the following chapter. We assumed a time scope of ten years and divided it into three segments:

- **Short-term (1-2 years, 2024 – 2025):**
  Short-term activities mainly comprise goals that can be achieved in the near future as many developments are ongoing, such as developing databases, exploring biogenic resources, or applying digital solutions.
- **Mid-term (3 years, 2026 – 2028):**
  Mid-term goals often build on short-term activities and are supposed to develop more complex solutions, such as defining standards, establishing data sharing platforms or bringing critical technologies to market maturity.
- **Long-term (5 years, 2029 – 2034):**
  There is only a small number of long-term objectives mainly comprising harmonization of legislation and taxation across Europe.

The following chapter summarizes the findings and outcomes of the transformation roadmap chemistry and materials. It was initially thought to mainly focus on chemicals as additives, but the workshop discussions showed that it is difficult to exclusively discuss additives. In the end, most of the findings are most likely valid for a large part of the organic chemistry sector.

For each of the three layers the findings are summarized in a table and described in more detail in the text. The findings were grouped into ‘outcomes’ to summarize several activities which may be related. The activities are assigned to the three different time frames as determined by the workshop participants.

The outcomes are summarized in an overview graphic indicating when the activities should start and how much time might be needed to implement them.

8. Transformation Roadmap Chemistry/Materials

The findings of the expert discussions are putative solutions for the gaps and barriers identified. These findings were summarized as 'Outcomes'.

The following illustration gives a graphical overview about the major outcomes along the timeline from 2024 to 2033. Blue bars represent the topics regarding **'Technologies, Research & Development, (Raw) Materials'** comprising activities to be taken regarding the access to resources, technology development, infrastructure and technical standards as well as digitization. Red bars stand for **'Business Modell Approaches'** and focus on business aspects, funding and incentives. Green bars comprise **'Legal and Political Framework & General Aspects'** with a major focus on regulations, taxation and legislation.

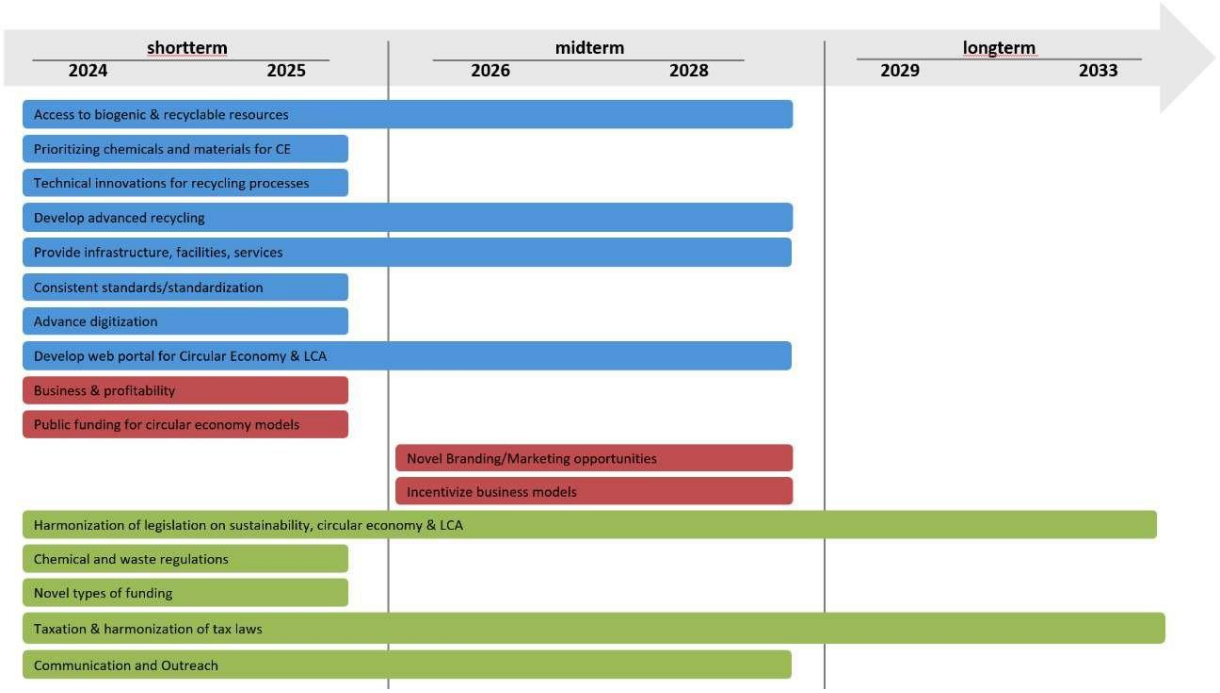

Figure 2: Overview of the roadmapping results on the time scale displaying the outcomes (grouped categories) on three levels: technological (blue), business model (red), legal/political framework (green)

As the shown in the illustration most of the outcomes are seen as activities that should be started within the next two years. Only two legal and political framework outcomes are seen as long-term activities.

a. Technologies, Research & Development, (Raw) Materials

Outcomes	Activities		
	shortterm (2024 - 2025)	midterm (2026 - 2028)	long-term (2029-2033)
Access to biogenic & recyclable resources		Identify new sources of feedstock for bioeconomy	
		Increase accessibility to recycled feedstocks	
Prioritizing chemicals and materials for circular economy	Prioritizing the recycling of high-impact chemicals		
	Research and produce a list of positive and negative materials that can/can't be produced with recycled materials		
	Registration system for CO_2 values of chemicals and materials		
Technical innovations for recycling processes	Create awareness, inform, and educate end-product manufacturers on impact of design choices		
		Develop harvesting and recovery of feedstocks from feedstock producers	
		Design for recycling based on specific external impact to trigger the recycling process	
Develop advanced recycling		Expand chemical recycling options and applications	
Provide infrastructure, facilities, services		Develop optimized processes for biobased chemicals and extend facilities for development, scale-up and production	
	Reevaluate the role of university service centers to focus on specialized fields	Establish specialized service centers tailored for SMEs to access analytic services	
		Consider creating organizations with a hybrid profit/non-profit model to offer services required by companies.	
Consistent standards/standardization	Develop reliable standards for recyclate qualities		
Advance digitization	Explore possibilities of digital material IDs for chemicals		
Develop web portal for Circular Economy & LCA	Standardization of LCAs to enable comparability between used tools and results		
	Data model with standardized content, "LCA Wikipedia"	Data sharing platform/ information system for standardized content	

Table 3: Summary of results from discussion on technological aspects showing the outcomes and activities

Technological Aspects

Concerning the technological gaps and barriers, the identified outcomes address the access to resources, the prioritization of relevant chemicals and technical innovations. Prioritizing the recycling of high-impact chemicals is one of the first important activities. A chemical inventory that lists materials that can or cannot be produced using recycled materials is considered to be beneficial. Furthermore, this could be integrated with a system that records CO_2 values for chemicals and materials.

To address the lack of alternatives to fossil materials and the problem of availability general measures were suggested such as the identification of new feedstock sources for the bioeconomy and the increase of the accessibility to recycled feedstocks.

When it comes to technical innovations for recycling of chemicals and materials an activity that could be implemented in a timely manner would be the creation of awareness by informing and educating end-product manufacturers on the impact of design choices.

In order to develop novel design for recycling processes more research on technologies will be needed. Such novel processes could be based on triggering the depolymerization of a material at a predetermined breaking point and upon an external stimulus such as pressure, temperature or similar. The expansion of various advanced/chemical recycling applications may aid in expediting up circular economy value chains.

Infrastructural Aspects

In order to benefit from the circular economy, SMEs will need to get access to optimized processes for biobased chemicals, and to an extended number of support facilities dedicated to development, scale-up and production services.

One proposal was to reassess the significance of university service centers to focus on specialized fields and to establish specialized service centers designed to provide access for SMEs to analytical services. Another approach could be the creation of organizations with a hybrid profit/non-profit model to offer technical support services required by SMEs.

Standards and Digitization Aspects

Consistent standards are a crucial factor in the advancement of the circular economy. Therefore, one of the most important topics was the demand for reliable standards for recyclate qualities from the industry.

The topic of digitization and data platforms to advance the circular economy was also extensively discussed. For example, the use of digital material IDs as an identification system to track chemicals and materials throughout the value chain and recycling loops.

Another important topic includes a web portal for circular economy and LCA data on chemicals and materials. A prerequisite would be the standardization of LCA tools and methods to facilitate the comparability of the outcomes. This requires the development of a data model with standardized content (e.g., 'LCA Wikipedia') and the development of a data sharing platform or an information system for standardized content.

b. Business Model Approaches

The transition from conventional linear economy models to cradle to cradle and circular economy business models is not easy. In order to encourage stimulate companies more strongly to develop business models based on circular economy, it seems necessary to strongly expand the public funding landscape for circular economy and bioeconomy activities.

Outcomes	Activities		
	shortterm (2024 - 2025)	midterm (2026 - 2028)	long-term (2029-2033)
Business & profitability	Rethinking sales targets and margins regarding development of cradle-to-cradle systems		
Public funding for circular economy models	Expand funding landscape for circular economy and bioeconomy activities		
Novel branding/ marketing opportunities		Research on novel branding possibilities in line with circular value chains	
Incentivize business models		Implement taxes on carbon and/or waste to provide economic incentives to manufacturers to use sustainable alternatives	

Table 4: Summary of results from discussion on business models showing the outcomes and activities

However, companies are also asked to reconsider their current business model, particularly regarding sales targets and margins to adapt them to a circular economy.

In the medium term, it might also be necessary to explore novel branding and marketing opportunities that are compatible with circular economy models. For instance, the use of colored plastic products was debated. Frequently, product branding is associated with colored packaging in order to be recognized by the customer. Nonetheless, the recycling of colored plastic packaging proves to be challenging, thus hindering the establishment of effective recycling loops.

Another last outcome is the idea that the development of circular business models could be incentivized through changes in regulation and legislation. Implementing taxation on carbon as a resource or on the use of waste and residual materials could make circular business models more attractive to manufacturers and lead to the use of more sustainable alternatives. Shaping the framework conditions for the circular economy by the legislative bodies could accelerate the development of new business models.

c. Legal and Political Framework & General Aspects

Outcomes	Activities		
	shortterm (2024 - 2025)	midterm (2026 - 2028)	long-term (2029-2033)
Harmonization of legislation on sustainability, circular economy & LCA	Uniform rules for LCA and carbon footprint calculations	European-wide LCA targets and standardization	
		Legislative initiative to develop the requirement for uniform use of LCA	
	Set up an EU working group to determine guidelines necessary to speed up circular economy		Tools to verify sustainability claims to avoid greenwashing
	Legislative initiative to make circular economy a requirement		
	Legal regulation to continuously increase proportion of sustainable components in products		
Chemical and waste regulations	Stimulate use of biobased chemicals by transparent information on EU chemical regulations		
	Stimulate biobased chemical/material innovations through temporary exclusions from chemical regulations during upscaling process		
	Harmonize waste regulation to support trans-European recycling		
	Develop predictable and binding targets for recycling quotas		
Novel types of funding	Higher funding rates for regional, national and EU programs		
	Set up funds for collaborative R&D projects of academia and industry allowing companies to get development services paid		
Taxation & harmonization of tax laws	Cost reduction for biobased/ recycled materials through tax reduction (pricing minimums for less sustainable options higher than sustainable ones)		
		Establish circular economy fee: manufacturers pay a service/ participation fee to bring materials on market. This fee is used to finance the recycling system.	
		Develop taxation for products with positive LCA impact	Harmonization of tax laws within the EU
Communication and outreach		Develop and implement communication campaign to inform consumers about the environmental impact of their purchasing choices	
	Providing best practices for SMEs on sustainability reporting/ monitoring, standardized tools and access to experts	Develop and implement campaign to improve communication between policy makers and industry	

Table 5: Summary of results from discussion on legal/political aspects showing outcomes and activities

Harmonization of Legislation and Waste Regulations

While modifications in legislation may trigger the creation of novel business models, it is generally considered as imperative to harmonize the legislation on sustainability, circular economy and related subjects such as life cycle assessment.

Furthermore, legal regulation is also required to continuously increase the proportion of sustainable components in products over time and to steadily drive the transition towards a circular economy.

Therefore, it is required to establish uniform guidelines for LCA and carbon footprint calculations in order to attain comparable information. In the best-case scenario, there will be uniform LCA targets and standardization within Europe. To achieve this, a legislative initiative is expected to develop the requirements for the uniform generation and use of LCA data.

In order to work on the harmonization, it was suggested to establish an EU working group to determine common guidelines necessary to speed up the circular economy. This could potentially lead to a legislative initiative to mandate circular economy and the development of a comprehensive set of tools to verify sustainability claims, thereby preventing greenwashing.

Chemical and materials solutions that are tailored to maintain materials in recycling loops are crucial for the success of a circular economy. It is considered to necessary to establish a transparent flow of information on EU chemical regulations in order to encourage the use of biobased chemicals. To increase the number of biobased/recyclable chemical and material innovations, it could be helpful to temporarily exclude them from restrictive chemical regulations such as REACH, at least during the upscaling process.

In general, national waste regulations should be harmonized to support trans European recycling efforts and to develop predictable and binding targets for recycling quotas.

Taxation

In the long term, the harmonization of tax regulations within the European Union is deemed imperative. One step into this direction would be to establish a unified taxation system for products that exhibit a favorable LCA impact. As fossil-based chemicals and

materials still have a cost advantage compared to biobased/recycled chemicals and materials, adjusting taxes through cost reduction for biobased/recycled chemicals could help to establish increasing market demand.

Another suggestion for promoting more sustainable materials is the implementation of a circular economy fee. According to this notion, manufacturers are required to pay a 'service' or 'participation' fee in order to introduce their materials and products onto the market. This fee is used to finance the recycling system, which is needed to bring the products back and convert them into new raw materials (including collection, sorting and conversion).

Novel Types of Funding

Accelerating the transition of the linear economy to a circular economy system requires significant investments. Regional, national and European authorities could facilitate the transition with higher funding rates. Additionally, it is feasible to implement programs that facilitate the funding of collaborative R&D projects between academic and industry partners, thereby facilitating the utilization of public funding for development services by companies.

Communication and Outreach

Finally, the importance of communication to all levels of society and industry is regarded as highly important. Hence, it is imperative to implement a comprehensive communication campaign aimed at informing consumers about the environmental impact of their purchasing decisions empowering them to opt for more sustainable products is important.

Providing best practices on sustainability reporting and monitoring, on necessary standardized tools and the access to supporting experts could effectively help SMEs on their path to circular economy. This could be accompanied by a broad campaign aimed at improving the communication between policymakers and industry.

9. Conclusion and Next Steps

The process to develop this transformation roadmap for chemicals and materials as a target sector in the EU Interreg Alpine Space funded project Cradle-ALP brought together representatives from industry/SMEs, academia and business support organizations from different regions of the alpine space including Upper Austria, Slovenia, Switzerland, Baden-Wuerttemberg and Bavaria.

The discussions showed that the challenges in the different regions are similar, and the exchange is an important way to broaden the network of each participant. The challenges and questions raised in the single workshops showed that collaboration can be a key factor to solve current problems because SMEs must find the right partners with the specific expertise to develop circular value chains. Some participants may have already made first suitable contacts to make the next step in their own transition efforts.

The initial focus of the transformation roadmap for chemicals and materials was set on chemicals to be applied as additives including adhesives, fillers, lubricants, colorants, inks, pigments, coatings, additives as plasticizer, for UV protection, as flame retardant or catalysts, etc.. However, the workshop discussion resulted in a broader outcome and most of the proposition and results are probably generally valid for chemicals in the context of cradle 2 cradle and circular economy.

Surprisingly but according to the statement of several participants, technologies for a circular and /or bioeconomy have been sufficiently developed. Indeed, the bigger challenge seems to be finding the right partners and the access to the needed (raw) materials and services.

The participating SMEs were quite positive about circular business models. Once the legal framework and European targets are clear, business models will be developed. However, this means that a reliable framework must be provided. There is still too much intransparency and insecurity about future legal aspects preventing companies from shifting to circular and biobased business models. Currently, the biggest draw back remains the disadvantage regarding costs of biobased and recycled products versus fossil-based ones. In addition, insufficient production capacities leading to uncertainty in

product availability and reliable quality of greener, more sustainable materials and chemicals make companies act with restraints.

According to the participating organizations, the lack of knowledge and differences in the waste and recycling regulations of other EU countries poses a problem preventing the advancement of circular economy models. Clearer communication about existing regulations is needed rather than more regulations. Additionally, it would be helpful for SMEs to get firsthand advice and support on circular economy laws and regulation, e.g., from non-profit organizations.

For the Cradle-ALP consortium partners this means that they should focus the activities of the planned pilot actions in period 4 and 5 (May 2024 to April 2025) to support SMEs in

- Identifying and connecting to the right business and technology partners,
- The ideation process for circular business models by providing best practice examples,
- Analyzing their business to start the transformation process towards circular business, and
- Acquiring knowledge on national and regional circular economy legislation.

The created transformation roadmap on chemicals and materials can be a starting point to further raise awareness of SMEs for the necessity to rethink their manufacturing processes and business models and to address the companies individually to offer support through the Cradle-ALP partner's network in identifying the right technology or business partner within the alpine region.

10. Annex

Literature Sources:

- The European Chemical Industry Council, Brussels, https://cefic.org/
- A Pillar Of The European Economy, Cefic, https://cefic.org/a-pillar-of-the-european-economy
- The EU Chemical Industry Transition Pathway, Cefic, https://transition-pathway.cefic.org/
- Transition pathway for the chemical industry, EU Commission DG Grow, https://single-market-economy.ec.europa.eu/sectors/chemicals/transition-pathway_en
- Chemistry4Climate, VCI, https://www.vci.de/themen/energie-klima/chemistry4climate/chemistry4climate.jsp

Organizations Registered/Participated in Roadmapping Workshops:

Name of organization	Country	Type of organization
ExoMatter GmbH	DE	Start-up
Fraunhofer IGB	DE	Research Organization
Süd-West-Chemie GmbH	DE	SME
Weimako GmbH	DE	SME
ADLER-Werk Lackfabrik Johann Berghofer GmbH & Co KG	AT	Enterprise
KRAIBURG TPE GmbH & Co. KG	DE	Enterprise
CSC Jäklechemie GmbH & Co. KG	DE	Enterprise
Wirtschaftskammer Österreich	AT	Chamber of Commerce
Polytives GmbH	DE	Start-up
WKOÖ Wirtschaftskammer Oberösterreich	AT	Chamber of Commerce
Amt der Oberösterreichischen Landesregierung	AT	Regional authority
Bloom Biorenewables	CH	Start-up
Fraunhofer ICT	DE	Research Organization
National Institute of Chemistry Slovenia	SLO	Research Organization
HEIA-FR Hochschule für Technik und Architektur Fribourg	CH	Research Organization
MITOL d.o.o.	SLO	Enterprise
Neue Materialien Bayreuth GmbH	DE	Research Organization
Belinka Perkemija d.o.o.	SLO	SME
SKZ Das Kunststoffzentrum	DE	Research Organization
ACD Nouvelle-Aquitaine	FR	Cluster organization
Wood K plus	AT	Research Organization
Pipelife		Enterprise