

**Interreg  
Danube Region**



Co-funded by  
the European Union



# Handbook for a circular plastics industry

Deliverable D.1.3.2

Responsible Partner: aws

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# Introduction to the project Plan-C

**Moving Plastics and mACHine iNDustry towards Circularity (Plan-C)** is an ambitious initiative aimed at transforming the plastics and machinery industries in the Danube Region towards a circular economy. The project brings together 14 partners from countries including Germany, Austria, Czechia, Slovakia, Hungary, Serbia, Bosnia and Herzegovina, Romania, and Moldova. By fostering transnational cooperation among plastics processors, producers, and the machine industry, Plan-C seeks to develop innovative solutions that emphasize reuse, recycling, and long-term value retention.

The core objectives of Plan-C include:

- **Co-creating circular plastic solutions** through **collaboration** and **design thinking**, resulting in practical prototypes and guidelines for SMEs.
- **Redesigning machinery** for reuse and recycling, covering the entire lifecycle and exploring digital opportunities.
- **Developing a transnational action plan** that aligns with EU regulations and national strategies, ensuring long-term impact through policy integration and SME support.

Plan-C aims to address significant barriers such as weak recycling infrastructure, outdated waste systems, and gaps in expertise. By promoting reuse, repair, remanufacturing, and smart recycling, the project aspires to accelerate clean growth in manufacturing sectors and strengthen business competitiveness across the region.

This handbook is intended to outline an overview of the topic circularity in the plastics sector and further the methods used, and solutions achieved in the course of the Plan-C project.

## Importance of Circularity in the Plastics Industry

The transition to a circular economy is crucial for the plastics industry, which faces significant environmental and economic challenges. Circularity in the plastics industry involves designing products and systems that prioritize reuse, recycling, and long-term value retention, thereby reducing waste and resource consumption. The EU set a goal to recycle 50% of plastics packaging by 2025, but many countries in the Danube Region face barriers such as weak recycling infrastructure, outdated waste systems, and gaps in expertise and know-how. Stricter regulations and standards for the use, production, and disposal of plastic products and pressure from international organizations present regulatory challenges for all plastic producers. The production, use, and disposal of plastics often conflict with environmental stewardship, raising concerns among oversight bodies and consumers. Furthermore, the plastics industry faces economic uncertainties, including fluctuating market conditions, supply chain pressures, and geopolitical tensions. Higher costs due to tariffs, transportation costs, and unpredictable geopolitical risks disrupt global trade routes and production sites, creating supply chain issues. Additionally,

outdated infrastructure and inefficiencies in recycling technologies, along with contamination issues, pose significant technological barriers.

And here comes the framework of circular economy in play. Key benefits of circularity in the plastics industry include environmental protection, which involves reducing plastic pollution and conserving natural resources by minimizing waste and promoting the reuse of materials. Economic efficiency is achieved by lowering production costs and creating new business opportunities through innovative business models including recycling and remanufacturing processes. Sustainable growth is enhanced by adopting sustainable practices and complying with evolving regulations, thereby improving the resilience and competitiveness of businesses.

By embracing circular principles, the plastics industry can significantly mitigate its environmental impact while unlocking new economic potentials. Initiatives like Plan-C demonstrate the feasibility and benefits of circularity, providing practical solutions and fostering collaboration across sectors to drive sustainable industrial development.

## The Basics of Design for Circularity Approaches

### Understanding Circular Economy

The concept of a circular economy represents a transformative approach to economic development, emphasizing sustainability and resource efficiency. In the context of plastics, understanding the circular economy involves recognizing the need to move away from the traditional linear model of production, use, and disposal. Instead, it advocates for a system where plastic materials are continuously reused, recycled, and repurposed, minimizing waste and environmental impact.

A circular economy for plastics aims to create closed-loop systems where products are designed for longevity, repairability, and recyclability. This involves **innovative design strategies**, such as using biodegradable materials, improving recycling technologies, and fostering collaboration across industries to ensure that plastic waste is effectively managed. By prioritizing the reduction of plastic waste and promoting the reuse of materials, the circular economy seeks to mitigate the adverse effects of plastic pollution on ecosystems and human health.

In this context, companies can generate revenue by adopting innovative business models that align with circular economy principles. For instance, the product-as-a-service model allows consumers to lease products rather than purchase them outright, ensuring that companies retain ownership and responsibility for the product's lifecycle. This model not only reduces waste but also creates continuous revenue streams through leasing fees. Additionally, businesses can invest in advanced recycling technologies to transform plastic waste into valuable raw materials, which can be sold or used to manufacture new products. Collaborations across industries can also lead to the development of closed-loop systems, where plastic materials are kept in circulation, reducing the need for virgin resources and lowering production costs. These new business models not only contribute to environmental sustainability but also open up new market opportunities and drive economic growth.

In conclusion, understanding the circular economy in the context of plastics is crucial for fostering a sustainable and resource-efficient future. By shifting from a linear to a circular model, we can significantly reduce plastic waste and its environmental impact. This approach involves as key factor the design of products for durability, repairability, and recyclability, and promoting innovative recycling technologies and sustainable practices. The circular economy not only addresses the pressing issue of plastic pollution but also encourages economic resilience and growth through sustainable business models and policy frameworks. Ultimately, embracing a circular economy for plastics is a vital step towards creating a regenerative system that benefits both the environment and society.

## The basics of design for circularity approaches within the plastics industry

Designing for circularity in the plastics industry involves creating products that can be reused, recycled, or composted, minimizing waste and environmental impact. This approach emphasizes the importance of considering the entire lifecycle of plastic products, from raw material extraction to end-of-life disposal. By incorporating principles of circular design, manufacturers can reduce reliance on virgin plastics and promote the use of recycled materials. Key strategies include designing for durability, ease of disassembly, and recyclability. Ultimately, the goal is to create a closed-loop system where plastic materials are continuously cycled back into production, reducing the need for new plastic production, and mitigating environmental harm. The basic principles are:

### Material Selection:

Choosing materials with a lower environmental impact is crucial for sustainable design. Utilize materials that can be mechanically recycled and fit into existing waste management systems. For instance, using biodegradable or compostable plastics can help close the loop by integrating into the biological cycle. These materials break down naturally, reducing long-term waste and environmental harm.

### Use of offcuts:

Offcuts of decorative plastic foils can be used for smaller products, e.g. offcuts of branded foils for large plastic parts can be used to add a decorative top layer to smaller parts and hence brand currently unbranded parts.

### Design for Longevity:

Creating durable products, that can be reused multiple times, extends their lifecycle and reduces the need for frequent replacements. This approach not only conserves resources but also minimizes waste. Durable products are often seen as higher quality, which can enhance brand reputation and customer satisfaction.

### **Recyclability:**

Ensuring that products can be easily recycled is essential for a circular economy. Design products with materials that are widely accepted in recycling programs and clearly label them to guide consumers. Simplifying the disassembly process can also facilitate recycling, making it easier to separate different materials.

### **Modular Design:**

Designing products for easy disassembly and repair allows for parts to be replaced or upgraded rather than discarding the entire product. Modular design supports sustainability by extending the product's life and reducing waste. It also offers consumers the flexibility to customize and upgrade their products over time.

### **Reuse Systems:**

Implementing systems for refilling and reusing products can significantly reduce waste. For example, creating a product-as-a-service model allows consumers to use products without owning them, encouraging the return and reuse of items. This model can be particularly effective for products like electronics, where frequent upgrades are common.

### **Waste Recovery:**

Capturing and sorting materials at the end of their life is vital for effective recycling and waste management. Deposit-Return Systems incentivize consumers to return empty containers, promoting reuse and recycling. These systems help reduce litter, support automatic sorting, and minimize environmental impact by ensuring materials are properly processed.

## **Tools and Instruments of Design Thinking Methods**

### **What is design thinking and can it be applied to circular transformation**

Design thinking is a creative and human-centered approach to problem-solving that can play a vital role in transforming how plastic products are designed and used. Rather than focusing solely on technical efficiency, design thinking emphasizes understanding the real needs and behaviours of people who interact with plastic products throughout their life cycle. This makes it especially valuable for driving circular innovation in the plastics industry.

The process begins with empathy - gaining deep insight into how consumers, manufacturers, recyclers, and other stakeholders engage with plastic products. This phase helps uncover pain points and opportunities for improvement, such as difficulties in recycling or the overuse of single-use plastics. In the Define phase, these insights are translated into clear, actionable challenges. For

example, a team might focus on reducing packaging waste or improving the reusability of containers.

Next comes Ideation, where diverse ideas are generated to challenge conventional, linear approaches. This could involve rethinking product formats, exploring refill systems, or designing components that can be easily separated and recycled. These ideas are then brought to life in the Prototype phase, where early versions of new plastic products or systems are developed and tested. Whether it's a compostable material or a modular packaging design, prototyping allows teams to explore feasibility and user acceptance.

Finally, in the Test phase, these prototypes are evaluated in real-world contexts. Feedback from users and stakeholders is used to refine the solutions, ensuring they are both practical and scalable. The iterative nature of design thinking means that each cycle brings the product closer to meeting both user needs and circular economy goals.

By applying this methodology, organizations can rethink plastic products not just as items to be used and discarded, but as part of a regenerative system. Design thinking enables a shift in mindset—from linear consumption to circular innovation—making it a powerful tool for creating sustainable plastic solutions.

## Techniques to encourage creativity and divergent thinking

Divergent thinking is at the core of the ideation process in design thinking, enabling participants to generate a wide array of ideas without immediately evaluating them. Encouraging creativity and divergent thinking is essential for developing innovative, out-of-the-box solutions, especially in complex contexts like circular transformation in the plastic industry.

The key techniques include:

### Brainstorming

Brainstorming is one of the most widely used and effective techniques for encouraging creativity. It involves group discussions where participants are encouraged to share as many ideas as possible in a free-flowing manner. To make brainstorming more effective:

- Set a clear focus: Start by framing the challenge in a way that promotes creativity. For instance, ask, "How might we reduce waste in the production of our product?" or "How can we make maintenance more circular?"
- Avoid judgment: During brainstorming, all ideas are valid, regardless of how feasible or practical they may seem at first. This opens the floor to a range of ideas that might not surface in a more formal setting.

- Build on ideas: Participants should be encouraged to listen carefully to others and build on their ideas. This creates a snowball effect, where even small, initial ideas can evolve into innovative solutions.

## Mind Mapping

Mind mapping is a visual brainstorming tool that helps participants explore a central idea and branch out into related topics or concepts. It's particularly effective in helping participants see connections between different aspects of the problem. Here's how to apply it:

- Start with a central question or concept, like "Circular transformation in plastic production."
- Draw branches for each life cycle stage such as design, manufacturing, logistics, use, and end-of-life.
- As participants contribute ideas related to each phase, continue to add branches and sub-branches, exploring different areas where circular economy principles can be applied. For example, under "manufacturing," participants might branch out to ideas around material efficiency, renewable energy use, or waste minimization.

## SCAMPER

SCAMPER is an acronym for a set of creative prompts that help participants explore ideas through different lenses. It encourages them to rethink existing processes or products by using specific actions. SCAMPER stands for:

- **Substitute:** It asks what materials or processes could be replaced with more sustainable alternatives—perhaps replacing virgin plastic with recycled or bio-based materials
- **Combine:** Can multiple phases or functions be combined to improve circularity? For instance, combining integrated packing with reuse systems
- **Adapt:** How can an existing solution or process be adapted to improve circularity? Can we adapt existing technologies to make plastic products easier to reuse/recycle?
- **Modify:** What can be changed, minimized, or optimized? Could the size or shape of components be modified to use less material and reduce waste?
- **Put to another use:** Considers how plastic components can be repurposed after their initial use—like turning used containers into construction materials.
- **Eliminate:** What unnecessary elements can be removed to enhance circularity? Could packaging be eliminated or drastically reduced in the logistics phase?
- **Reverse:** What happens if the process or system is reversed? For instance, instead of linear waste management, can waste materials be reincorporated into the production cycle as raw materials?

## Brainwriting

Brainwriting is a quieter, more introspective form of brainstorming where participants write down their ideas individually before sharing them with the group. This technique is effective for encouraging contributions from people who may feel less comfortable speaking up in traditional brainstorming sessions. The process typically involves:

- Providing each participant with a sheet of paper or a digital document to write down their ideas related to a specific problem, such as "How can we make plastic products easier to refurbish and reuse?"
- After a set time (e.g., 5 minutes), participants pass their ideas to the next person, who adds to them by expanding or refining the concepts.
- The process continues for several rounds until each idea has been iterated upon by multiple participants.

## Six Thinking Hats

Developed by Edward de Bono, the **Six Thinking Hats** technique encourages participants to approach a problem from different perspectives by metaphorically "wearing" different coloured hats, each representing a distinct way of thinking:

- **White Hat:** Focus on data, facts, and information. What are the known details about the product life cycle and circular practices?
- **Red Hat:** Look at the problem through intuition and emotion. What are the gut feelings or concerns about current practices that could inspire circular solutions?
- **Black Hat:** Consider potential challenges and risks. What obstacles might hinder circular transformation in the plastic industry?
- **Yellow Hat:** Focus on the benefits and opportunities. What positive outcomes could result from applying circular principles to each life cycle phase?
- **Green Hat:** Explore creativity and innovation. What radical or unconventional solutions can we propose for more sustainable plastic products?
- **Blue Hat:** Focus on process control. How can we structure and manage the ideation process to ensure productive outcomes?

## Role-Playing and Empathy Mapping

Role-playing exercises and empathy mapping allow participants to put themselves in the shoes of different stakeholders, fostering creative thinking about their needs and perspectives. In the context of circular transformation, participants could:

- Take on roles such as producer, maintenance technicians, material suppliers, or end-of-life managers to explore how circular changes would impact their work.
- Use empathy mapping to delve deeper into stakeholder pain points, behaviours, and needs. For example, what does the producer experience when creating a part? What are their goals, frustrations, and concerns related to sustainability?

## 5 Whys

The 5 Whys technique helps participants identify the root cause of a problem by repeatedly asking "why" until the underlying issue is revealed. In the context of circular transformation, participants could:

- Start with a specific problem, such as excessive waste in the production process, and ask "why" it occurs.
- Continue asking "why" for each subsequent answer to dig deeper into the root cause. For example, why is there excessive waste? Why are materials not being reused? Why is there a lack of recycling infrastructure?
- Use the insights gained to develop targeted solutions that address the core issues, leading to more sustainable practices.

## Affinity Diagrams

Affinity Diagrams allow participants to organize and categorize ideas, insights, and data into meaningful groups, fostering a deeper understanding of complex issues. In the context of circular transformation, participants could:

- Gather a diverse set of ideas and observations related to sustainability challenges, such as reducing carbon footprint, improving resource efficiency, or enhancing product lifecycle management.
- Group similar ideas together to identify common themes and patterns. For example, cluster ideas related to energy efficiency, waste reduction, and material reuse.
- Use the grouped insights to prioritize key areas for action and develop a cohesive strategy for implementing circular practices.

## Methods to guide participants toward innovative, circular solutions

Guiding participants toward innovative, circular solutions requires structured methods that encourage creativity while maintaining a clear focus on circular economy principles. During the ideation process, the facilitator's role is to ensure that participants not only generate a wide range of ideas but also move toward solutions that align with the goals of circularity—reducing resource consumption, minimizing waste, extending product life, and improving recyclability.

### Circular Value Mapping

Circular value mapping is a method that helps participants identify value creation opportunities across different stages of a product's life cycle by highlighting areas for circular interventions. The focus is on uncovering potential for value retention, recirculation, or creation through processes like material reuse, energy efficiency, or product-life extension. In practice, this involves:

- **Identifying key life cycle stages** and mapping out existing linear processes.
- **Pinpointing circular opportunities** at each stage. For example, participants may discover opportunities to recirculate materials through better recycling or reuse practices, or they might identify potential for reducing waste during the production phase by redesigning the manufacturing process.
- Facilitators ask probing questions, such as, “How can we retain more value at the design stage through modularity or product life extension?” or “What circular business models can emerge from shifting to product-as-a-service offerings in the use phase?”

By framing discussions around specific value-creating opportunities, participants are naturally guided toward solutions that maximize resource efficiency and circularity.

### Reverse Brainstorming

Reverse brainstorming flips the typical ideation process by asking participants to first identify potential failures or barriers to circularity, then work backward to develop solutions to these problems. This method can be particularly useful when participants struggle to generate innovative ideas directly. In practice:

- Start by asking participants to brainstorm **how things could go wrong** in the product's life cycle when it comes to circularity. For example, “What would prevent this product from being easily recycled?” or “What could lead to excessive resource consumption in manufacturing?”
- Once a list of potential failures has been created, guide participants in brainstorming solutions to these problems. For instance, if the challenge is “Materials are difficult to separate at end-of-life,” participants might propose a solution such as using standardized, easily disassembled materials.

Reverse brainstorming helps participants approach challenges from a new perspective, uncovering innovative circular solutions by addressing potential barriers head-on.

### Value Proposition Canvas

This method can be applied to circular solutions by helping participants focus on how their ideas create both economic and environmental value. In practice, this tool guides participants through a structured process of matching customer (or stakeholder) needs with innovative circular solutions. It includes two main parts:

- **Customer Profile:** Participants define the needs, pains, and gains of the users or other stakeholders (e.g., recyclers or maintenance technicians). They should explore pain points related to sustainability, such as difficult recycling components or high operational costs due to inefficient resource use.
- **Value Proposition:** Participants then brainstorm how their circular ideas address these needs or alleviate pains. For example, a value proposition might involve developing a modular product design that reduces non-recyclability and facilitates easier upgrades, thereby meeting customer needs for long-term performance and lower total cost of ownership.

This method is particularly effective for guiding participants to align their circular solutions with real-world business and environmental benefits, ensuring their ideas are both innovative and practical.

### Crazy Eight

It is a rapid brainstorming method that challenges participants to generate eight distinct ideas in just eight minutes. This technique encourages divergent thinking by pushing individuals to think beyond their initial concepts and explore a wide range of possibilities. The time constraint helps to bypass the usual mental barriers and promotes spontaneous, out-of-the-box thinking. Participants sketch or write down their ideas quickly, focusing on quantity rather than quality, which can later be refined and developed further.

### Idea Tower

It builds on the Crazy Eight technique by selecting the most promising idea from the initial set and encouraging collaborative development. Participants work together to enhance and expand the chosen idea, adding layers of detail and exploring its potential from various angles. This collaborative approach ensures that the idea is thoroughly vetted and improved upon, leveraging the collective creativity and expertise of the group.

## Feasibility-Impact Matrix or How/Now/Wow/Ciao - Matrix

This is a prioritization tool that helps participants assess the feasibility of their circular ideas alongside their potential impact. This method encourages participants to focus on solutions that are both innovative and practical. In practice, it works like this:

- Draw a 2x2 matrix, with **Feasibility** on the x-axis (low to high) and **Impact** on the y-axis (low to high).
- After brainstorming a range of ideas, participants plot them on the matrix according to how feasible they are to implement and their potential for impact. For example, a solution involving the use of recycled materials may have high impact but low feasibility due to current supply chain limitations.
- Once ideas are plotted, the group can focus on **high-feasibility, high-impact ideas** for immediate action and explore ways to improve feasibility for high-impact, lower-feasibility ideas.

## Circular Business Model Canvas

The Circular Business Model Canvas is an adaptation of the traditional Business Model Canvas, specifically tailored for circular economy initiatives. This method guides participants to develop circular solutions that are not only innovative but also commercially viable. In practice:

- Participants use the canvas to map out key components of their circular business model, such as value propositions, key resources, customer relationships, revenue streams, and cost structures.
- Focus areas for circularity are added to each section. For example, under "Key Resources," participants explore the use of renewable or recycled materials; under "Revenue Streams," they consider product-as-a-service models.
- By filling in the canvas, participants develop comprehensive circular business models that integrate sustainability with economic viability, ensuring that their solutions are both innovative and implementable in real-world scenarios.

## Dot Voting

Dot voting is a simple, yet effective technique used to help participants prioritize circular solutions based on collective input. It ensures that the group converges on the most promising ideas for further development. In practice:

- After brainstorming, facilitators present all the ideas to the group—often using sticky notes or a digital platform.
- Each participant is given a set number of dots (e.g., three to five) and asked to vote for the ideas they believe have the highest potential for circular transformation. Participants can place all their dots on one idea or spread them across several.

- The ideas with the most dots are then selected for further exploration and development.
- Dot voting helps move the ideation process from a divergent phase (idea generation) to a convergent phase (idea selection) in a democratic, efficient way, ensuring that participants focus on solutions with the greatest consensus and potential.

### Rapid Prototyping

Rapid Prototyping involves quickly creating scaled-down versions of a product or solution to test and iterate on ideas. In the context of circular transformation, participants could:

- Develop quick, low-fidelity prototypes of sustainable products or processes using materials like paper, cardboard, or digital tools.
- Test these prototypes with stakeholders to gather feedback on functionality, usability, and sustainability aspects. For example, how does a new packaging design reduce waste? How easy is it to recycle or reuse the product?
- Use the feedback to refine and improve the prototypes, ensuring that the final solution is both innovative and environmentally friendly.

### Lego Serious Play

Lego Serious Play is a hands-on, minds-on approach that uses Lego bricks to foster creative thinking and problem-solving. In the context of circular transformation, participants could:

- Build models representing different aspects of the circular economy, such as closed-loop systems, resource flows, or sustainable business models.
- Use the models to facilitate discussions and explore various scenarios. For example, how can a product be designed for disassembly and recycling? What are the potential impacts of a circular supply chain on different stakeholders?
- Encourage participants to share their insights and ideas through storytelling, using the Lego models as visual aids to communicate complex concepts and solutions.

# Summary of Identified Challenges & Needs in the Plastics Producer Industry in the Danube region

The transition towards a circular economy presents both significant challenges and promising opportunities for the plastics producer industry. This chapter explores the multifaceted dimensions of this transition, focusing on legal/policy, technical, economic, societal/behavioural, and environmental aspects across various project partner countries. By examining the unique and shared challenges faced by these countries, as well as the opportunities they can leverage, we aim to provide a comprehensive understanding of the current landscape and the potential pathways to a more sustainable and circular economy. This analysis highlights the importance of innovative solutions, supportive policies, technological advancements, and increased public awareness in driving the shift towards circular practices. Ultimately, addressing these challenges while capitalizing on opportunities can accelerate progress, benefiting both the environment and the economy.

## Legal/Policy

### Challenges:

- **Hungary:** Implementation of Extended Producer Responsibility (EPR) systems and compliance with new legislation.
- **Austria:** Lack of clear legal requirements, inconsistent regulations, and outdated frameworks.
- **Czech Republic:** Complex and evolving legislation regarding sustainable plastics management.
- **Germany:** Ambiguity in regulations hindering business investment and innovation.
- **Slovakia:** Lack of clear legal requirements and incorporation of circular economy principles.
- **Romania:** Strategy for circular economy lacks detailed action plans and regulatory deficiencies.
- **Serbia:** Non-compliance with EU regulations and gaps in national frameworks.
- **Moldova:** Ineffective economic instruments and regulatory frameworks.
- **Bosnia and Herzegovina:** Limited incorporation of circular economy principles into existing frameworks.

### Opportunities:

- **Hungary:** Research and development in renewable materials and upcoming sustainable regulations.
- **Austria:** Strong incentives in public procurement and standardized regulations favouring circular practices.
- **Czech Republic:** Structured frameworks from delegated acts to guide sustainable practices.
- **Germany:** Incentives in public procurement for circular products and clearer legal frameworks.
- **Slovakia:** Strong incentives in public procurement and advancement in technologies.
- **Romania:** Concrete measures under the circular economy strategy and improving regulations.
- **Serbia:** Defining circular economy as a strategic goal and harmonizing regulatory documents.
- **Moldova:** Introducing economic incentives and developing recycling-promoting regulations.
- **Bosnia and Herzegovina:** Implementation of comprehensive policies and investment in waste management

### Technical

#### Challenges:

- Similar challenges across countries include outdated infrastructure, inefficiencies in recycling technologies, and contamination issues.
- Specific challenges like energy-intensive processes (Moldova, Slovakia) and quality degradation in recycling (Austria, Czech Republic) are prevalent.

#### Opportunities:

- Common opportunities include adopting new technologies for circular material use and enhancing recycling infrastructure.
- Advancements in technology (Germany, Serbia) and investment in energy-efficient technologies (Moldova, Bosnia and Herzegovina) are highlighted.

## Economic

### **Challenges:**

- High costs and availability issues of bio-based raw materials are common challenges (Hungary, Austria, Romania).
- Funding constraints and economic barriers (Slovakia, Serbia, Moldova) are significant challenges.
- Limited integration between manufacturers, recyclers, and end-users is a shared economic hurdle (Germany, Romania).

### **Opportunities:**

- Utilization of AI for cost efficiencies and development of new digital business models are noted opportunities across several countries (Hungary, Austria, Germany).
- Accessing EU funds and participating in circular economy programs are highlighted as opportunities (Romania, Serbia, Czech Republic).

## Societal/Behavioural

### **Challenges:**

- Low public awareness and acceptance of new technologies are common challenges (Hungary, Slovakia, Serbia).
- Limited awareness and understanding of circular economy principles among consumers (Austria, Moldova, Bosnia and Herzegovina).

### **Opportunities:**

- Educational programs and public awareness campaigns are identified opportunities across the region (Romania, Austria, Serbia).
- Shifting societal norms towards sustainability and promoting eco-design principles are common strategies (Czech Republic, Germany, Bosnia and Herzegovina).

## Environmental

### **Challenges:**

- Plastic waste pollution and microplastic presence in the environment are shared challenges (Hungary, Austria, Romania).
- Greenhouse gas emissions from plastic waste incineration are noted environmental concerns (Germany, Serbia, Czech Republic).

### **Opportunities:**

- Reducing plastic pollution through circular practices and improving waste management infrastructure are identified opportunities (Austria, Romania, Slovakia).
- Supporting initiatives for cleaning water bodies and protecting habitats are common environmental goals (Moldova, Bosnia and Herzegovina, Czech Republic).

While each country faces unique challenges in their transition towards a circular economy, there are significant similarities in the opportunities they can leverage. Common opportunities include advancing technological capabilities, implementing supportive policies, enhancing public awareness, and fostering collaboration across sectors. Addressing these challenges while capitalizing on opportunities can accelerate progress towards a more sustainable and circular economy across the region, benefiting both the environment and the economy.

# Guideline for the Development of Circular Plastics Solutions

Ultimately, the DTWs as well as peer review session led to a guideline in the plastics sector. In alignment with the European Union's evolving regulatory landscape—particularly Regulation (EU) 2024/1781—the guideline should support small and medium-sized enterprises (SMEs) in the plastics sector in adopting circular economy principles. The objective is to unify and streamline innovation processes, reduce environmental impact, and enhance competitiveness through sustainable practices.

## Foundational Pillars of Circular Innovation

Based on the DTWs and the prototype concepts, a guideline with four pillars was created. These are briefly presented here with a concrete example from the workshops:

1. **Recyclability** – Prioritize product designs that enable multiple recycling cycles; phase out non-recyclable materials.

The prototype concept outlines a structured approach to enhancing the recyclability of plastic waste, particularly focusing on the reuse of sludge generated during plastic recycling processes. This sludge, currently classified as hazardous waste and typically landfilled, presents a significant disposal challenge. The proposed solution involves repurposing this waste material into useful products such as building elements (e.g., tiles, blocks) or grass grates. The initiative aims to extend the lifecycle of materials originally derived from fossil sources, thereby contributing to sustainability goals.

The prototyping process is divided into several steps. First, the concept is clarified, targeting recycling plants and manufacturers of technical plastic parts. The prototype is designed to test the feasibility of processing sludge into durable, safe, and aesthetically acceptable materials using conventional technologies like crushing, sorting, compounding, extrusion, and injection molding. Real sludge from recycling plants is used to ensure authenticity.

The prototype evolves through multiple stages, culminating in semi-final products with commercial potential. Testing includes mechanical property assessments, aging simulations, and comparisons with standards for primary raw materials. Feedback from these tests, along with economic and marketing evaluations, informs further development. The process also includes feasibility and resource availability studies, as well as consultations with potential customers.

Crucially, the solution supports circular economy principles by reducing reliance on primary raw materials, minimizing landfill and incineration, and lowering environmental impacts such as greenhouse gas emissions and toxicity. This approach not only addresses waste management challenges but also promotes sustainable material use in industrial applications.

2. **Recycled Content** – Mandate the use of recycled materials, especially in packaging, excluding food-contact applications.

The prototype described focuses on integrating bioplastics into robotic components, particularly grippers, to enhance sustainability in industrial automation. Its primary goal is to reduce the environmental impact of robotics manufacturing by substituting petroleum-based plastics with biodegradable and renewable bioplastics such as PLA, PHA, and PBS. This substitution aims to lower the carbon footprint, reduce component weight, and improve energy efficiency in robotic systems.

The prototype addresses several key challenges: the high carbon emissions associated with traditional materials, the energy demands of heavy robotic parts, and the limited recyclability of conventional components. It targets robotics manufacturers, R&D teams, and sustainability advocates, aiming to demonstrate the feasibility of bioplastics in demanding industrial environments.

The development process follows a structured, step-by-step approach. It begins with defining the prototype's purpose and testing hypotheses related to material performance, weight reduction, sustainability, and end-of-life management. Core functions include mechanical strength, flexibility, and compatibility with existing robotic systems, while future enhancements may involve smart materials, self-healing capabilities, and embedded sensors.

Technologies used include robotic simulation software, 3D printing, CAD/CAM tools, and material testing equipment. The prototype progresses from low-fidelity sketches and simulations to high-fidelity, 3D-printed components tested on robotic arms under real-world conditions. Testing evaluates mechanical properties, environmental resistance, and biodegradability, using metrics such as tensile strength, energy consumption, and recyclability.

An iterative development cycle ensures continuous improvement based on test results, stakeholder feedback, and simulation data. Final refinements lead to a pilot demonstration and the creation of a technical dossier and knowledge pack for scaling or replication.

The prototype strongly supports circular economy principles by using renewable materials, designing for energy efficiency, and enabling end-of-life composting or recycling. It also contributes to broader awareness and adoption of sustainable practices in robotics, potentially influencing policy, industry standards, and educational initiatives.

3. **Reuse** – Define and enforce reuse standards for specific product groups and materials.

The prototype described focuses on minimizing production waste by repurposing high-quality materials that would otherwise be discarded. It introduces two main strategies: first, utilizing unused space within the punching grids from the automotive sector to create new small products, and second, recycling production scraps into customizable plastic films for enclosures used across various industries. These approaches aim to reduce material loss, improve resource efficiency, and support sustainability goals.

The prototype addresses the issue of valuable material waste during manufacturing, offering a solution that not only conserves resources but also opens new business opportunities. By

integrating new products into existing production processes and developing recycled plastic films, the company can expand its product line, attract eco-conscious customers, and diversify its market base.

Key features of the prototype include waste reduction, quality assurance, product design, and collaboration with recycling partners. Technologies involved range from CAD modelling and 3D design to pilot-scale production and quality testing. Both low-fidelity (e.g., sketches, process maps) and high-fidelity (e.g., 3D models, production samples) prototypes are developed to test feasibility and performance.

Testing strategies focus on material quality, production efficiency, customization, and sustainability metrics such as waste reduction rate, material efficiency, and cost savings. Feedback from these tests informs iterative improvements in design, materials, and processes.

Ultimately, the prototype supports circular economy principles by transforming waste into valuable products, reducing reliance on virgin materials, and aligning with EU and global sustainability regulations. It enhances environmental performance, supports ESG goals, and demonstrates a scalable model for sustainable manufacturing.

4. **Collection** – Establish robust collection and sorting systems to ensure material recovery and reintegration.

The prototype concept described, titled "CircularPlastHub: Accelerating Funding & Partnerships", is a digital platform designed to enhance collaboration between research institutions and industry while simplifying access to funding for circular economy projects in the plastics sector. It addresses key challenges such as limited research-industry collaboration, complex funding processes, and administrative barriers that hinder the adoption of circular practices.

The core purpose of the prototype is to act as a centralized hub that connects stakeholders—researchers, SMEs, industry players, and policymakers—offering structured access to funding opportunities, matchmaking tools, and knowledge-sharing resources. It aims to foster innovation, support sustainable development, and accelerate the implementation of circular economy solutions in Romania, where such a dedicated initiative is currently lacking.

Key features of the prototype include a user-friendly funding search tool, clear eligibility guidelines, a centralized database, and collaboration support tools. It also integrates circular economy principles by promoting eco-friendly materials, recycling technologies, and sustainable business models. Future enhancements may include mentorship programs, impact assessment tools, and community-building features like webinars and online forums.

The prototype development follows a two-stage approach: a low-fidelity phase with sketches and wireframes to conceptualize the platform, and a high-fidelity phase with interactive mockups and a functional beta version for pilot testing. Technologies used include digital platforms (e.g., Airtable, Notion), AI-based recommendation systems, and collaboration tools like Miro and Microsoft Teams.

Testing involves pilot campaigns, user feedback, and expert validation, with metrics such as platform engagement, funding success rates, and user satisfaction. Feedback will guide iterative improvements, ensuring the platform evolves to meet stakeholder needs effectively.

In terms of circularity, the prototype supports investment in sustainable plastics, builds infrastructure for recycling, drives innovation, and fosters a sustainability-oriented business culture. It ultimately serves as a catalyst for circular innovation, making funding more accessible and enabling impactful partnerships that advance the circular economy in the plastics industry.

**These pillars form the backbone of any effective circular strategy and must be implemented in a coordinated manner.**

### Implementation Framework for SMEs

To operationalize circularity, SMEs should adopt a structured approach that includes:

- **Internal Readiness Assessment:** Conduct Design Thinking Workshops (DTW) to evaluate current practices, identify gaps, and align internal capabilities with circular goals.
- **Legislative Mapping:** Utilize AI tools to interpret relevant EU legislation and standards applicable to specific product categories.
- **Impact Mapping:** Quantify the environmental and economic impact of both existing and proposed solutions using lifecycle assessments and circularity metrics.

### Prototyping and Innovation Design

Prototyping should be guided by the following principles:

- **Problem Definition and Hypothesis Testing:** Clearly articulate the problem, target audience, and expected outcomes.
- **Material and Technology Selection:** Prioritize recycled, bio-based, or waste-derived materials and scalable technologies.
- **Circular Design Integration:** Ensure prototypes are modular, repairable, recyclable, and energy/resource efficient.
- **Testing and Iteration:** Implement robust testing protocols and integrate stakeholder feedback to refine solutions.

## Business Model Considerations

Circular prototypes must be evaluated for:

- **Economic Viability:** Demonstrate cost-effectiveness and potential for market competitiveness.
- **Scalability:** Assess feasibility for mass production using existing infrastructure.
- **Market Entry Strategy:** Develop phased go-to-market plans, including pilot launches, crowdfunding, and strategic partnerships.

## Monitoring and Verification

To ensure continuous improvement and compliance:

- **Performance Metrics:** Track mechanical performance, environmental impact, and user acceptance.
- **Circularity Indicators:** Measure waste reduction, resource efficiency, and recycled content utilization.
- **Stakeholder Engagement:** Collect feedback from customers, industry experts, and regulatory bodies to validate and enhance circular practices.

# Conclusion

The transition to a circular plastics economy is not only a necessity but a powerful opportunity for innovation, sustainability, and economic resilience. This handbook has outlined the foundational concepts, tools, and strategies that can guide stakeholders—especially SMEs—toward meaningful circular transformation.

## Recap of Key Points

- **Plan-C** fosters transnational collaboration to drive circular innovation in the plastics and machinery sectors across the Danube region.
- The **importance of circularity** lies in addressing environmental, economic, and regulatory challenges through reuse, recycling, and sustainable design.
- **Design for circularity** emphasizes material selection, modularity, recyclability, and reuse systems to close the loop in plastic lifecycles.
- **Design thinking methods** offer creative, human-centered approaches to problem-solving, enabling the development of innovative circular solutions.
- A comprehensive **analysis of regional challenges and opportunities** highlights the need for harmonized policies, technological upgrades, and public awareness.
- The **guideline for circular plastics solutions** is built on four pillars—Recyclability, Recycled Content, Reuse, and Collection—supported by practical prototyping and business model strategies.

## Future Outlook for Circular Plastics

The future of plastics lies in **regenerative systems** that prioritize sustainability without compromising functionality or economic viability. As EU regulations evolve and consumer demand for sustainable products grows, circularity will become a competitive advantage. Emerging technologies, digital platforms, and cross-sector partnerships will further accelerate this transition, enabling scalable, impactful solutions.

## How to Use This handbook

This handbook serves as a **practical roadmap** for SMEs and stakeholders:

- Begin with an internal readiness assessment using design thinking workshops.
- Align with EU legislation through legislative mapping tools.
- Use the prototyping framework to develop, test, and refine circular solutions.
- Apply the business model canvas to ensure economic viability and scalability.
- Monitor progress through circularity indicators and stakeholder feedback loops.

By following this structured approach, organizations can confidently navigate the complexities of circular transformation and unlock new value streams.

### Call to Action

The shift to a circular plastics economy starts with **bold ideas and collaborative action**. Whether you're a manufacturer, designer, policymaker, or entrepreneur, your role is vital. Use this handbook as your guide, engage with your peers, and take the first step toward a more sustainable, innovative, and resilient future.

**Let's close the loop—together.**