Interreg Danube Region

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Creation of innovative, circular machine life cycle phases

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Content

INTRODUCTION

A pilot design thinking workshop on the potential of the circular transformation of the machine industry is being implemented within the Plan-C project activity (D 2.2.2.).

The primary objective of the workshop is to foster the exploration of circular economy principles within the machine industry, aiming to identify innovative solutions for transforming the entire life cycle of machines. The goal is to enable participants—representatives of different companies within the machine industry—to collaborate in identifying areas where circular practices can be integrated, from design and development to waste management and refurbishment. By the end of the workshop, participants should have generated concrete, innovative proposals for circular transformation in various life cycle phases. These proposals will be considered for pilot implementation, encouraging companies to adopt circular strategies and reduce waste while improving sustainability.

A secondary objective is to promote cross-sectoral collaboration and shared learning among companies, encouraging participants to think beyond their traditional practices and explore new opportunities for efficiency, resource reuse, and waste reduction. By leveraging the design thinking methodology, the workshop aims to guide participants through a structured, creative process that emphasizes user needs, collaborative ideation, and rapid prototyping of solutions. This approach not only facilitates innovation but also ensures that the proposed solutions are practical, scalable, and aligned with the principles of circularity.

This document consists of two parts:

1. Guideline for organization and implementation of design thinking workshops for piloting circular solutions in the machine industry, and
2. Summary of all developed innovative, circular machine life cycle phases

The first part presents detailed instructions for conducting the workshops, while the second part summarizes all the pilot solutions developed at the project partners' implemented workshops.

GUIDELINE FOR ORGANIZATION AND IMPLEMENTATION OF DESIGN THINKING WORKSHOPS FOR PILOTING CIRCULAR SOLUTIONS IN THE MACHINE INDUSTRY

Explanation of the circular economy principles

The circular economy is an economic model that aims to minimize waste, maximize resource efficiency, and create closed-loop systems where materials, components, and products are reused, repaired, remanufactured, or recycled rather than discarded. It represents a shift away from the traditional linear economy, which follows a "take-make-dispose" approach, to a more sustainable system that keeps resources in use for as long as possible. The circular economy is based on three key principles: designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.

Designing out waste and pollution: One of the fundamental principles of the circular economy is the idea that waste is not an inevitable byproduct but a design flaw. By rethinking how products are designed from the outset, companies can minimize or even eliminate waste. This means choosing materials that are reusable or recyclable and designing products that can be easily disassembled, repaired, or upgraded, reducing the need for constant replacement. Pollution is also addressed by designing products and systems that reduce emissions, avoid harmful chemicals, and minimize the environmental impact throughout the product’s lifecycle.

Keeping products and materials in use: The circular economy focuses on extending the life cycle of products and materials. This involves adopting practices such as repair, refurbishment, and remanufacturing, allowing products to be reused or upgraded instead of being disposed of after a short lifespan. Businesses can explore strategies like leasing or offering products as a service, where the manufacturer retains ownership and responsibility for maintaining and eventually reclaiming the product. This not only prolongs the product's life but also ensures that valuable materials stay in circulation rather than end up in landfills.

Regenerating natural systems: The circular economy goes beyond reducing harm—it aims to have a restorative and regenerative impact on natural systems. This principle involves using renewable resources and creating processes that regenerate ecosystems. For example, instead of depleting finite resources, companies are encouraged to adopt sustainable practices such as using biodegradable materials or investing in renewable energy sources. Additionally, biological materials that cannot be reused or recycled should be safely returned to the environment in a way that supports regeneration, such as composting or returning nutrients to the soil.

Implementing these principles in the machine industry can significantly contribute to sustainability by encouraging circular approaches throughout the machine's life cycle, from design and material sourcing to refurbishment and end-of-life management. Adopting the circular economy model helps reduce the industry's reliance on finite resources, cut costs by making processes more efficient, and create new business opportunities by offering innovative services and products. It also aligns with global sustainability goals, helping companies meet environmental regulations and reduce their carbon footprint while gaining a competitive edge.

Importance of circular transformation in the machine industry

The circular transformation in the machine industry is of critical importance as it addresses several pressing global challenges, including resource scarcity, environmental degradation, and the need for sustainable industrial growth. Traditionally, the machine industry has operated on a linear model, consuming large amounts of raw materials, generating significant waste, and contributing to environmental pollution. By adopting circular principles, the industry can shift to a more sustainable model that focuses on maximizing resource efficiency, reducing waste, and minimizing environmental impact throughout the entire life cycle of machines—from design and manufacturing to end-of-life management.

One of the most important reasons for circular transformation is the potential to significantly reduce resource dependency. The machine industry is highly reliant on raw materials, many of which are finite or come from regions with volatile supply chains. Circular approaches, such as refurbishing, reusing, and recycling components, can help companies reduce their dependence on virgin materials, thereby increasing supply chain resilience. This is especially important given the rising costs and environmental impacts associated with the extraction of raw materials. By keeping materials in circulation, companies not only conserve valuable resources but also reduce the need for energy-intensive production processes, which contribute to greenhouse gas emissions and climate change.

Furthermore, circular transformation can lead to substantial cost savings and operational efficiency. By extending the life cycle of machines and their components through refurbishment or remanufacturing, companies can reduce production costs while offering high-quality, cost-effective solutions to customers. This shift also opens the door for new business models, such as product-as-a-service (PaaS), where machines are leased or rented rather than sold outright. In such models, manufacturers maintain responsibility for the upkeep and eventual recycling of the machines, fostering longer product life cycles and reduced material waste. These models not only create new revenue streams but also align with growing customer demand for sustainable and service-oriented solutions.

From a regulatory and reputational perspective, circular transformation is becoming increasingly essential. Governments and international bodies are introducing stricter regulations on waste management, carbon emissions, and resource usage. Companies in the machine industry that proactively adopt circular practices will be better positioned to comply with these regulations and avoid potential penalties. Additionally, businesses that prioritize sustainability are likely to gain a competitive advantage, as consumers and investors increasingly favor companies that demonstrate environmental responsibility.

Circular transformation in the machine industry is not just a necessity but an opportunity, offering tangible benefits in terms of resource conservation, cost savings, innovation, and regulatory compliance, while also contributing to the broader goal of environmental sustainability.

Overview of workshop phases – ideation, prototyping, validation

The workshop will follow a structured sequence of phases designed to guide participants through the design thinking methodology while focusing on circular transformation in the machine industry. Each phase builds on the previous one, ensuring a logical flow from problem identification to the development of innovative, circular solutions.

Below is an overview of the key phases of the workshop:

1. Introduction and Context Setting (max. 30 minutes)

- **Objective**: To introduce participants to the workshop's goals, clarify the importance of circular economy principles, and set the stage for the interactive exercises to follow.

- **Content**:
  - Welcome and brief introductions of participants and facilitators.
  - Overview of circular economy principles and their relevance to the machine industry.
  - Introduction to the design thinking methodology and its role in fostering circular innovation.
  - Presentation of the machine's life cycle phases, with a focus on identifying potential circular interventions.
- **Dynamics**: Interactive presentations followed by a Q&A session. Participants may be asked to briefly share their expectations and any previous experience with circular initiatives.

2. Empathy and Problem Identification (max. 60 minutes)

- **Objective**: To understand the challenges and opportunities for circular transformation within the machine life cycle, considering stakeholder needs and the current state of each phase.
- **Content**:
  - Presentation of case studies and real-world examples of circular practices in the machine industry.
  - Participants will be divided into smaller groups, each assigned to a specific phase of the machine's life cycle (e.g., design, material sourcing, manufacturing, etc.).
  - Each group will explore the pain points, inefficiencies, and environmental impacts of their assigned phase, with a focus on understanding the user and stakeholder needs.
- **Dynamics**: Group discussions and brainstorming sessions. Participants will use tools such as stakeholder mapping and journey mapping to capture insights. Group presentations will follow to share findings with the larger group.

3. Defining the Problem Statement (max. 30 minutes)

- **Objective**: To clearly define the specific problems or opportunities for circular transformation that emerged from the empathy phase.
- **Content**:
  - Facilitators will guide participants in refining their understanding of the problems they identified, ensuring that each issue is framed within the context of circularity.
  - Each group will write a concise problem statement that outlines the key challenges in their life cycle phase and the impact on circularity.
- **Dynamics**: Group discussions, facilitated by guiding questions to ensure clarity and focus. Each group will present its problem statement to the larger group for feedback.

4. Ideation and Solution Generation (max. 60 minutes)

- **Objective**: To generate a wide range of innovative solutions that address the problems identified and support circular transformation.
- **Content**:
    - Participants will engage in creative exercises to generate ideas for how circular practices can be applied to their life cycle phase.
    - Techniques such as brainstorming, mind mapping, and reverse brainstorming will be used to encourage divergent thinking.
    - Facilitators will guide participants to consider how to integrate circular strategies such as resource efficiency, product life extension, reuse, and recycling into their solutions.
- **Dynamics**: Small group work with time allocated for idea generation, followed by peer feedback. The goal is to generate a large quantity of ideas without focusing on feasibility at this stage.

5. Prototyping and Testing (max. 90 minutes)

- **Objective**: To develop and refine selected ideas into tangible, pilot-ready proposals for circular innovation.
- **Content**:
    - Each group will select the most promising ideas from the ideation phase and begin to prototype solutions. Prototypes can be physical models, sketches, process diagrams, or business model canvases, depending on the nature of the solution.
    - Groups will assess their prototypes by considering feasibility, scalability, and alignment with circular economy principles.
    - Facilitators will provide tools such as the Circular Design Toolkit or business model templates to support this process.
- **Dynamics**: Interactive prototyping sessions with feedback from facilitators and peers. Participants will iterate on their solutions based on constructive input.

6. Solution Presentation and Feedback (max. 45 minutes)

- **Objective**: To present the developed solutions to the larger group for feedback and further refinement.
- **Content**:
    - Each group will present their solution, including the problem it addresses, the proposed circular approach, and how the solution will work in practice.
    - The presentation should include both the process (how the solution was developed) and the intended impact on the machine's life cycle.
    - After each presentation, there will be a round of constructive feedback from other participants and facilitators.
- **Dynamics**: Group presentations followed by facilitated feedback sessions. The emphasis is on collaborative learning and refinement of ideas.

7. Evaluation and Selection of Pilot Solutions (max. 60 minutes)

- **Objective**: To evaluate the proposed solutions and select those with the greatest potential for pilot implementation.
- **Content**:
  - Facilitators will present criteria for evaluating solutions, such as environmental impact, cost-effectiveness, scalability, and feasibility within the machine industry.
  - Each group will evaluate its solution against these criteria, and the larger group will vote or discuss which solutions should be developed as pilot projects.
  - Facilitators will offer guidance on next steps for further development and implementation.
- **Dynamics**: Facilitated group discussions followed by an evaluation process (e.g., voting or scoring). Participants will collectively agree on the solutions that will be proposed as pilots for their respective organizations.

8. Conclusion and Next Steps (max. 30 minutes)

- **Objective**: To wrap up the workshop by summarizing key learnings and outlining the next steps for implementation.
- **Content**:
  - Facilitators will provide a recap of the day's activities, highlighting key insights, innovative solutions, and the collaborative spirit of the workshop.
  - Participants will be given guidance on how to document their solutions and develop them further within their companies.
  - Information about follow-up activities, including potential pilot projects, ongoing support, and collaboration opportunities, will be provided.
- **Dynamics**: Closing remarks by facilitators, followed by participant reflections and Q&A. The session ends with networking and discussion of future collaborations.

Description of the expected workshop outcomes

The expected outcomes of the workshop include the development of innovative, pilot-ready solutions aimed at enabling circular transformation across various phases of the machine's life cycle. By the end of the workshop, participants will have collaboratively identified key opportunities for circularity within their assigned life cycle phases and proposed practical, scalable solutions to address these challenges. These solutions will focus on areas such as resource efficiency, product life extension, material reuse, and waste reduction. The workshop will also foster cross-company collaboration, promote knowledge sharing, and equip participants with the tools and methodologies needed to implement circular practices in their own operations. Ultimately, the goal is to create a set of viable, pilotable projects that can be tested and further developed within participating companies, driving the broader adoption of circular economy principles in the machine industry.

Life cycle phases of machines

The machine life cycle can be broken down into 8 phases, and within them, different circular strategies are defined and implemented. Those 8 phases (and strategies within them) are:

1. Design and Development

Design for Longevity: Create machines with a longer lifespan by using durable materials and modular designs that allow for easy upgrades and repairs;

Design for Disassembly: Ensure that machines can be easily disassembled into components for repair, refurbishment, or recycling at the end of their life;

Eco-design: Incorporate sustainable materials and energy-efficient technologies into the design phase to reduce environmental impact throughout the machine's life cycle;

Standardization of Parts: Use standardized components that can be easily replaced or upgraded, reducing the need for custom parts and simplifying repairs.

2. Material Sourcing

Use of Recycled Materials: Prioritize the use of recycled or renewable materials in the manufacturing of machines to reduce reliance on virgin resources;

Sustainable Material Sourcing: Source materials from suppliers who adhere to sustainable practices, ensuring the minimization of environmental impacts and ethical labor practices;

Closed-Loop Material Systems: Implement closed-loop systems where materials can be continuously recycled back into new products without losing quality.

3. Manufacturing and Assembly

Additive Manufacturing (3D Printing): Utilize 3D printing to produce parts on demand, minimizing waste and enabling on-site production of components;

Lean Manufacturing: Adopt lean manufacturing techniques to minimize waste, reduce energy consumption, and optimize resource use during production;

Remanufacturing: Implement remanufacturing processes where used machines or components are restored to like-new condition, extending their lifecycle.

4. Distribution and Logistics

Efficient Transportation: Use optimized logistics to reduce transportation emissions, such as through route planning, load optimization, and the use of electric or low-emission vehicles;

Local Production and Distribution: Encourage local production to reduce transportation distances and associated emissions, while supporting regional economies;

Reusable Packaging: Implement reusable or returnable packaging solutions to minimize packaging waste in the supply chain.

5. Use phase and Maintenance

Predictive Maintenance: Utilize IoT and AI technologies to monitor machine performance and predict maintenance needs, reducing unplanned downtime and extending machine life;

Shared Ownership Models: Promote shared ownership or leasing models where machines are used by multiple entities, maximizing utilization and reducing the need for new machines;

Upgrading and Retrofitting: Provide options for upgrading or retrofitting machines with the latest technologies rather than replacing them, prolonging their useful life.

6. End-of-life Management

Recycling and Material Recovery: Develop systems for the effective recycling of machine components and recovery of valuable materials at the end of the machine's life;

Reverse Logistics: Implement reverse logistics systems to take back used machines for refurbishment, remanufacturing, or recycling;

Product-as-a-Service (PaaS): Transition from selling machines to offering them as a service, where the manufacturer retains ownership and is responsible for maintenance, upgrades, and end-of-life disposal.

7. Refurbishment and Reuse

Component Reuse: Encourage the reuse of functional components from decommissioned machines in the manufacturing of new or refurbished machines;

Refurbishment Programs: Establish refurbishment programs where used machines are restored to working condition and resold, reducing the need for new production;

Marketplaces for Used Machines: Create platforms or marketplaces for the sale of refurbished or second-hand machines, promoting reuse.

8. Waste Management

Zero Waste to Landfill: Implement strategies to ensure that no components of the machine are sent to landfills, through recycling, composting, or other waste management techniques;

Biodegradable or Compostable Components: Design certain components to be biodegradable or compostable, reducing the impact of waste disposal;

Material Recovery Facilities: Develop specialized facilities for recovering and processing materials from end-of-life machines.

The real potential for circular transformation across the machine life cycle is evident in proven **circular business models**:

<u>Design and Development:</u> The real potential in this phase lies in eco-design and modular product design, which have been successfully implemented by companies like Philips and Caterpillar. Designing machines for disassembly, upgradeability, and repairability has been proven to extend product life and make refurbishment easier. Companies that adopt design for longevity—where products can be repaired or upgraded without being replaced—reduce the need for new resources and minimize waste.

<u>Material Sourcing:</u> Circular sourcing strategies, such as using recycled or renewable materials, have shown great promise in reducing reliance on virgin resources. For example, Siemens and Bosch have adopted recycled steel and aluminum in their manufacturing processes. The real potential here lies in building closed-loop supply chains, where companies reclaim and reuse materials from end-of-life products, as seen in industries that use metal alloys, plastics, and rare earth elements.

<u>Manufacturing and Assembly:</u> Companies like Renault and Rolls-Royce have demonstrated that remanufacturing components—where used parts are restored to like-new condition—offer significant potential for circularity. Remanufacturing requires less energy than producing new parts, while also extending the life of valuable materials. Lean manufacturing techniques also reduce waste and energy usage, and 3D printing allows for more precise use of materials, minimizing off-cuts and excess material usage.

<u>Distribution and Logistics:</u> Circular potential in logistics is proven through innovations like reverse logistics, where companies ensure products are returned at the end of their life cycle for recycling or refurbishment. Shared logistics models, such as DHL's circular economy partnerships, allow companies to reduce transportation emissions and optimize product recovery. Packaging reduction strategies, where companies like IKEA reduce packaging materials and increase the reusability of transport containers, also enhance circularity.

<u>Use phase and Maintenance:</u> Product-as-a-Service (PaaS) models have been transformative in this phase. Companies like Xerox and Caterpillar offer machines on a leasing basis, where they retain ownership and are responsible for maintenance, repair, and eventual recycling. This model incentivizes companies to design longer-lasting products and ensures they are refurbished rather

than discarded. Predictive maintenance technologies have also proven their worth in extending machine life, reducing unplanned downtime, and preventing premature disposal of machines.

End-of-life Management: Take-back schemes have proven highly effective, with companies like Apple and Cummins offering programs where customers return end-of-life products for recycling or remanufacturing. This ensures valuable components and materials are recovered and put back into production, reducing reliance on virgin materials. Dismantling technologies have also advanced, making it easier to recover valuable materials from complex products like engines and heavy machinery.

Refurbishment and Reuse: Companies like Siemens and GE have built successful business models around refurbishment, offering certified refurbished machines and parts that meet the same quality standards as new products. This extends product life and offers customers cost-effective solutions, while also reducing the need for new production. The reuse of components, such as engines or heavy machinery parts, has proven viable in maintaining supply chains and keeping materials in circulation longer.

Waste Management: Proven circular potential in waste management comes from closed-loop recycling systems, where materials are continually recovered and reintroduced into production. Toyota and Renault have implemented waste-to-resource models where scrap materials from manufacturing are repurposed into new products. Industrial symbiosis, where one company's waste becomes another's raw material, is also gaining traction, reducing waste while creating new business opportunities.

Steps of design thinking – Empathize, Define, Ideate, Prototype, Test

Design thinking is a human-centered methodology that encourages creative problem-solving and innovation. It's particularly effective in tackling complex challenges like circular transformation in the machine industry because it focuses on understanding user needs and iterating on solutions. The design thinking process is structured into five key phases: **Empathize, Define, Ideate, Prototype,** and **Test**.

1. **Empathize**: The first step is to gain a deep understanding of the people or systems involved in the problem you are trying to solve. In the context of circular transformation, this means empathizing with various stakeholders, including machine users, operators, manufacturers, suppliers, and recyclers, to identify their pain points and needs related to sustainability. Techniques such as interviews, observation, and user journey mapping help uncover insights about the challenges faced in different phases of the machine's life cycle. For instance, understanding how a machine operator struggles with maintenance or how end-of-life materials are handled can reveal opportunities for circular innovation. This step is crucial because solutions must align with the real-world needs of stakeholders for them to be effective and adoptable.

2. **Define**: Once you have a deep understanding of the stakeholders, the next step is to clearly define the problem based on the insights gained during the Empathize phase. In the Define phase, the focus is on narrowing down the broader challenge into a specific problem statement. In the context of circular transformation, this could mean defining a clear challenge like "How might we design machines that are easier to disassemble and recycle?" or "How might we reduce material waste in the manufacturing process?" A well-defined problem is critical as it guides the entire innovation process and ensures that the team's efforts are focused on solving the most impactful issue. The Define phase transforms empathy-driven insights into actionable opportunities for circularity.

3. **Ideate**: Ideation is the creative brainstorming phase where teams generate a wide range of potential solutions to the defined problem. This step encourages divergent thinking—

exploring as many ideas as possible without worrying about feasibility in the initial stages. Various brainstorming techniques can be used, such as mind mapping, role-playing, and “how might we” questions. In the context of circular transformation, ideas might range from creating machines with fewer components for easier recycling to developing shared maintenance services to extend product life. The goal of this phase is to generate innovative, out-of-the-box solutions that challenge existing practices and introduce new ways to apply circular economy principles. It’s essential to foster an open, collaborative environment where all ideas are welcome, as even the wildest ideas can spark creative breakthroughs.

4. **Prototype**: After selecting the most promising ideas from the Ideate phase, the next step is to create prototypes. Prototyping is about building tangible representations of your ideas to explore and test their viability. These prototypes can range from simple sketches or models to more advanced simulations or working versions of a product. In the machine industry, prototypes might include physical models of redesigned machine parts or process diagrams for new recycling systems. The key is to start small and rapidly develop prototypes that can be tested and iterated upon. Prototyping allows teams to experiment with different approaches and identify potential flaws or improvements before moving to full-scale implementation. This phase embodies the principle of "fail fast, learn fast," enabling teams to refine their ideas through hands-on experimentation.

5. **Test**: In the final phase, prototypes are tested with users or stakeholders to gather feedback and evaluate how well the solution addresses the problem. Testing can involve simulations, field trials, or user feedback sessions. In the circular transformation context, testing might include piloting new circular business models, evaluating the recyclability of redesigned machine components, or assessing the efficiency of a new material recovery process. The feedback gathered during testing is essential for refining the solution and ensuring it aligns with both user needs and sustainability goals. The Test phase also allows for further iteration—based on feedback, teams may return to the earlier stages of design thinking to tweak and improve the solution. Ultimately, this process of iteration and testing helps develop solutions that are both innovative and practical, ensuring that circular strategies can be effectively implemented in the machine industry.

How design thinking can be applied to circular transformation

Design thinking is particularly well-suited to circular transformation because it encourages a systems-level view of challenges while focusing on human needs and behaviors. By applying the five phases of design thinking, organizations can creatively address the complexities of implementing circular principles across all life cycle phases of machines. For example, during the Empathize phase, understanding how different stakeholders interact with machines throughout their life cycle reveals where circularity can be improved. The Define phase helps narrow the focus to specific circular challenges, such as reducing resource use or improving end-of-life management. Through Ideation, participants generate innovative ideas that challenge linear thinking, such as modular designs or service-based models. In the Prototype and Test phases, these ideas are translated into practical, scalable solutions that can be piloted within organizations. The iterative nature of design thinking ensures that solutions are refined based on real-world feedback, making it an ideal methodology for driving circular innovation in the machine industry.

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 machine industry.

The key techniques include:

1. 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 machine's production phase?" 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.

2. 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 machine manufacturing."
- Draw branches for each phase of the machine's life cycle, such as design, manufacturing, logistics, or end-of-life management.
- 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.

3. 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**: What materials, processes, or components can be replaced with more sustainable or circular alternatives? For example, could steel parts be substituted with recycled or biocomposite materials?
- **Combine**: Can multiple phases or functions be combined to improve circularity? For instance, combining the manufacturing and maintenance phases by designing machines that automatically detect wear and send data for predictive maintenance.
- **Adapt**: How can an existing solution or process be adapted to improve circularity? Can we adapt existing technologies to make machines easier to 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**: Can machine components or materials be repurposed after their initial use? For example, can a component at the end of its life cycle be used in a different industry?
- **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?

4. 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 machines 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.

5. 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 colored hats, each representing a distinct way of thinking:

- **White Hat**: Focus on data, facts, and information. What are the known details about the machine 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 machine 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 machines?
- **Blue Hat**: Focus on process control. How can we structure and manage the ideation process to ensure productive outcomes?

6. 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 machine operators, 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, behaviors, and needs. For example, what does the operator experience when performing maintenance? What are their goals, frustrations, and concerns related to sustainability?

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.

1. Circular Value Mapping

Circular value mapping is a method that helps participants identify value creation opportunities across different stages of a machine'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.

2. Life Cycle Thinking

Life cycle thinking encourages participants to assess the environmental and circular impact of their ideas across all stages of a product's life cycle. This method shifts the focus away from single phases of the machine industry, ensuring that participants consider the entire life cycle when brainstorming solutions. In practice, facilitators guide participants through these steps:

- Break down the machine's life cycle into key phases.
- For each phase, encourage participants to explore circular strategies. For example, in the **design phase**, they might explore modular design or eco-friendly materials; in **manufacturing**, they could look at minimizing waste or using renewable energy.
- Ask guiding questions to ensure ideas focus on circularity: "How can we reduce environmental impact during the sourcing phase?" or "What would enable this machine to be more easily disassembled for recycling or refurbishment?"

By thinking across the full life cycle, participants are encouraged to develop holistic solutions that reduce environmental impact while closing material loops.

3. 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 machine's life cycle when it comes to circularity. For example, "What would prevent this machine 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.

4. 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 machine users or other stakeholders (e.g., recyclers or maintenance technicians). They should explore pain points related to sustainability, such as difficulty recycling machine 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 machine design that reduces downtime 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.

5. Feasibility-Impact 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.

6. 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.

7. 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.

Interactive exercises for each life cycle phase (examples)

Design and Development: Circular Product Design Workshop

In this exercise, participants focus on rethinking machine design to incorporate circularity from the very start. They are divided into small groups and tasked with redesigning an existing machine or component using circular design principles such as modularity, durability, and ease of disassembly.

Process:

- **Phase 1:** The facilitator presents a real-world machine (e.g., an industrial compressor or engine part) and provides background on its design, materials, and lifecycle challenges.
- **Phase 2:** Each group uses a template to rethink the machine design, focusing on improving its circularity. Key questions are: “How can we design this machine for easier repair and disassembly? What materials can be used to extend its life?”
- **Phase 3:** Teams present their designs and explain how their changes increase the machine’s potential for recycling, reusing, or upgrading.

Material Sourcing: Circular Material Selection Exercise

In this hands-on activity, participants explore how sourcing sustainable, renewable, or recycled materials can reduce environmental impact. Each team is provided with a list of materials commonly used in machine production and tasked with selecting alternative materials that support circularity.

Process:

- **Phase 1:** The facilitator provides details on different materials used in manufacturing, including information on their environmental impact, availability, and recyclability. These could include traditional materials like virgin steel or plastic and circular options like recycled aluminum or biocomposites.
- **Phase 2:** Teams must select materials for a specific machine component, considering factors like durability, ease of recycling, and carbon footprint. The challenge is to strike a balance between performance and circularity.
- **Phase 3:** Teams present their selected materials, explaining the trade-offs they considered and how their choices contribute to a circular lifecycle.

Manufacturing and Assembly: Zero-Waste Production Simulation

This exercise simulates a manufacturing process where participants are tasked with optimizing a production line to minimize waste and energy use while enhancing circularity. Participants must re-engineer a simple machine assembly process, applying principles of lean manufacturing and zero waste.

Process:

- **Phase 1:** The facilitator explains the current manufacturing setup for a specific product and highlights areas where waste is generated (e.g., material scraps, energy inefficiencies).
- **Phase 2:** Teams receive a kit of materials (e.g., LEGO pieces or similar modular components) to assemble a machine part. Their task is to modify the process to reduce waste. For example, they might find ways to reuse leftover materials or suggest energy-saving techniques.
- **Phase 3:** Teams share their optimized processes, focusing on how they reduced waste and increased resource efficiency.

Distribution and Logistics: Circular Supply Chain Mapping

In this interactive session, participants are tasked with mapping out a circular logistics strategy, exploring how to minimize environmental impact in the transportation, storage, and distribution of machines and their components.

Process:

- **Phase 1:** The facilitator provides participants with an overview of a traditional supply chain for a machine (from raw material sourcing to final delivery). Participants are asked to identify inefficiencies, such as high energy use during transport or excessive packaging waste.
- **Phase 2:** Teams then work together to redesign the supply chain, focusing on circular strategies such as reducing transportation distances, optimizing load capacity, using reusable packaging, or shifting to electric delivery vehicles.

- **Phase 3:** Teams present their circular supply chain models, explaining how these changes will reduce emissions and waste while enhancing sustainability.

Use and Maintenance: Predictive Maintenance Challenge

This exercise helps participants think about how predictive maintenance can extend a machine's life and reduce resource consumption. Participants are given data from a machine's operation and tasked with developing a maintenance schedule that prevents breakdowns and minimizes downtime.

Process:

- **Phase 1:** The facilitator provides historical data (e.g., operating hours, maintenance records, common failure points) from a real machine. Participants analyze this data to detect patterns and predict when maintenance should be performed to avoid costly failures.
- **Phase 2:** Teams design a maintenance plan that incorporates predictive strategies, such as using IoT sensors to monitor machine health or setting up regular inspections to catch potential issues early.
- **Phase 3:** Teams present their maintenance plans, explaining how predictive techniques can extend the machine's life and reduce the need for premature replacement of parts.

End-of-Life Management: Disassembly and Recycling Game

In this hands-on exercise, participants practice disassembling a mock machine or component to understand the challenges and opportunities for recycling at the end of a product's life.

Process:

- **Phase 1:** The facilitator presents a machine model (e.g., an electronic device or small mechanical system) and explains its key components and materials.
- **Phase 2:** Participants work in teams to disassemble the machine, focusing on how easily the components can be separated for recycling. They identify parts that are difficult to recycle or contain harmful materials and brainstorm ways to redesign these components for better end-of-life management.
- **Phase 3:** Teams present their findings and propose design changes that would make future disassembly and recycling easier.

Refurbishment and Reuse: Remanufacturing Simulation

Participants in this exercise simulate the refurbishment or remanufacturing of a machine component, exploring how products can be restored to like-new condition rather than discarded.

Process:

- **Phase 1:** The facilitator provides participants with worn-out or damaged components (e.g., bearings, gears, or other mechanical parts) and explains the typical remanufacturing process.
- **Phase 2:** Teams work together to assess the condition of the components and determine what steps are needed to refurbish them. They might clean, repair, or replace certain parts and ensure the component meets original specifications.

- **Phase 3:** Teams present their refurbished components, explaining the process they followed and how refurbishment contributes to circularity by extending the product's life.

Waste Management: Circular Waste Audit

In this activity, participants perform a waste audit of a simulated manufacturing process, identifying waste streams and proposing ways to close the loop by reusing or recycling materials.

Process:

- **Phase 1:** The facilitator sets up a mock production process, providing materials such as scraps of paper, plastic, or metal to simulate waste generated during manufacturing.
- **Phase 2:** Teams conduct an audit, sorting the waste into categories (e.g., recyclable, reusable, landfill) and calculating the amount of waste generated.
- **Phase 3:** Teams brainstorm ways to minimize or eliminate waste in the process, such as reusing off-cuts, composting organic waste, or finding alternative uses for byproducts. They present their solutions and discuss how circular strategies can be applied to real-world waste management.

These examples of interactive exercises engage participants in hands-on learning, encouraging them to think creatively and practically about circular solutions within each phase of a machine's life cycle.

Prototyping and Testing

The prototyping and testing phase is a critical component of the design thinking process, where abstract ideas and concepts are transformed into tangible, workable solutions. Prototyping allows teams to create physical or digital models of their ideas, which can then be tested in real-world scenarios. This phase provides essential feedback on functionality, usability, and sustainability, enabling participants to refine and improve their solutions. In the context of circular transformation in the machine industry, prototyping and testing are crucial for ensuring that proposed solutions are not only innovative but also feasible, durable, and aligned with circular economy principles. By iterating through this phase, teams can assess the practicality of their ideas and make necessary adjustments before moving forward with implementation.

How to create and present pilot innovative solutions

After ideation, participants are tasked with translating their ideas into functional prototypes, which serve as preliminary versions of their proposed solutions. These prototypes should clearly demonstrate how the circular innovation will work in practice, considering the machine's life cycle phases and circular principles. Here's how the process unfolds:

Steps for Creating Pilot Solutions:

- **Identify Key Features**: The first step in prototyping is determining which aspects of the solution need to be represented. Participants should prioritize features that address the core problem and highlight the circular innovation. For example, if the solution involves a machine with modular components for easy disassembly, the prototype should demonstrate how these components can be removed and replaced.
- **Choose the Right Type of Prototype**: Depending on the complexity of the idea, the prototype can range from simple sketches and physical models to more detailed 3D renderings or functional digital simulations. For tangible products, low-fidelity prototypes such as cardboard models or mock-ups may suffice. For digital or process innovations, participants might use software tools or flowcharts to illustrate their solutions.

- **Iterate Rapidly**: Prototyping is an iterative process, meaning teams should be prepared to build, test, and refine multiple versions of their solutions. Each iteration offers valuable feedback that brings the solution closer to feasibility.
- **Collaborate and Share**: Collaboration is key during the prototyping phase. Teams should engage with stakeholders—whether company representatives, industry experts, or potential users—to gather input and ensure that the solution aligns with real-world needs.

Presenting Pilot Solutions:

Once the prototype is ready, teams must effectively present their solutions to stakeholders or decision-makers. The presentation should be clear, concise, and focused on the circular benefits of the solution. Teams can use the following structure:

1. **Problem Statement**: Begin by restating the problem or challenge the solution addresses, emphasizing its circular economy context.
2. **Proposed Solution**: Explain the key elements of the solution and how it enhances circularity across the machine's life cycle.
3. **Prototyping Process**: Briefly discuss the journey of creating the prototype, the challenges faced, and how the team iterated to improve the design.
4. **Demonstration**: If possible, provide a live demonstration of the prototype or a video showcasing its functionality.
5. **Expected Impact**: Conclude by outlining the potential environmental, economic, and operational benefits of the solution, and how it can be scaled for real-world application.

This structure ensures that participants effectively communicate the value and practicality of their innovative solutions.

Testing methods for feasibility and sustainability

Testing is a crucial phase where the viability, feasibility, and sustainability of the prototype are evaluated. For circular innovations, it's not just about determining whether the solution works—it's about assessing its long-term environmental impact, resource efficiency, and alignment with circular economy principles. By incorporating both feasibility and sustainability testing into the prototyping process, participants can ensure their solutions are not only functional and innovative but also aligned with the principles of circularity and environmental protection.

Feasibility Testing

Feasibility testing focuses on evaluating whether the proposed solution can be practically implemented, manufactured, and scaled. The following methods are commonly used:

- **Technical Feasibility Testing**: This method assesses whether the proposed solution can be constructed or implemented with existing technology and resources. For example, if a team designs a modular machine for easy disassembly, technical feasibility testing would involve checking whether the components can indeed be separated and reassembled without specialized tools or excessive effort.
    - **Key Questions**: Can the solution be manufactured with current technology? Are there sufficient materials and resources available for production? Will the design work under real-world conditions?

- **Operational Feasibility Testing**: This method examines how well the solution can function within existing operational structures. For example, testing might involve running the machine prototype under real-world operating conditions, checking whether maintenance is easier or if disassembly times are reduced as expected.
  - **Key Questions**: Can the solution be integrated into existing operational processes? Does it align with current business workflows?
- **Economic Feasibility Testing**: This method analyzes the cost-effectiveness of the solution, both in terms of production and long-term operational savings. Participants test whether the circular innovation reduces material and energy costs over the machine's life cycle.
  - **Key Questions**: What are the up-front costs of implementing the solution? Will the solution lead to long-term cost savings? How quickly can the investment be recouped through resource efficiency?

Sustainability Testing

Sustainability testing focuses on the environmental impact of the prototype. This method evaluates whether the solution truly contributes to circularity and minimizes negative ecological effects. The following methods are essential for sustainability testing:

- **Life Cycle Assessment (LCA)**: LCA is a detailed method for assessing the environmental impact of a product or solution across its entire life cycle—from raw material extraction to end-of-life disposal. Teams analyze energy consumption, emissions, material usage, and waste generation at each stage to determine the environmental footprint of their prototype.
  - **Example Application**: If the solution involves using a new recycled material, LCA would calculate how much energy is saved by using that material compared to virgin materials, as well as any reductions in carbon emissions or waste generation.
  - **Key Questions**: How does the solution reduce resource consumption or waste? Does it minimize carbon emissions and energy use? What is its end-of-life impact?
- **Circularity Metrics Testing**: Circularity metrics focus on quantifying how well the solution adheres to circular economy principles. Metrics might include:
  - **Material Recovery Rate**: The percentage of materials that can be recycled or reused at the end of the product's life.
  - **Product Life Extension**: How much longer the product lasts due to repair, refurbishment, or modular design.
  - **Resource Efficiency**: The amount of material or energy saved through the circular solution compared to traditional linear approaches.
  - **Example Application**: If the solution involves a machine with components that can be easily refurbished, participants could calculate how much waste is avoided and how many materials are saved by extending the life of the machine.
- **Stakeholder Sustainability Testing**: This method involves engaging with external stakeholders (such as sustainability experts, industry regulators, or NGOs) to test the solution's alignment with environmental regulations and sustainability standards.

- **Example Application**: Participants present their solution to a sustainability panel for feedback on its real-world environmental and regulatory viability. The panel might raise concerns or suggest improvements to make the solution more sustainable.
- **Key Questions**: Does the solution comply with existing environmental regulations? How does it contribute to company sustainability goals or industry standards?

Assessment and Evaluation

The assessment and evaluation phase is a vital step in the design thinking process, where the ideas and prototypes developed during the workshop are rigorously reviewed to determine their viability, feasibility, and alignment with the intended goals. This phase ensures that the solutions proposed not only address the core problem but also meet the practical, economic, and environmental criteria required for successful implementation. In the context of circular transformation in the machine industry, assessment and evaluation help identify the solutions that best incorporate circular principles, ensuring sustainability and long-term value. The thorough evaluation process allows participants to make informed decisions on which ideas to pursue further, focusing on innovations that have the greatest potential for real-world application and impact.

Criteria for evaluating ideas and pilot solutions

Effective evaluation of ideas and pilot solutions requires well-defined criteria that align with the workshop's objectives and the principles of circular transformation.

1. Circularity and Sustainability

This criterion examines how well the proposed solution adheres to circular economy principles. Solutions should aim to minimize resource consumption, reduce waste, enhance product longevity, and enable material recovery at the end of the product's life cycle. The evaluation should focus on:

- **Material Efficiency**: Does the solution use materials that are renewable, recyclable, or biodegradable?
- **Waste Reduction**: How effectively does the solution reduce or eliminate waste throughout the machine's life cycle?
- **Resource Recovery**: Does the solution enable easy disassembly, repair, or recycling at the end of its life?

2. Feasibility and Technical Viability

Evaluating feasibility ensures that the solution can realistically be implemented within current technological and operational constraints. This criterion assesses whether the necessary infrastructure, materials, and expertise are available to bring the idea to life.

- **Technical Feasibility**: Can the solution be produced using available technology? Does it require specialized tools or new processes?
- **Scalability**: Can the solution be scaled up for wider adoption, or is it limited to small-scale implementation?

3. Economic Viability

Economic evaluation focuses on the solution's cost-effectiveness. Even if a solution is innovative and sustainable, it must also make economic sense for businesses. Key factors include:

- **Cost Efficiency**: What are the estimated production and implementation costs? Will the circular approach reduce long-term costs compared to a linear model?
- **Return on Investment (ROI)**: How quickly will businesses see returns from investing in the solution? Does it offer tangible financial benefits, such as reduced material costs or longer product life?

4. Innovation and Originality

This criterion evaluates the novelty of the idea and how it pushes the boundaries of traditional thinking within the machine industry.

- **Creativity**: How innovative is the solution in addressing circular challenges? Does it offer a unique approach to a well-known problem?
- **Disruptive Potential**: Does the solution have the potential to transform existing business models or industry practices?

5. Alignment with Business Needs

A practical solution must align with the company's operational, strategic, and sustainability goals. This evaluation looks at how well the solution fits into the business context.

- **Compatibility**: Does the solution integrate seamlessly into the company's existing operations?
- **Strategic Alignment**: Does it support the company's broader sustainability or innovation goals?

6. Stakeholder Value

Finally, the solution should create value for all stakeholders involved, including customers, employees, and partners.

- **Customer Benefits**: Does the solution enhance product value, user experience, or service life for customers?
- **Supply Chain Impact**: How will the solution affect suppliers, distributors, and other key partners in the supply chain?

Process for selecting the best ideas for implementation

After evaluating ideas against the defined criteria, the next step is to select the best solutions for further development and implementation. This process involves collaboration, discussion, and prioritization to ensure that the most viable, innovative, and impactful ideas are chosen.

1. Multi-Criteria Decision Analysis (MCDA)

MCDA is a structured approach for decision-making that allows workshop participants to score each idea based on the various evaluation criteria. This method provides a transparent and systematic way to compare different ideas:

- **Assign Weightings**: First, assign weightings to each evaluation criterion based on its importance to the project's overall goals. For example, if circularity is a top priority, it might receive a higher weighting than economic viability.

- **Score Ideas**: Next, participants score each idea on a scale (e.g., 1-10) based on how well it meets each criterion. Scores are multiplied by the respective weightings, and the total score for each idea is calculated.
- **Ranking**: Ideas are then ranked according to their total scores. This method ensures that the best ideas, based on all the criteria, rise to the top.

2. Group Discussions and Consensus

After scoring the ideas, group discussions are essential for building consensus among participants. While scoring provides a quantitative assessment, qualitative insights from stakeholders can add value. Participants should consider factors such as:

- **Long-Term Vision**: Does the solution align with the long-term strategic vision of the companies involved?
- **Potential Risks**: Are there any risks or challenges that might not be captured by the scoring process, such as regulatory barriers or market resistance?

This discussion stage allows participants to share perspectives, challenge assumptions, and collectively decide on which solutions are most promising.

3. Pilot Project Selection

Once a shortlist of ideas has been identified, the final stage is selecting which ideas to turn into pilot projects. This involves:

- **Prototyping Readiness**: Teams should assess how quickly and easily a prototype can be developed for each solution. Ideas that can move to the prototyping phase with minimal delays are often prioritized.
- **Business Case Development**: For each selected idea, a preliminary business case is developed, outlining the costs, benefits, risks, and potential returns. This document will serve as a roadmap for moving the idea from concept to reality.
- **Stakeholder Commitment**: Final selection also depends on stakeholder commitment. Ideas that receive strong support from key decision-makers and align with business objectives are more likely to be chosen for pilot implementation.

SUMMARY OF ALL DEVELOPED INNOVATIVE, CIRCULAR MACHINE LIFE CYLE PHASES

Current Situation of the Circular Economy in the Machine Industry

In the machine industry, the concept of circular economy is gaining traction across Europe, driven by the need for sustainable development and resource efficiency. However, despite its potential, the adoption of circular economy principles in this sector remains uneven.

The machine industry in Europe is currently in a transitional phase. Many companies are exploring innovative solutions to reduce their environmental footprint, but large-scale implementation of circular practices is still limited. Manufacturing processes remain heavily reliant on linear models, which involve extracting raw materials, producing goods, and disposing of waste. This linear approach poses significant environmental challenges, particularly in terms of resource depletion, energy consumption, and waste generation.

The European Union (EU) has taken a proactive role in promoting the circular economy. Initiatives such as the European Green Deal and the Circular Economy Action Plan (CEAP) aim to transform industries by fostering sustainability and resource efficiency. These policies provide a framework for encouraging companies in the machine industry to adopt circular practices, such as remanufacturing components, extending product lifespans, and designing machinery with recyclability in mind.

Several trends are emerging within the European machine industry to align with circular economy principles:

1. **Design for Durability and Recyclability**: Companies are increasingly focusing on designing machines with longer lifespans and ensuring components can be easily recycled or reused.
2. **Digitalization**: The use of digital technologies, such as the Internet of Things (IoT) and predictive maintenance, is enabling manufacturers to monitor machine performance and reduce downtime, thereby extending the lifecycle of products.
3. **Servitization**: Transitioning from selling machines to providing services (e.g., leasing or maintenance contracts) allows companies to maintain control over the product lifecycle and promote reuse and remanufacturing.
4. **Material Innovation**: The development of sustainable materials, such as biodegradable composites or recycled metals, is becoming a priority to reduce dependency on traditional resources.
5. **Collaboration Across Value Chains**: Collaborative efforts among manufacturers, suppliers, and recyclers are fostering closed-loop systems where materials are continuously reused.

The shift toward a circular economy presents several opportunities for the machine industry in Europe:

- **Cost Savings**: By adopting circular practices, companies can reduce production costs and dependence on raw materials.
- **Competitive Advantage**: Businesses that prioritize sustainability can differentiate themselves in the market, appealing to environmentally conscious consumers and investors.
- **Innovation and New Markets**: Circular business models open avenues for innovation, such as the development of modular machines and advanced recycling technologies.
- **Regulatory Compliance**: Aligning with EU directives and policies provides companies with a clear roadmap for sustainable growth and reduces the risk of penalties for non-compliance.

Despite the opportunities, several challenges hinder the widespread adoption of circular economy principles in the machine industry:

- **High Initial Investment**: Transitioning to circular practices often requires significant capital investment in new technologies, infrastructure, and training.
- **Complex Supply Chains**: Ensuring a closed-loop system requires effective collaboration across diverse stakeholders, which can be logistically challenging.
- **Regulatory Barriers**: While EU regulations promote sustainability, differences in national implementation can create inconsistencies and confusion for companies operating across borders.
- **Consumer Awareness**: Limited understanding of circular products and services among consumers can reduce demand and slow adoption rates.

The EU has introduced several policies and directives to support the circular transformation of industries, including the machine industry. Key initiatives include:

1. **European Green Deal**: A comprehensive strategy aiming to make Europe the first climate-neutral continent by 2050. It emphasizes resource efficiency and the adoption of circular economy practices across all industries.
2. **Circular Economy Action Plan (CEAP)**: This plan outlines measures to stimulate sustainable product design, promote circular business models, and encourage the responsible use of resources. It specifically targets resource-intensive sectors such as machinery and equipment.
3. **Eco-design Directive**: This directive establishes requirements for the environmental performance of energy-related products. It encourages manufacturers to consider energy efficiency and recyclability during the design phase.
4. **Waste Framework Directive**: This directive sets the foundation for waste management and recycling practices, emphasizing the need to minimize waste generation and promote resource recovery.
5. **Industrial Emissions Directive (IED)**: Aims to reduce industrial emissions by enforcing stricter pollution control measures, thereby encouraging industries to adopt cleaner production methods.

Summary of the results of implemented design thinking workshops for the machine industry within the Plan-C project

The project partners organized and implemented workshops for representatives of companies from the machine industry following the Guidelines from the first part of this document. The workshops are designed in advance so that the result of them are proposals - pilot solutions for all 8 phases of the machine life cycle. Hereafter, an overview of innovative pilot solutions for each phase of the machine's life cycle will therefore be given.

Design and Development

The design and development phase of a machine's life cycle offers a critical opportunity to integrate sustainability and circularity into its core. By adopting innovative approaches during this stage, workshops have proposed transformative solutions that optimize material usage, extend the machine's lifespan, and minimize environmental impact.

One of the central ideas is optimizing process parameters to align machines with chosen materials and products, resulting in reduced energy and material consumption during manufacturing. This efficiency ensures that fewer resources are expended while achieving the desired output, laying a foundation for sustainable production.

A shift in business models also plays a pivotal role. By focusing on a modular machine design, manufacturers enable easy replacement and upgrading of parts, enhancing the durability and adaptability of machines. Modular designs are further supported by a cloud-based platform, which allows engineers to access a library of standardized components made from recyclable or biodegradable materials. This platform integrates real-time environmental impact assessments, providing insights into carbon footprints and resource usage, and offers recommendations for alternative materials or configurations to reduce ecological impact. Such tools promote collaboration and innovation, ensuring scalability across industries like automotive and heavy machinery.

Technological advancements are another cornerstone of sustainable design. Leveraging software simulators and programming tools, designers can simulate machine operations before production, allowing them to optimize functionality while minimizing errors and resource wastage. Augmented reality (AR) and virtual reality (VR), coupled with artificial intelligence (AI), create virtual environments to test machine performance, enabling designers to identify and address inefficiencies early in the process. These methods not only improve machine performance but also significantly lower development costs and environmental impact.

Recycling and material reuse are emphasized as critical components of circular design. Innovative methods, such as freezing plastics before breaking them down, improve energy efficiency and reduce wear on machinery, thereby extending equipment life and enhancing productivity. Combining these processes with biodegradation introduces a novel approach to recycling, ensuring that materials like plastics are efficiently decomposed with minimal ecological harm.

The focus on modularity extends to automotive components, where the integration of recycled and recyclable plastics simplifies disassembly, repair, and upgrades. By incorporating these principles early in the design process, the solutions address significant environmental challenges and ensure that components can be reused or remanufactured, reducing waste across the machine's lifecycle. Furthermore, portable modules developed for energy-intensive processes, such as chopping and biodegradation, demonstrate the potential to reduce energy consumption by up to 20%, showcasing the scalability of these innovations across diverse applications.

Some workshops highlighted the importance of planning and maintenance strategies, emphasizing the need to determine optimal approaches early in the design phase. Surveys conducted among manufacturers inform these strategies, ensuring that the design aligns with practical needs and long-term sustainability goals.

The developed pilot solutions are in accordance with the following concepts of circularity: Design for Longevity; Eco-design; Standardization of Parts.

Material Sourcing

The material sourcing phase plays a vital role in ensuring the sustainability of a machine's life cycle. By prioritizing the use of recycled and sustainable materials, innovative approaches discussed during the workshops aim to minimize environmental impact, reduce production costs, and enhance resource efficiency.

A significant focus of the proposed solutions is the integration of recycled materials, such as plastics, copper, and iron, into the manufacturing process. These materials are often more affordable than virgin resources and, in some cases, offer comparable or superior mechanical properties, improving the quality and sustainability of the final product. By sourcing recycled inputs, manufacturers can reduce their dependency on raw resources and lower the carbon footprint associated with material extraction and processing. Modular design further complements these efforts, allowing for the reuse of functioning or repaired parts, extending the lifecycle of individual components, and minimizing waste.

The concept of a closed-loop system is central to these solutions, emphasizing the importance of designing products and supply chains that enable materials to be recycled and reused at the end of their lifecycle. For instance, recycled plastics can be transformed into modular automotive components, creating a sustainable cycle that reduces waste and supports a circular economy. This approach not only aligns with environmental goals but also provides businesses with a competitive advantage by lowering production costs and fostering innovative business models.

Technology plays a pivotal role in enhancing the transparency and accountability of material sourcing. The workshops proposed the use of blockchain technology to create a transparent and traceable system for recycled materials. By assigning digital tokens to each batch of material, manufacturers can verify its origin, quality, and environmental certifications. This fosters trust within the supply chain, ensures compliance with industry standards, and incentivizes suppliers to adopt sustainable practices. Integrating blockchain with existing enterprise resource planning (ERP) systems further streamlines material tracking, making it easier to meet regulatory requirements and provide transparent data for audits.

Another technological innovation discussed is the use of augmented reality (AR) to monitor the condition and history of reused machine parts. This ensures that only high-quality components are reintegrated into the production process, maintaining the integrity of the final product. The combination of AR and blockchain could revolutionize material sourcing by ensuring traceability and quality assurance at every step of the supply chain.

A prototype developed during the workshops highlights the industrial application of recycling and reusing plastics, with a focus on optimizing machinery to facilitate these processes. This solution aligns with the broader goals of a circular economy by reducing waste, enhancing equipment efficiency, and supporting low-emission production practices. By decreasing the energy intensity of production, these innovations also contribute to reducing CO_2 emissions per unit of production, advancing long-term environmental goals.

Some results exemplifie how these principles can be implemented in practice. By sourcing recycled materials and producing high-quality regrinds and granulates, the company supports closed-loop cycles that minimize reliance on virgin inputs. Their commitment to maintaining the purity of recycled outputs ensures that these materials can be seamlessly reintegrated into the production process, reinforcing the circular economy model.

The developed pilot solutions are in accordance with the following concepts of circularity: Sustainable Material Sourcing; Use of Recycled Materials; Closed-Loop Material Systems

Manufacturing and Assembly

The manufacturing and assembly phase is crucial for translating sustainable design principles into tangible products. Innovative solutions discussed during the workshops emphasize resource efficiency, waste minimization, and the integration of advanced technologies to create a more circular and sustainable production process.

Central to these solutions is the use of modular designs, which simplify manufacturing by enabling the easy disassembly, remanufacturing, and repair of machine components. This approach not only extends the lifecycle of machines but also allows manufacturers to reuse functioning parts from older machines, reducing the need for virgin materials. By integrating data from previous machines, manufacturers can further optimize workflows, reducing complexity and enhancing precision.

Additive manufacturing, or 3D printing, emerges as a transformative solution in this phase. Regional hubs equipped with advanced 3D printers using bio-based or recycled materials can produce components on demand, minimizing excess inventory and overproduction waste. These hubs not only lower transportation emissions and shorten lead times but also foster innovation through rapid prototyping and customization. However, challenges such as the aesthetic quality of layered surfaces remain a barrier to broader adoption, requiring further development of finishing techniques to meet market expectations.

The workshops also highlighted lean manufacturing as a complementary approach to additive manufacturing. By streamlining processes, eliminating inefficiencies, and maximizing resource utilization, lean manufacturing ensures that production is both cost-effective and environmentally sustainable. Precision machining further enhances this by tailoring components for optimal functionality, conserving resources, and reducing material waste.

Advanced technologies like augmented reality (AR) and virtual reality (VR) are pivotal in optimizing the manufacturing process. These tools allow manufacturers to simulate workflows, visualize complex assembly tasks, and test machine and component performance under various conditions before production begins. This reduces errors, enhances precision, and improves overall efficiency. Sensors and real-time monitoring systems add another layer of innovation, enabling predictive maintenance and reducing downtime by identifying potential issues early.

The recycling of materials also plays a key role in this phase. Solutions include optimizing machines for sorting, cleaning, and processing recycled plastics into usable components. These processes transform waste into new products, such as decorations or functional parts, expanding the applicability of recycled materials. Prototyped products undergo rigorous testing to ensure durability and quality before transitioning to mass production, demonstrating a commitment to both sustainability and performance.

Lastly, the integration of advanced manufacturing techniques ensures the creation of lightweight, durable, and sustainable components. This is particularly evident in the production of automotive parts, where precision and customization are critical. By combining additive and lean manufacturing with modular design principles, manufacturers can produce components that meet high sustainability and quality standards while minimizing environmental impact.

The developed pilot solutions are in accordance with the following concepts of circularity: Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing.

Distribution and Logistics

The distribution and logistics phase is pivotal for ensuring that machines and their components are delivered efficiently while minimizing environmental impacts. Workshop discussions highlighted the importance of integrating sustainable practices and innovative solutions to optimize logistics operations, reduce emissions, and embrace the principles of the circular economy.

A key focus area is the adoption of reusable, sustainable, and efficient packaging systems. Traditional single-use materials such as plastics and cardboard are being replaced by durable, returnable packaging designed for multiple use cycles. Innovations like the Smart Returnable Packaging System incorporate RFID tags for real-time tracking, enabling logistics partners and customers to schedule returns conveniently. This closed-loop system minimizes waste, reduces costs, and fosters greater accountability in the supply chain. Packaging materials, designed from recycled or biodegradable substances, further reduce the environmental footprint while maintaining durability and functionality. By optimizing the size of packaging, transportation efficiency is improved, reducing space and fuel consumption during shipment.

Transportation efficiency is another cornerstone of sustainable logistics. Solutions proposed include the use of low-emission vehicles, route optimization technologies, and consolidated shipments to minimize the carbon footprint of deliveries. Advanced tools such as AR/VR can simulate logistics workflows, identify inefficiencies, and streamline processes, ensuring smoother operations while reducing costs and emissions. Localized production and distribution networks complement these strategies by reducing the need for long-distance transportation. This approach not only cuts emissions but also bolsters local economies by promoting regional infrastructure development.

Support programs for collecting, recycling, and reusing materials were also emphasized. These programs incentivize customers and logistics providers to return used components and packaging, which can then be refurbished, reworked, or recycled. Such systems align with circular economy principles, ensuring that materials are reintegrated into the production cycle rather than discarded. Partner organizations can play a vital role by creating efficient pathways for material redistribution and reuse within regional networks.

The overall impact of these solutions is measured through quantitative evaluations, including carbon footprint calculations and economic analyses of operations. This data-driven approach ensures that proposed solutions deliver tangible environmental and economic benefits while aligning with the company’s sustainability goals.

The developed pilot solutions are in accordance with the following concepts of circularity: Efficient Transportation; Reusable Packaging; Local Production and Distribution.

Use phase and Maintenance

The use phase and maintenance represent a critical juncture in the machine life cycle, where efficiency, reliability, and sustainability must converge to maximize value and minimize environmental impact. The solutions proposed emphasize predictive maintenance, modular design, retrofitting, and innovative ownership models to extend the life of machinery, reduce costs, and enhance operational efficiency.

A cornerstone of modern maintenance strategies is the integration of predictive maintenance systems. Using AI, IoT sensors, and data analytics, these systems monitor machine performance in real-time, identifying potential failures before they occur. By leveraging pattern recognition, swarm intelligence databases, and intuitive dashboards, manufacturers can optimize process parameters and address wear and tear proactively. This reduces downtime, extends machine life, and minimizes maintenance costs. Technologies like AR/VR enhance this capability by providing visual diagnostics and instructions, enabling faster repairs and preventing significant damage. These tools empower service personnel and ensure a more efficient and reliable maintenance process.

Modular design plays a vital role in simplifying maintenance and extending the machine's lifecycle. Machines designed with easily replaceable parts facilitate quick repairs and upgrades, reducing waste and ensuring operational continuity. This modular approach also supports resource efficiency by enabling components to be reused or refurbished, further promoting circularity.

Retrofitting old machinery is another effective strategy to enhance energy efficiency and integrate modern technologies without replacing the entire unit. Upgrades, such as optimizing thermal management systems or replacing obsolete components, improve performance and reduce energy consumption. Advanced monitoring technologies, like thermography and fluid analysis, ensure optimal lubrication and heat management, preventing long-term damage and improving machine longevity.

Innovative ownership models, such as rental or subscription services, shift the focus from ownership to shared usage and maintenance. These models lower upfront costs for customers while incentivizing manufacturers to design durable, energy-efficient machines. IoT-enabled monitoring ensures timely maintenance and extends machine life, while refurbished machines can be reintegrated into the rental cycle, reinforcing the principles of the circular economy.

Additional solutions address specific maintenance needs, such as monitoring oil quality to detect wear or leakage, tracking energy consumption for operational transparency, and optimizing tool lifecycle management. Regional or national registers of machine parks could further enhance resource utilization by better aligning supply and demand for operational machinery.

The developed pilot solutions are in accordance with the following concepts of circularity: Predictive Maintenance; Upgrading and Retrofitting; Shared Ownership Models.

End-of-life Management

End-of-life management is a pivotal phase in the machine life cycle, focusing on minimizing waste, optimizing material recovery, and promoting sustainability. The solutions proposed aim to ensure that machines and their components are efficiently dismantled, recycled, and repurposed at the end of their operational life, thus reducing environmental impact and reinforcing circular economy principles.

One of the most effective strategies for end-of-life management is the design of machines for easy disassembly. Modular designs, where components can be easily separated and reused, play a critical role in this process. By ensuring that materials like metals, plastics, and electronics are easily identifiable and accessible, the recovery process is streamlined. This design approach not only facilitates recycling but also enables the reuse of functional parts in new machines, thereby extending the lifecycle of valuable materials.

The use of technologies like AR/VR can assist in disassembling machines at the end of their life. Virtual guides can help workers navigate the dismantling process efficiently, ensuring that all reusable parts are identified and extracted safely. This is particularly important for ensuring that the valuable materials within the machines are recovered for future use, minimizing the environmental footprint of disposal.

An innovative circular solution is the concept of the "Machine-as-a-Service" model, where machines are leased rather than sold. In this model, manufacturers retain ownership of the machines throughout their lifecycle. Once the lease period ends, the machines are returned, refurbished, and either leased to new customers or disassembled for parts. This incentivizes manufacturers to prioritize durability and ease of disassembly when designing their products. Additionally, the service model lowers the upfront costs for customers while encouraging the reuse and recycling of machine components at the end of the product's life.

Reverse logistics plays a critical role in this phase by enabling the efficient collection, transportation, and processing of used machines. Once machines reach the end of their life, reverse logistics systems ensure that they are returned to manufacturers or specialized recycling facilities for proper disposal, refurbishment, or recycling. This minimizes waste and ensures that valuable materials are recovered and reintegrated into the manufacturing process, further supporting circularity.

Strategic planning and execution of end-of-life activities are essential for ensuring that machines are sustainably managed. This process focuses on reducing waste, maximizing resource efficiency, and ensuring that all parts are either reused or responsibly disposed of. By aligning machine design with end-of-life considerations, manufacturers can create products that contribute to a circular economy by facilitating recycling, reducing environmental impact, and promoting sustainable practices throughout their lifecycle.

The developed pilot solutions are in accordance with the following concepts of circularity: Reverse Logistics; Product-as-a-Service; Recycling and Material Recovery; Design for Disassembly; Reverse Engineering.

Refurbishment and Reuse

The refurbishment and reuse phase of the machine life cycle plays a crucial role in extending the lifespan of machinery, promoting sustainability, and reducing waste. The primary focus of this phase is to restore and reuse functional components from machines that have reached the end of their initial life cycle. By refurbishing these components, manufacturers can create high-quality, cost-effective products while minimizing the demand for new raw materials, contributing to the goals of the circular economy.

One of the core strategies for refurbishment is the establishment of a reverse supply chain for components. This approach emphasizes the collection of used machines and components, followed by a meticulous process of sorting, cleaning, inspecting, and testing these parts to ensure they meet the required quality standards. Once restored, these components are either reintegrated into new machines or sold separately on the secondary market. This system not only facilitates the reuse of materials but also creates economic opportunities by making refurbished parts more accessible to smaller businesses and reducing the need for new production.

Machines are designed with modular components that can be easily disassembled and refurbished. This modularity makes it easier to assess which parts are still functional and which require upgrading. As a result, machines can be restored to nearly-new conditions by replacing only the necessary parts, thereby reducing waste and conserving natural resources. Refurbished machines are then reintroduced into the market, often with a "like-new" label, offering customers the benefit of high-quality, affordable equipment.

The refurbishment and reuse process also contributes to the creation of a secondary market for used machinery, encouraging businesses to adopt more sustainable practices. Incentive programs, such as offering discounts for returning old machines or components, can further promote the adoption of refurbishment and reuse practices. This fosters a circular economy where the value of materials is maximized, and machines and their components remain in use for as long as possible.

Additionally, the extended use of refurbished equipment allows for continued operation within the original installation or in subsequent applications, further aligning with sustainability goals. Even components that are no longer in perfect working condition can be repurposed or given a new life in different applications, ensuring that valuable resources are not wasted.

The developed pilot solutions are in accordance with the following concepts of circularity: Component Reuse; Refurbishment Programs; Marketplaces for Used Machines; Secondary Markets.

Waste Management

The waste management phase of the machine life cycle is vital for ensuring sustainability and minimizing the environmental impact of machine production and disposal. This phase focuses on efficiently handling waste materials by prioritizing recycling, material recovery, and the development of biodegradable components. The key objective is to reduce waste, recover valuable resources, and ensure that the disposal of non-recyclable parts is carried out in an environmentally responsible manner.

One of the central strategies for effective waste management is the targeted recycling of materials throughout the machine's lifecycle. By leveraging data collected during the machine's use, companies can direct non-reusable components to specialized material recovery facilities, where valuable materials such as metals, plastics, and electronics are recovered. This process ensures maximum resource recovery, reducing the need for new raw materials and minimizing waste sent to landfills. In addition, the refurbishment and reuse of functional parts helps extend the life of machines and reduces the overall volume of waste generated.

A key aspect of waste management is the use of advanced sorting, processing, and recycling technologies. Companies can implement systems that repurpose materials into reusable forms, such as regrinds and granulates, which can be used in the production of new products. This not only reduces reliance on landfills but also mitigates the environmental impact of plastic waste. Waste management systems that focus on material purity and efficient recycling play a crucial role in reducing environmental harm and ensuring that materials are repurposed for further use.

Innovative solutions also include the development of bio-material components, such as biodegradable composites made from bio-resins and natural fiber-reinforced polymers. These materials are designed to decompose in industrial composting facilities at the end of their lifecycle, leaving no harmful residues behind. The use of biodegradable components in non-critical machine parts ensures that even when materials can no longer be reused or recycled, they will not contribute to environmental pollution.

The developed pilot solutions are in accordance with the following concepts of circularity: Material Recovery Facilities; Zero Waste to Landfill; Biodegradable or Compostable Components.

Implementation potential and environmental impact of the pilot solutions

The potential for implementing pilot solutions in real business models generally varies from medium to high. The proposed solutions are based on innovation and the maximum fulfillment of the circularity principles, but the possibility of their implementation in practice, through the adoption of circular business models by companies from the machine industry, was also assessed.

The implementation potential is higher in more developed countries and regions, where the benefits of the circular economy have already been recognized and adopted to some extent. Also, in countries and within the companies that follow the leading circular economy regulations, the transformation process is visibly accelerated and innovations and the implementation of circular models are encouraged. However, what is recognized as a challenge for the potential implementation of pilot solutions in practice, in almost all cases, are national regulations that are often not aligned with international ones, a lack of cooperation between different industries that could use waste as a resource, but also insufficiently developed technology and technological processes that would support the scaling of innovative circular solutions. On the other hand, the benefits of considering and accepting circular practices stand out, primarily in the form of large long-term savings, competitive advantages, as well as, of course, the reduction of negative impacts on the environment.

When we talk about the impact on the environment, a preliminary assessment of each developed pilot solution was made in the form of assumptions about its impact.

The proposed circular solutions presented in the workshops emphasize a significant shift toward sustainability and environmental responsibility within the machine industry. These solutions not only offer innovative methods to enhance operational efficiency but also prioritize the reduction of the industry's environmental impact. Key to these strategies is the optimization of resource use, waste minimization, and an overarching commitment to fostering a circular economy that stretches across product lifecycles.

One of the primary contributions of these solutions is their ability to reduce the environmental impact of industrial operations by promoting the efficient use of materials and energy. Predictive maintenance and pattern recognition technologies, for instance, help minimize unplanned downtime, ensuring that machines are utilized more effectively. This, in turn, leads to a more efficient consumption of resources such as raw materials and energy. The ability to refurbish and reuse components significantly extends the lifecycle of machines, further reducing the need for new raw materials and, consequently, lessening the demand for energy-intensive manufacturing processes. The integration of material recovery strategies ensures that end-of-life components are properly recycled, reducing landfill waste and supporting sustainable industry practices.

The adoption of a product-as-a-service model is another key solution that supports circularity and environmental sustainability. By shifting to this model, where machines are leased and maintained by a service provider, the frequency of machine refurbishment and reuse increases. As the responsibility for the machine's condition and performance lies with the service provider, the lifecycle of each unit is lengthened, and materials are saved. Furthermore, the environmental impact of energy consumption is reduced in areas such as cooling systems.

The environmental benefits extend beyond the reuse of components. Circular approaches in machine design, such as modular platforms and additive manufacturing hubs, dramatically reduce raw material waste. These systems are designed to facilitate easier repair, upgrade, and adaptation of existing machines, cutting down on the environmental cost of producing entirely new units. A focus on material traceability via blockchain ensures that the raw materials used in manufacturing come from responsible sources, minimizing the environmental degradation typically associated with material extraction. Similarly, the establishment of reverse supply chains allows for the efficient recovery and repurposing of components, reducing the environmental cost of manufacturing and waste generation.

Circular solutions also make considerable strides in reducing the carbon footprint of production processes. Using recycled materials, especially plastics, in machine components lowers the demand for new, energy-intensive plastic production. Since recycling typically requires less energy than producing virgin plastics, it results in a reduction of greenhouse gas emissions. Additionally, the modularity and reusability of components means that fewer new materials need to be extracted, processed, and transported, further reducing the overall environmental footprint.

Energy savings are also a critical component of the proposed solutions. For instance, the implementation of augmented and virtual reality (AR/VR) simulations reduces the energy consumption associated with designing and manufacturing new machines. Similarly, energy-efficient, renewable-powered machines contribute to lower emissions and reduced energy use.

The environmental impact of these solutions is not only measured in terms of energy savings and reduced material consumption but also in their ability to prevent waste and pollution. The use of recycled materials reduces reliance on raw materials like metals and plastics, which helps protect natural ecosystems and prevents the degradation caused by extraction processes. The shift from traditional manufacturing methods to more sustainable practices, including the use of on-demand manufacturing hubs and smart packaging systems, helps decrease material waste and transportation emissions. In particular, reducing packaging waste through smarter, returnable packaging systems helps minimize the environmental impact of logistics and product distribution.

The proposed solutions also promote a shift in corporate responsibility and social awareness. By adopting circular practices, companies show their commitment to sustainability, which is increasingly important to environmentally conscious consumers. Regulatory frameworks provide additional incentives for companies to adopt circular practices. As businesses invest in these environmentally friendly technologies, they also contribute to raising awareness among their employees and customers about the importance of sustainability, fostering a broader culture of environmental responsibility.

In conclusion, the circular solutions developed through the workshops represent a powerful step toward mitigating the environmental impact of the machine industry. These solutions foster greater resource efficiency, reduce waste, and minimize carbon emissions, all while promoting sustainability across the product lifecycle. By focusing on the principles of circularity, the proposed innovations contribute significantly to a more sustainable and resilient industrial ecosystem. Moreover, by addressing key issues like energy consumption, waste reduction, and material reuse, these solutions have the potential to create long-term environmental benefits, not just for the machine industry but for the planet as a whole.

CONCLUSION

The transition toward a circular economy within the machine industry represents a significant opportunity for companies to not only enhance their sustainability efforts but also drive long-term economic benefits.

The life cycle phases of a machine offer multiple opportunities for circular adaptation, and through the interactive exercises, workshop participants were equipped to explore these possibilities in a hands-on, collaborative environment. The design thinking methodology, with its focus on user-centered innovation and iterative problem-solving, provides the perfect framework for tackling complex sustainability challenges and driving the machine industry toward a circular future.

The workshops guided by design thinking methodology enable representatives from various companies to actively engage with circular principles and apply them to their specific business contexts. By facilitating creativity and encouraging divergent thinking, participants can break free from conventional approaches and develop new, circular-focused ideas. However, the process doesn’t end with ideation; the true impact of this work lies in the prototyping and testing phases, where participants had to opportunity build tangible models of their solutions and evaluate their feasibility and sustainability through testing methods.

Once pilot innovative solutions are developed and selected, the focus shifts to how companies can effectively implement them in their own business activities. The success of this stage depends on several key factors: commitment from leadership, alignment with strategic goals, integration into existing operations, and a clear roadmap for scaling the innovation. For this phase, the conclusions regarding the implementation potential of the developed pilot solutions in real business models will be used, as well as their potential impact, and specific solutions proposals for the efficient circular transformation of the machine industry will be defined.

ANNEX

Report from the design thinking workshop for the machine industry

Partner:	Biz-up and AWS
Participants (name and surname and company name):	7 Companies: HAUSER GmbH WFL Millturn Technologies GmbH & Co. KG Trotec Laser GmbH Furch Consulting X-Net Technologies GmbH Silicon Austria Labs GmbH Linz Center of Mechatronics Gmbh
Date:	04.12.2024
Place:	Linz, AT

Proposed solution(s) identification:

Group 1 – Using the Customers Machine date to improve productivity and minimize machine downtime:

- Recognizing potential downtimes in advance through pattern recognition and report these potential downtimes automatically.
- Using a swarm intelligence database and AI support on the machine to optimize the process parameters.

Group 2 - Cooling system for supermarkets (Hauser GmbH):

The aims of the company are to increase the longevity and efficiency of the cooling system (machine) and to strengthen customer loyalty:

- New business model -> cooling system as a service (after-sales), sharing energy costs with the customer depending on the energy usage
- Supporting technical buyer in meeting the ESG guideline -> providing fact sheets
- Modular and flexible system -> can exchange parts easily
- Offering energy to Increase efficiency by establishing a heat recovery system

Short description of the proposed solution(s) (please upload photos if you have any):

Group 1:

To support the service department in recognizing unplanned machine downtime so that it can identify the work assignment in advance, the group suggested to recognize potential downtimes in advance through pattern recognition and report these potential downtimes automatically.

Alternatively, a swarm intelligence database and AI support on the machine can be utilized to support product planning in recognizing the lack of know-how with regard to process parameters so that production resources can be used with optimum efficiency. The group established that the pattern recognition might be preliminary stage to the swarm intelligence database.

Group 2 - Cooling system for supermarkets (Hauser GmbH):

In order to enhance the longevity and efficiency of the machine one solution is to offer a cooling system as a service. The customer receives after-sales benefits such as maintenance, energy costs support (depending on the usage), support in ESG reporting. Furthermore, in case of sustainability, the company plans to make use of the heat by introducing a heat recovery system. The seller would have the incentive to make the central cooling system as durable as possible, modular, and efficient, since the attributed cost savings would go straight into his own results. The risk of failure in this case stays with the producer.

Solutions in the context of the machine's life cycle phases:

Design & Development	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Group 1: With the optimization of the process parameters, the machine can be designed optimally for the chosen material and product. This leads to less energy and material being used to produce the chosen parts. Group 2 - Cooling system: Since the business-model change, the producer has a huge interest in a new design of the machine. First of all, the machine will be designed in a modular way, so easy replacement of parts is possible. Secondly, the machine is/will be designed in way, so the durability is as high as possible.
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	Group 1: Design for longevity suits the solution best. With the optimal process parameters and specialized maintenance, the life cycle of the machine is extended. Group 2 - Cooling system: The strategies that fit best are longevity and eco-design, since parts of the system can be exchanged easily due to the modular design.
What is the real potential of implementing this solution in real business models?	Group 1: The real potential of this solution is to minimize unplanned machine downtime and to utilize the optimal process parameters. Therefore, the overall productivity and efficiency is increased, with material and energy usage being minimized. Group 2 - Cooling system: There are some legal restrictions, which have to be addressed (some parts are welded together), so the system can be installed in a modular way. However, there are options, and it is quite possible to introduce the innovation (~50%).

Additional comments:	
Material Sourcing	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Group 1: These aspects were not discussed with the group and are not as important to it. However, the solution proposes the use of recycled materials for manufacturing machines, leveraging insights from lifecycle data to identify opportunities for sustainable sourcing. By integrating recycled or sustainable materials, manufacturers can reduce dependency on virgin resources and lower the environmental footprint of production. Group 2 - Cooling system: It was not discussed within the group, but the use of recycled material (copper, iron, etc.) is possible. Other than that, the machine will be designed modular, so the parts which are still functioning can be used as often as possible.
Which circular strategy does the solution best suit? (Use of Recycled Materials; Sustainable Material Sourcing; Closed-Loop Material Systems)	Group 1: The solution best suits Sustainable Material Sourcing and Use of Recycled Materials. These strategies align with the goal of creating machines that are both environmentally friendly and cost-effective through the reuse of high-quality recycled components. Group 2 - Cooling system: The circular strategy Use of recycled materials would fit best to the solution, since it is possible to use recycled material for the different parts of the machine.
What is the real potential of implementing this solution in real business models?	Group 1: The potential is moderate to high, as sourcing recycled materials is increasingly viable due to advancements in material processing technologies and rising industry standards for sustainability. However, implementation requires collaboration with suppliers and ensuring the quality of recycled materials meets production requirements. Companies that adopt this approach can gain a competitive edge by appealing to environmentally conscious customers. Group 2 - Cooling system: The potential of implementing the solution is quite possible (70%).
Additional comments:	
Manufacturing & Assembly	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Group 1: With the data gathered from all previous machines, the manufacturing and assembly process can be simplified and optimized. Group 2 - Cooling system: Due to the modular design parts can be remanufactured and disassembled easily. Manufacturing and assembly will stay the same as it is right now, except that the machine will

	come back after the use by the customer. Therefore, new capacities or capacity reserves are used to remanufacture/repair the old machines.
Which circular strategy does the solution best suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	<u>Group 1:</u> Refurbishment and remanufacturing fit the best. <u>Group 2 - Cooling system:</u> As circular strategy Remanufacturing, Repair and Refurbishment would fit to the solution for the cooling system.
What is the real potential of implementing this solution in real business models?	<u>Group 1:</u> The potential for implementing this solution in real business models is significant. By leveraging data from previous machines, the manufacturing process can be streamlined and optimized, leading to reduced material waste and energy consumption. Predictive insights allow for better planning and the use of remanufactured or refurbished components, further lowering production costs. However, successful implementation will depend on the integration of AI-driven analytics into manufacturing workflows and the willingness of companies to adapt to these advanced processes. <u>Group 2 - Cooling system:</u> It is more challenging, since it requires new capacities and logistics, but this aligns naturally with the business-model transformation (50%).
Additional comments:	
Distribution & Logistics	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	<u>Group 1:</u> These aspects were not discussed with the group, in this solution Logistics and Distribution is not as important. The logistics behind a large data server must be discussed further. <u>Group 2 - Cooling system:</u> The aspects of distribution and logistics were not discussed during the development of the solution. However, new logistical approaches involve the pick-up and delivery of the machine after customer use, while repair and service offerings are already well established within the company. Other than that, nothing was discussed in this regard. But the reuse of packaging would come in handy, since it would save a lot of costs.
Which circular strategy does the solution best suit? (Efficient Transportation; Local Production and Distribution; Reusable Packaging)	<u>Group 1:</u> The solution best suits the strategy of Efficient Transportation, as data-driven insights could optimize the logistics network for recovering and transporting machines or components. Additionally, Reusable Packaging can be integrated for shipping refurbished or replacement parts, reducing material waste and costs.

	<u>Group 2 - Cooling system:</u> The company should consider efficient transportation and reusable packaging for moving their machine to the customer in order to be sustainable.
What is the real potential of implementing this solution in real business models?	<u>Group 1:</u> The potential for implementing efficient transportation and reusable packaging in real business models is significant. Optimized logistics networks can reduce costs associated with transporting machines and parts while minimizing environmental impact. However, the effectiveness will depend on developing partnerships with logistics providers and ensuring customer collaboration for smooth reverse logistics processes. Reusable packaging, if standardized across products, can further lower waste and transportation expenses. <u>Group 2 - Cooling system:</u> The reuse of packaging is relatively easy to implement (80%), the new logistics (pick-up) comes automatically with the new business model (50%).
Additional comments:	
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	<u>Group 1:</u> The solution impacts use phase and maintenance the most as it recognizes potential downtimes in advance through pattern recognition and reports these potential downtimes automatically. Using a swarm intelligence database and AI support on the machine can be used to optimize the process parameters. Propossing the development of an intuitive dashboard for visualizing downtime predictions and process parameter recommendations, ensuring accessibility for service department personnel. <u>Group 2 - Cooling system:</u> Certainly, the focus of the cooling system is on prolonging the product's life cycle. By providing a modular design parts of the machine can be replaced easily, which leads to easier maintenance. Moreover, during the use phase the heat that comes out of the cooling system can be used, which increases resource efficiency.
Which circular strategy does the solution best suit?	<u>Group 1:</u>

(Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Definitely predictive maintenance, upgrading and retrofitting. The machines can be intelligently upgraded and retrofitted. <u>Group 2 - Cooling system:</u> During the use phase there is a black box in the machine, in which data is collected. Thus, it is possible to predict when maintenance is needed. Upgrading and Retrofitting are also part of the business model.
What is the real potential of implementing this solution in real business models?	<u>Group 1:</u> The potential is very large, the biggest problem remains the provision of data by the users. <u>Group 2 - Cooling system:</u> The possibility of implementing the solution is around 50%, as it depends on the new business model.
Additional comments:	
End-of-life Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	<u>Group 1:</u> After an extended life cycle of optimized use, the machines can be refurbished or stripped for parts used in new machines. <u>Group 2 - Cooling system:</u> Usually, the cooling system will be thrown away after its life cycle, which is about 7 to 20 years. With the new flexible and modular system and constant maintenance and monitoring the life cycle can be prolonged.
Which circular strategy does the solution best suit? (Recycling and Material Recovery; Reverse Logistics; Product-as-a-Service	<u>Group 1:</u> Reverse logistics probably fits the best. <u>Group 2 - Cooling system:</u> The strategy Product as a Service fits the best to this solution.
What is the real potential of implementing this solution in real business models?	<u>Group 1:</u> The solution has significant potential to enhance the circularity of business models. By utilizing predictive maintenance data to determine which components can be refurbished, reused, or recycled, businesses can extend machine life cycles and reduce waste. Additionally, the integration of reverse logistics processes to recover end-of-life machines can lower overall production costs and improve sustainability. The adoption of these practices will depend on establishing robust data-sharing agreements with customers and developing streamlined refurbishment workflows. <u>Group 2 - Cooling system:</u>

	Depending on the new business model the real potential of implementing the solution is around 50%.
Additional comments:	
Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	<u>Group 1:</u> After an extended life cycle of optimized use, the machines can be refurbished more easily. The data collected will indicate which parts are more important to change or upgrade and which older parts can stay longer. <u>Group 2 - Cooling system:</u> Refurbishment and Reuse are integral parts of the business model. As long as the machine remains reusable, it will be refurbished, with reusable parts being utilized again. Then the machine will be distributed to a new customer, with as good as new label.
Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	<u>Group 1:</u> Component Reuse and Refurbishment Programs probably fit best. <u>Group 2 - Cooling system:</u> Circular strategies such as Component reuse, Refurbishment and Marketplace for used machines would fit the best, since the company keeps updating, refurbishing and focusing on maintaining the cooling system, which they will also sell to new customers as good as new.
What is the real potential of implementing this solution in real business models?	<u>Group 1:</u> The potential for implementing refurbishment and reuse is substantial, as predictive maintenance and collected machine data enable precise identification of components suitable for refurbishment. This approach reduces material costs, extends machine life cycles, and aligns with circular economy principles. However, successful implementation requires investment in refurbishment facilities, skilled labor, and customer cooperation for returning end-of-life machines. <u>Group 2 - Cooling system:</u> The real potential comes naturally with the new business model (50%).
Additional comments:	
Waste Management	
Briefly describe the innovative circular solution	<u>Group 1:</u> Leveraging data collected during the machine's lifecycle, the solution facilitates targeted recycling and refurbishment

that fits this phase of the machine's life cycle:	efforts. Components identified as non-reusable are directed to material recovery facilities, ensuring maximum resource recovery. This reduces waste and promotes the sustainable repurposing of valuable materials <u>Group 2 - Cooling system:</u> After a machine/part cannot be used again, the material within the part will be recovered through established contractor for material recovery, to gain as much value (economically and ecologically) from it as possible.
Which circular strategy does the solution best suit? (Zero Waste to Landfill; Biodegradable or Compostable Components; Material Recovery Facilities)	<u>Group 1:</u> Material Recovery Facilities best suit this solution, as they allow for the efficient processing and extraction of usable materials from end-of-life components. <u>Group 2 - Cooling system:</u> The strategy of Material recovery facilities would fit the best.
What is the real potential of implementing this solution in real business models?	<u>Group 1:</u> The potential is high, as material recovery can significantly reduce raw material costs and environmental impact. However, successful implementation requires establishing partnerships with specialized recovery facilities and optimizing the logistics for collecting and transporting end-of-life components. Companies adopting this strategy can also enhance their sustainability credentials, appealing to eco-conscious customers and stakeholders. <u>Group 2 - Cooling system:</u> It is already in place, the machines after the end-of-life are used to recover valuable parts.
Additional comments:	

If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:
<u>Group 1:</u> The proposed solutions significantly reduce the environmental impact by optimizing resource usage and minimizing waste. Predictive maintenance and pattern recognition reduce unplanned downtime, leading to better utilization of materials and energy. Additionally, the ability to refurbish and reuse components extends the life cycle of machines, cutting down the need for new raw materials. The integration of material recovery strategies ensures that end-of-life components are recycled effectively, further reducing landfill contributions and promoting sustainable practices within the industry. <u>Group 2 - Cooling system:</u> Environmentally, the world would benefit from the product-as-a-service model, as it promotes the frequent reuse and refurbishment of machines. All the time somebody is

responsible for the machine and its value. Therefore, a lot of material could be saved. Furthermore, at the moment a lot of supermarkets use the cooling system more than they need to. Through thorough observation, a lot of energy could be saved as well.

Report from the design thinking workshop for the machine industry

Partner:	SORINTEX, REPUBLIC OF MOLDOVA
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Date:	29.11.2024
Place:	Chisinau municipality, Republic of Moldova

Proposed solution(s) identification:
The proposed solution revolves around modular automotive parts designed using advanced principles of sustainability and circularity. These components are created from recycled and recyclable plastics, with features enabling easy disassembly and reassembly. This design strategy supports reuse, upgradeability, and remanufacturing at the end of the product lifecycle.
Short description of the proposed solution(s) (please upload photos if you have any):
The proposed solution focuses on the development of modular automotive components designed for circularity, emphasizing durability, reusability, and recyclability. These components are crafted from high-quality recycled plastics, ensuring resource efficiency and reduced environmental impact. The design prioritizes easy disassembly, allowing for efficient repair, upgrades, and eventual recycling. This approach minimizes waste, extends product lifecycle, and integrates seamlessly into a circular economy framework, supporting sustainable innovation in the automotive industry.

Solutions in the context of the machine's life cycle phases:

Design & Development	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The proposed solution is an innovative circular approach focusing on modular automotive components that integrate recycled and recyclable plastics. This solution fits into the design and development phase of the machine's lifecycle by incorporating principles of circular economy into the earliest stages of production, where the most significant environmental and functional impacts can be addressed.

	The components are designed for easy disassembly, enabling efficient repair and upgrades, while also simplifying the recycling process at the product's end of life. This ensures that parts can be reused or remanufactured, promoting material efficiency and reducing waste.
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	The solution aligns best with the following circular strategies: • Design for Longevity: Durable materials and modular designs extend product lifespan. • Design for Disassembly: Facilitates repairs, upgrades, and recycling. • Eco-design: Prioritizes sustainable materials and minimal environmental impact. • Standardization of Parts: Ensures compatibility across multiple product lines, simplifying maintenance and reducing waste.
What is the real potential of implementing this solution in real business models?	The proposed solution has significant potential for integration into real business models. It can: • Reduce production costs through the use of recycled materials. • Appeal to environmentally conscious consumers and meet regulatory demands for sustainability. • Foster partnerships for material recovery and remanufacturing, creating value chains that support circularity. This innovation also positions businesses as leaders in sustainability, offering a competitive edge in markets increasingly prioritizing environmental responsibility.
Additional comments:	For maximum impact, collaboration with stakeholders across the value chain is essential. This includes material suppliers, manufacturers, and recycling facilities to create closed-loop systems that support the solution's implementation and scalability.
Material Sourcing	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The innovative circular solution focuses on sourcing recycled and sustainably produced plastics for manufacturing modular automotive components. This approach ensures the materials are not only environmentally friendly but also support the development of closed-loop systems where products at the end of their lifecycle can be recycled back into the production process. The use of advanced material tracking and certification technologies (e.g., blockchain for material provenance) further enhances traceability and accountability in the supply chain, ensuring compliance with sustainability standards.
Which circular strategy does the solution best suit? (Use of Recycled Materials; Sustainable Material Sourcing; Closed-Loop Material Systems)	The solution aligns with the following circular strategies: • Use of Recycled Materials: Prioritizes plastics sourced from post-consumer and post-industrial waste, reducing reliance on virgin materials. • Sustainable Material Sourcing: Encourages responsible procurement practices, emphasizing low-carbon and ethically sourced inputs.

	• Closed-Loop Material Systems: Establishes systems where materials are continuously cycled back into production, minimizing resource extraction and waste.
What is the real potential of implementing this solution in real business models?	The implementation potential in business models is substantial: • Cost Savings: Utilizing recycled plastics can reduce raw material costs, particularly as regulations and market demand for sustainable materials grow. • Market Differentiation: Appeals to eco-conscious consumers and meets stricter regulatory requirements for sustainable production. • Partnership Opportunities: Collaborations with recycling facilities and material suppliers can strengthen supply chain resilience and lower operational costs. • Innovation Incentives: Access to subsidies and incentives for adopting sustainable practices can offset initial investment costs.
Additional comments:	To maximize impact, companies must invest in partnerships with material recovery facilities and advocate for better recycling infrastructure in their operating regions. Education campaigns for suppliers and customers can further bolster the transition to sustainable material sourcing while ensuring transparency and trust in the process.
Manufacturing & Assembly	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The innovative circular solution for the manufacturing and assembly phase centers around integrating advanced production techniques like additive manufacturing and lean manufacturing to create modular and sustainable automotive components. Additive manufacturing, commonly known as 3D printing, allows for the precise creation of lightweight and durable components using recycled materials. This approach minimizes material waste and energy consumption while enabling the flexibility needed for customization and scalability. Lean manufacturing complements this by optimizing production processes to eliminate waste, reduce inefficiencies, and maximize resource efficiency, ensuring a sustainable and cost-effective approach to manufacturing. Together, these strategies ensure that products are built with a focus on sustainability, quality, and extended lifecycle.
Which circular strategy does the solution best suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	This solution aligns best with circular strategies such as additive manufacturing, lean manufacturing, and remanufacturing. Additive manufacturing supports the localized production of components, reducing logistical complexities and environmental impacts associated with long-distance transportation. Lean manufacturing focuses on resource efficiency and reducing waste, making it a cornerstone of sustainable production. Remanufacturing involves the recovery and reuse of materials and components from end-of-life products, reintroducing them into the production cycle and significantly reducing reliance on virgin raw materials. These strategies ensure that the manufacturing and assembly processes contribute to the broader goals of the circular economy by extending the value of materials and minimizing environmental impact.

What is the real potential of implementing this solution in real business models?	The potential for implementing these solutions in real-world business models is transformative. Businesses adopting these strategies can benefit from reduced production costs through efficient use of materials and energy, aligning economic advantages with environmental sustainability. These solutions cater to the growing demand for environmentally responsible products, giving companies a competitive edge in markets that prioritize green innovation. Furthermore, the adoption of such strategies ensures compliance with stricter environmental regulations and positions businesses as leaders in sustainability. By embracing these practices, companies can create resilient supply chains that adapt to material shortages and fluctuations in resource availability while maintaining a commitment to circular principles.
Additional comments:	Implementing these solutions requires a collaborative approach across the supply chain to ensure the recovery and reintegration of materials. Companies must invest in cutting-edge technologies and training programs to equip employees with the skills necessary to adopt sustainable manufacturing practices. A cultural shift within organizations, prioritizing sustainability at every level, is essential for embedding these practices into core business operations. By fostering innovation and collaboration, businesses can realize the full potential of these circular strategies in the manufacturing and assembly phase.
Distribution & Logistics	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The innovative circular solution for the distribution and logistics phase focuses on optimizing transportation efficiency, embracing local production and distribution networks, and implementing reusable packaging systems. Efficient transportation involves the strategic use of low-emission vehicles, route optimization technologies, and consolidated shipments to minimize the environmental impact of logistics operations. Local production and distribution reduce the need for long-distance shipping, significantly lowering carbon emissions while promoting the economic growth of local communities. Reusable packaging systems replace single-use materials, ensuring a sustainable and cost-effective approach to protecting goods during transport. Together, these measures streamline distribution while aligning with the principles of the circular economy.
Which circular strategy does the solution best suit? (Efficient Transportation; Local Production and Distribution; Reusable Packaging)	This solution aligns most closely with circular strategies such as efficient transportation, local production and distribution, and reusable packaging. Efficient transportation reduces energy consumption and emissions during the delivery of products, supporting environmental objectives. Local production and distribution ensure that products are manufactured and delivered closer to their final destinations, reducing logistical complexities and environmental footprints. Reusable packaging eliminates the waste associated with traditional disposable materials, promoting a circular flow of resources through repeated use and eventual recycling.
What is the real potential of implementing this	The potential for implementing this solution in real-world business models is substantial. By optimizing transportation and embracing local distribution, companies can significantly

solution in real business models?	reduce costs associated with fuel, storage, and handling. Reusable packaging systems lead to long-term savings by minimizing the need for constant procurement of new materials. These strategies also enhance brand reputation by demonstrating a commitment to sustainability, attracting environmentally conscious consumers. Furthermore, businesses adopting such circular strategies can align themselves with increasingly stringent environmental regulations and market trends favoring green logistics practices.
Additional comments:	Achieving the full potential of this solution requires an integrated approach involving collaboration across the supply chain. Companies must invest in infrastructure for local production, adopt digital tools for route optimization, and establish partnerships for managing reusable packaging systems. Education and awareness among employees and stakeholders are also critical to fostering a culture of sustainability within logistics operations. By prioritizing these initiatives, businesses can create a resilient and sustainable logistics network that drives value for both the environment and the bottom line.
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The innovative circular solution for the use phase and maintenance focuses on predictive maintenance, shared ownership models, and upgrading and retrofitting strategies to maximize the longevity and efficiency of the machine. Predictive maintenance uses data analytics and IoT (Internet of Things) sensors to monitor the condition of the machine in real time, anticipating potential failures before they occur. This proactive approach helps reduce downtime, lowers maintenance costs, and extends the machine's operational life. Shared ownership models allow multiple users or companies to share the use of machinery, maximizing its utilization and ensuring that the asset is used efficiently. Upgrading and retrofitting involve enhancing or replacing specific parts of the machine to improve performance, reduce energy consumption, or integrate new technologies without needing to replace the entire unit.
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	This solution best suits circular strategies such as predictive maintenance, shared ownership models, and upgrading and retrofitting. Predictive maintenance enables machines to operate at their full potential while preventing unnecessary repairs or replacements, reducing waste and resource consumption. Shared ownership models increase asset efficiency, leading to more sustainable use across multiple users or businesses. Upgrading and retrofitting allow machines to evolve over time, maintaining their value and adapting to new needs without contributing to excessive waste.
What is the real potential of implementing this solution in real business models?	The potential for implementing this solution in real business models is significant. Predictive maintenance can lead to substantial cost savings by minimizing unplanned downtime and reducing maintenance expenses. Shared ownership models can help businesses make the most out of high-cost machinery, allowing them to offer products and services at more affordable rates, thus broadening market access.

	Upgrading and retrofitting extend the machine's useful life, reducing the need for costly replacements and the environmental impact associated with manufacturing new machines. Additionally, these strategies contribute to a more circular economy by ensuring that resources are used more efficiently throughout the lifecycle of the machine.
Additional comments:	For this solution to be fully implemented, companies must invest in the necessary technologies, such as IoT sensors, data analytics platforms, and retrofitting infrastructure. Collaboration with other businesses for shared ownership and maintenance models will be crucial to ensure wide adoption. Moreover, training employees and users to maintain and upgrade machines effectively is important to realize the benefits of these strategies. With the right investments and partnerships, this approach can drive sustainability, reduce costs, and create long-term value for businesses and the environment.
End-of-life Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The innovative circular solution for end-of-life management involves implementing systems focused on **recycling and material recovery**, **reverse logistics**, and **product-as-a-service** models. In this phase of the machine's life cycle, the primary goal is to ensure that all components are efficiently recovered, reused, and recycled to minimize waste and environmental impact. The machine is designed with modularity in mind, enabling easy disassembly into recyclable parts, such as metals, plastics, and electronics. This approach aligns with the strategy of **material recovery**, where valuable materials can be extracted and reintegrated into the production process. **Reverse logistics** plays a critical role in the solution by enabling the collection, transportation, and handling of used machines. The process ensures that once the machine reaches the end of its life, it can be returned to the manufacturer or designated recycling facilities for proper disposal or refurbishment. This reduces waste and ensures that components are processed in an environmentally friendly way. Additionally, the **product-as-a-service** model ensures that the product is leased or rented instead of owned, which encourages return and recycling at the end of its use, rather than contributing to landfill waste.
Which circular strategy does the solution best suit? (Recycling and Material Recovery; Reverse Logistics; Product-as-a-Service	This solution best suits the circular strategies of **recycling and material recovery**, **reverse logistics**, and **product-as-a-service**. Recycling and material recovery are essential for reintroducing valuable resources back into the supply chain, thus reducing dependency on raw materials. Reverse logistics optimizes the movement of used products, facilitating a seamless process for collecting end-of-life machines and ensuring they are appropriately managed. The product-as-a-service model enables businesses to retain ownership of products, incentivizing the development of durable, repairable, and recyclable machinery that can be reused or remanufactured after the lease period.
What is the real potential of implementing this	The potential for implementing this solution in real business models is significant. Recycling and material recovery allow companies to reduce raw material costs by reusing valuable materials extracted from old machines. Reverse logistics

solution in real business models?	creates a cost-effective and environmentally responsible method of product collection and processing. Furthermore, the product-as-a-service model provides an opportunity for businesses to generate consistent revenue through long-term leasing or subscription models, while also reducing their environmental footprint by ensuring that products are returned for recycling at the end of their lifecycle.
Additional comments:	In real business models, implementing this solution can help companies reduce production costs, enhance brand reputation through sustainable practices, and meet regulatory requirements for waste management and environmental responsibility. However, for successful implementation, businesses must develop robust logistics systems for the return and processing of end-of-life products, establish clear agreements with customers for product leasing, and partner with recycling or remanufacturing facilities. This solution promotes sustainability, reduces environmental impact, and supports the transition to a circular economy.
Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The innovative circular solution for the refurbishment and reuse phase focuses on extending the lifespan of machines by enabling the reuse of components and refurbishing them to meet performance standards. This solution involves systematic processes for inspecting, repairing, and restoring used machines and their parts to a state that allows them to be resold or reused. By designing machines with modular components that can be easily disassembled and refurbished, the solution reduces waste and decreases the need for new raw materials. The refurbishment process ensures that parts such as engines, electrical components, and structural elements are restored, enhancing their value for the secondary market.
Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	The solution best aligns with the circular strategies of **component reuse**, **refurbishment programs**, and **marketplaces for used machines**. **Component reuse** ensures that high-quality, functioning parts are extracted from old machines and integrated back into the manufacturing process or sold for continued use, minimizing the need for new materials. **Refurbishment programs** play a critical role by allowing machines or components to be overhauled and made suitable for further use, rather than being discarded. These programs can be integrated into the manufacturer's service offerings or provided through third-party businesses that specialize in remanufacturing. Lastly, **marketplaces for used machines** provide a platform where businesses can buy and sell refurbished equipment, creating a circular economy ecosystem that supports the longevity of products.
What is the real potential of implementing this solution in real business models?	The real potential of implementing this solution in business models is substantial. Companies can save on raw material and production costs by reusing components, which directly reduces manufacturing expenses. Refurbishment programs offer businesses the opportunity to create new revenue streams by reselling or leasing refurbished machines or parts. The establishment of marketplaces for used machines further supports this by providing a marketplace where machines can

	be sold, exchanged, or leased, ensuring that they are reused instead of being disposed of.
Additional comments:	The key to successful implementation lies in establishing effective logistics for collecting and refurbishing used components, as well as ensuring that the quality and performance of refurbished products meet market standards. This requires investment in skilled labor, equipment for refurbishing, and partnerships with resellers or marketplaces for used machines.
Waste Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The innovative circular solution for the waste management phase focuses on minimizing waste generation and ensuring that materials are either recycled, reused, or safely disposed of, rather than ending up in landfills. This solution involves the development of processes and systems for sorting, processing, and recovering valuable materials from machines at the end of their life cycle. Key strategies for achieving this goal include the use of **material recovery facilities** that can efficiently extract metals, plastics, and other recyclable materials for reuse in new products. Additionally, the design of machines with **biodegradable or compostable components** is an essential part of the solution, ensuring that non-recyclable parts break down naturally without causing environmental harm.
Which circular strategy does the solution best suit? (Zero Waste to Landfill; Biodegradable or Compostable Components; Material Recovery Facilities)	This solution fits well with the circular strategies of **zero waste to landfill**, **biodegradable or compostable components**, and **material recovery facilities**. The **zero waste to landfill** strategy is based on the principle of diverting all waste from landfills by finding alternative uses for it, such as recycling, repurposing, or composting. By incorporating **biodegradable or compostable components**, the solution ensures that products decompose in an environmentally friendly manner, minimizing long-term waste accumulation. Furthermore, **material recovery facilities** play a critical role in efficiently extracting valuable materials from waste streams, reducing the need for virgin materials and promoting resource circularity.
What is the real potential of implementing this solution in real business models?	The real potential of implementing this solution in business models is significant. Businesses can reduce waste disposal costs, meet regulatory standards for waste management, and strengthen their sustainability credentials by minimizing landfill contributions. For industries such as manufacturing, automotive, and electronics, integrating waste management practices into their business models not only aligns with global trends toward more sustainable operations but also opens opportunities for cost-saving through the recovery of valuable materials like metals, plastics, and rare earth elements.
Additional comments:	Businesses can benefit from innovations in recycling technology, which can enhance the efficiency and effectiveness of waste management operations. By partnering with waste management service providers and investing in modern recycling and recovery technologies, companies can optimize their waste streams, ensuring that as much material as possible is repurposed for new products.

If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:
The potential environmental impacts of the developed innovative circular solutions are generally positive, particularly in terms of resource conservation, waste reduction, and minimizing pollution. By focusing on sustainability and circularity, these solutions significantly contribute to reducing the environmental footprint of various industries. • Reduced Raw Material Extraction; • Lower Carbon Footprint; • Waste Reduction; • Enhanced Energy Efficiency; • Resource Recovery and Circular Supply Chains; The proposed circular solutions have the potential to generate considerable environmental benefits, particularly through reducing resource depletion, waste generation, carbon emissions, and pollution. These solutions promote sustainability by fostering the efficient use of materials, energy, and resources throughout a product’s lifecycle.

Report from the design thinking workshop for the machine industry

Partner:	Foundation for Innovation, Technology and Transfer of Knowledge
Participants (name and surname and company name):	Almir Mešić – Kantonalna privredna komora Tuzlanskog kantona (Cantonal chamber of commerce Tuzla Canton) Mirza Šehović – Centar za razvoj i podršku (CRP) (Center for development and support)
Date:	18.12.2024
Place:	Tuzla, Federation of Bosnia and Herzegovina

Proposed solution(s) identification:
AR/VR (Augmented/Virtual Reality) technology for preventive diagnostics of machines
Short description of the proposed solution(s) (please upload photos if you have any):
Our solution improves machine maintenance and prolongs lifecycle of the machine by using AR/VR technologies for preventive diagnosis. This method encourages machine component repair, reuse, and recycling by spotting possible problems early and allowing for targeted interventions. In line with the circular economy's principles, it prevents waste, prolongs machine lifespans, and decreases downtime to improve sustainability and the use of resources.

Solutions in the context of the machine's life cycle phases:

Design & Development

Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	- Using programming software tools and software simulators to program machines and simulate their operation during the design phase - Applying AR/VR and optionally AI to create virtual environments for testing machine performance
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	Design for Longevity
What is the real potential of implementing this solution in real business models?	- Reduces prototyping costs and design iteration time - Predicts and resolves potential issues in a controlled virtual environment - Ensures designs made for circularity - Innovative and sustainable design practices
Additional comments:	
Material Sourcing	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Regarding this, we have discussed reusing used functional or repaired machine parts for new machine production to reduce costs and maximize resource efficiency, and also prioritizing materials that are sustainable and environmentally friendly, so they can be reused or recycled at the end of the machine's lifecycle. AR could potentially be used to track the history and condition of reused machine parts, ensuring that they meet the necessary quality standards.
Which circular strategy does the solution best suit? (Use of Recycled Materials; Sustainable Material Sourcing; Closed-Loop Material Systems)	- Use of Recycled Materials, - Sustainable Material Sourcing, - Closed-Loop Material Systems
What is the real potential of implementing this solution in real business models?	Helps identify which reused or recycled materials can be most effectively integrated and reduces material costs.
Additional comments:	
Manufacturing & Assembly	
Briefly describe the innovative circular	AR and VR technologies can be applied in this phase to optimize various processes:

solution that fits this phase of the machine's life cycle:	- Simulate the entire work process of the machine, allowing manufacturers to visualize and plan workflows before production begins - Reduce mistakes and improve precision, especially for complex or intricate tasks - Simulate how machines and components will perform under specific conditions, helping to identify potential issues before they occur in the real world
Which circular strategy does the solution best suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	- Lean Manufacturing
What is the real potential of implementing this solution in real business models?	Through simulation manufacturers can visualize and plan workflows before production starts, which leads to better-prepared and more efficient operations. AR and VR also help reduce mistakes and improve precision, particularly for complex tasks. Additionally, by simulating machine performance under various conditions, potential issues can be identified and addressed before they occur in real-world production. This way we avoid costly delays and rework. Results in real life can be increased efficiency, reduced costs, and higher-quality products, all of which contribute to a more sustainable and competitive manufacturing process.
Additional comments:	
Distribution & Logistics	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	This aspect was not specifically discussed during the workshop, but potential solutions could include using AR/VR to simulate logistics processes, optimize delivery routes, and enhance supply chain visibility to reduce costs and emissions, and using reusable or sustainable packaging to minimize waste.
Which circular strategy does the solution best suit? (Efficient Transportation; Local Production and Distribution; Reusable Packaging)	- Efficient Transportation - Reusable Packaging
What is the real potential of implementing this solution in real business models?	Implementing these solutions in real business models could lead to faster deliveries and a more sustainable supply chain overall. Sustainable packaging option could result in minimizing waste. This solution also aligns with environmental regulations, and would improve brand reputation for eco-friendly practices.
Additional comments:	

Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	By using AR/VR we can detect potential failures in advance and diagnose machine malfunctions, allowing us to prevent breakdowns and make repairs more efficiently. Workers can receive visual instructions and insights into the machine's operation, helping to identify problems before they cause significant damage. This contributes to extending the machine's and its components' lifecycle, reducing the need for frequent replacements and minimizing waste.
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	- Predictive Maintenance
What is the real potential of implementing this solution in real business models?	Companies can reduce downtime and avoid expensive machine breakdowns. Detecting problems early helps prevent major repairs and machines last longer. By making machines last longer and reducing waste, the company can lower its environmental impact and use fewer materials and resources.
Additional comments:	
End-of-life Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	When the life cycle of machine reaches its end, used machines or components are returned to the company for proper disposal, recycling, or reuse. The focus will be on dismantling machines carefully to recover materials like metals, plastics, and electronics for recycling. Functional parts of the machines will be reused in the production of new machines (as mentioned in the material sourcing phase). AR/VR technology will provide virtual guides to assist workers in disassembling the machines efficiently and safely, ensuring that reusable parts and recyclable materials are properly identified and separated.
Which circular strategy does the solution best suit? (Recycling and Material Recovery; Reverse Logistics; Product-as-a-Service	- Recycling and Material Recovery - Reverse Logistics - Design for Disassembly
What is the real potential of implementing this solution in real business models?	Companies can reduce the cost of sourcing raw materials through dismantling machines for material recovery and reusing functional parts. The recovery of metals, plastics, and electronics for recycling also lowers material procurement costs. Reusing used components and parts for new machine production reduces manufacturing expenses and lowers the need for new parts. The use of AR/VR helps ensure that workers follow the correct procedures in the disassembly process.

Additional comments:	
Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Here we are focusing on repairing and reusing parts of machines that are still functional. The goal is to extend the life of the machine by refurbishing its components instead of producing new ones. Functional parts recovered from machines at the end of their life cycle are used to create new machines.
Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	- Component Reuse - Refurbishment Programs
What is the real potential of implementing this solution in real business models?	- Companies can save money by recycling and repairing parts rather than manufacturing new parts or machinery. - Reusing and refurbishing gives oppportunity to businesses to make better use of their existing machines and components, lowering the need for new items and decreasing waste. This also lowers the requirement for raw materials and energy, therefore decreasing the company's environmental footprint. It also reduces waste by prolonging the life cycle of machine parts and keeping them out of landfills. - Companies might generate new money by selling refurbished machinery or components.
Additional comments:	
Waste Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	As mentioned in previous phases, companies will focus on management of machine waste by recovering valuable materials such as metals, plastics, and electronics for recycling or reuse. Functional machine parts are refurbished and reused in production of new machines.
Which circular strategy does the solution best suit? (Zero Waste to Landfill; Biodegradable or Compostable Components; Material Recovery Facilities)	- Material Recovery Facilities - Zero Waste to Landfill
What is the real potential of implementing this solution in real business models?	This solution increases the life cycle of machine components, postponing the need for new materials, and reduces the environmental impact by redirecting trash away from landfills. Recovered materials and repaired parts can be reused in

	production, reducing the need for virgin resources and contributing to a more sustainable supply chain.
Additional comments:	AR/VR technology can help during this phase by providing workers with virtual disassembly guides that enable them to identify and recover components easily and precisely.

If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:
Less need for new materials - By reusing and recycling machine parts, we use fewer natural resources like metals and plastics. Less waste on landfills – Solutions proposed ensure machine waste is recycled or reused, keeping it out of landfills and reducing pollution. Lower pollution - Processes like refurbishment and recycling use less energy than making new parts, which means fewer harmful gases are released into the air. Longer-lasting machines - Fixing and reusing machine parts makes machines last longer, which reduces waste and the need for new materials. Better use of resources - Using sustainable materials and recycling ensures we use what we have more efficiently, resulting in reducing the negative effect on the environment. Energy savings – AR/VR simulations reduce the energy needed to design and make new machines.

Report from the design thinking workshop for the machine industry

Partner:	9 - ICMF
Participants (name and surname and company name):	ICMF Dr. Olga Gavrić (trainer) Veselinka Perović - KREMAKO Obrad Drakulović – E&T HealthY Bee Mira Mladenović – Feromont Inženjering doo Petar Omrčen – Perun Lab Miloš Pavlović – Optimus Nikola Topo – PLANS DOO NOVI SAD Dimitrije Miljković – NIS Gaspromneft Boban Petrović – Bulevar kompany Vinko Turudija – Hydrocor doo
Date:	30.10.2024.
Place:	Online (Zoom)

Proposed solution(s) identification:
Modular Machine Design Platform Blockchain for Transparent Material Traceability On-Demand Additive Manufacturing Hubs Smart Returnable Packaging System Machine Rental & Maintenance Subscription Service Circular Machine-as-a-Service Platform Reverse Supply Chain for Components Bio-Material Component Development Initiative
Short description of the proposed solution(s) (please upload photos if you have any):
The workshop participants focused on trends and potentials in the field of circular economy, primarily in Europe, and thus came up with 8 proposed pilot solutions. Pilot solutions are based on innovativeness but also the possibility of implementation, both in European countries and in the Republic of Serbia, where these concepts are still not sufficiently recognized. All 8 proposed solutions have real implementation potential in real businesses in the machine industry, and it is recognized that they can bring numerous benefits and long-term business growth.

Solutions in the context of the machine's life cycle phases:

Design & Development	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**Modular Machine Design Platform** This solution involves creating a cloud-based design platform that enables engineers to design machines using a library of standardized, modular components. Each component is designed for ease of disassembly and is made from materials that are either recyclable or biodegradable. The platform integrates real-time environmental impact assessments, allowing designers to instantly view the carbon footprint, water usage, and other ecological metrics of their designs. Advanced

	algorithms would recommend alternative materials or configurations to reduce environmental impacts further. By promoting modularity, the platform ensures that machines can be easily repaired, upgraded, or disassembled at the end of their life. This not only extends the machine's lifespan but also reduces waste and facilitates component reuse. The solution could also include a community feature where designers share best practices and collaborate on sustainable innovations. The platform’s scalability makes it suitable for various industries, from automotive to heavy machinery. Implementation would involve partnerships with software developers, material scientists, and industry stakeholders.
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	Eco-design
What is the real potential of implementing this solution in real business models?	High, since it can be integrated with existing CAD systems and facilitate compliance with EU eco-design directives.
Additional comments:	
Material Sourcing	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**Blockchain for Transparent Material Traceability** This pilot solution uses blockchain technology to create a transparent and traceable system for sourcing recycled materials. Manufacturers can use the blockchain network to verify the origin, quality, and environmental certifications of recycled inputs. Each batch of material is assigned a digital token containing information about its source, recycling process, and environmental impact. This fosters supplier accountability and assures manufacturers that the materials meet industry standards. The system also rewards suppliers who consistently provide high-quality recycled materials, encouraging more companies to adopt sustainable practices. By integrating with existing enterprise resource planning (ERP) systems, manufacturers can seamlessly track the materials through their supply chains. Blockchain also makes compliance reporting easier, providing transparent data for audits and regulatory bodies. Scaling this solution requires collaboration with blockchain developers and partnerships with recycling facilities.
Which circular strategy does the solution best suit? (Use of Recycled	Use of Recycled Materials

Materials; Sustainable Material Sourcing; Closed-Loop Material Systems)	
What is the real potential of implementing this solution in real business models?	High, as companies increasingly seek supply chain transparency and certification for green materials.
Additional comments:	
Manufacturing & Assembly	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**On-Demand Additive Manufacturing Hubs** This concept involves setting up regional hubs equipped with advanced 3D printers that use bio-based or recycled materials to produce machine components. The hubs operate on an on-demand basis, minimizing excess inventory and the waste associated with overproduction. Localized production reduces transportation emissions and shortens lead times, improving supply chain efficiency. The 3D printers would use innovative filaments made from bio-resins or recycled plastics, further reducing the environmental impact. These hubs can cater to multiple industries, creating a shared manufacturing ecosystem that lowers costs and resource usage. They also allow for rapid prototyping and customizations, supporting innovation. The solution requires collaboration between manufacturers, material suppliers, and local governments.
Which circular strategy does the solution best suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	Additive Manufacturing - 3D Printing
What is the real potential of implementing this solution in real business models?	Moderate, as it requires industry collaboration and development of robust bio-based filaments.
Additional comments:	
Distribution & Logistics	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**Smart Returnable Packaging System** This solution introduces durable, reusable packaging designed for machine components and equipped with RFID tags for tracking. These packages can be folded or collapsed to save space during return logistics. An accompanying mobile app

	allows customers and logistics partners to schedule packaging returns, earning credits or discounts as incentives. This creates a closed-loop system where packaging materials are continuously reused, reducing dependency on single-use plastics or cardboard. The RFID technology ensures real-time tracking of packaging, preventing losses and optimizing supply chain efficiency. Over time, the data collected can be used to improve logistics routes and packaging designs. The packaging itself would be made from recycled or sustainable materials to further reduce its environmental footprint.
Which circular strategy does the solution best suit? (Efficient Transportation; Local Production and Distribution; Reusable Packaging)	Reusable Packaging
What is the real potential of implementing this solution in real business models?	High, given increasing interest in reducing single-use plastics in packaging.
Additional comments:	
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**Machine Rental & Maintenance Subscription Service** This solution shifts from traditional ownership to a subscription-based model, where customers rent machines and receive regular maintenance services as part of the package. IoT sensors installed in the machines monitor their performance, enabling predictive maintenance to prevent breakdowns and extend machine life. Customers benefit from lower upfront costs, while manufacturers gain a steady revenue stream and deeper customer relationships. The subscription model incentivizes manufacturers to design durable, energy-efficient machines that require less maintenance. At the end of the rental period, machines can be refurbished and reintroduced into the rental cycle, further promoting circularity. Partnerships with IoT developers and service providers would be key to implementing this solution effectively.
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Shared Ownership Models
What is the real potential of	High in industries where capital expenses for machines are a significant barrier.

implementing this solution in real business models?	
Additional comments:	
End-of-life Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**Circular Machine-as-a-Service Platform** Under this model, manufacturers retain ownership of the machines they produce, leasing them to customers instead of selling them outright. At the end of the lease period, machines are returned, refurbished, and leased to new customers or disassembled for parts. This approach motivates manufacturers to prioritize durability and ease of disassembly in their designs. Customers benefit from lower upfront costs and access to the latest technology without the burden of ownership. The platform would include an app where customers can manage their leases, request maintenance, and schedule machine returns. Manufacturers can analyze usage data to improve product designs and service offerings.
Which circular strategy does the solution best suit? (Recycling and Material Recovery; Reverse Logistics; Product-as-a-Service)	Product-as-a-Service
What is the real potential of implementing this solution in real business models?	High, aligning with trends in product-service systems and customer preferences for usage over ownership.
Additional comments:	
Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**Reverse Supply Chain for Components** This solution establishes a strong reverse logistics system to collect used machines, sort reusable components, and refurbish them to meet original specifications. Dedicated facilities would inspect, clean, and test components, ensuring they meet quality standards before being reintegrated into new machines or sold separately. This creates a secondary market for high-quality refurbished parts, making sustainable practices more accessible to smaller businesses. Customers would receive discounts for returning old machines or components, incentivizing participation. The system requires partnerships with logistics providers and investments in refurbishment technology.
Which circular strategy does the solution best	Component Reuse

suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	
What is the real potential of implementing this solution in real business models?	High, particularly in the EU, where directives encourage component reuse.
Additional comments:	
Waste Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**Bio-Material Component Development Initiative** This pilot focuses on developing machine components from biodegradable composites such as bio-resins and natural fiber-reinforced polymers. These components are designed to decompose in industrial composting facilities at the end of their lifecycle, leaving no harmful residues. The initiative includes partnerships with material scientists and composting facilities to ensure feasibility and scalability. Manufacturers can pilot these components in non-critical machine parts, gradually expanding their use as materials prove their durability and performance.
Which circular strategy does the solution best suit? (Zero Waste to Landfill; Biodegradable or Compostable Components; Material Recovery Facilities)	Biodegradable or Compostable Components
What is the real potential of implementing this solution in real business models?	Moderate, as it depends on advances in bio-material technology and industrial composting infrastructure.
Additional comments:	

If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:
The potential environmental impact of each pilot solution concept is identified as follows: Modular Machine Design Platform - Significant reduction in raw material waste, extended product lifespans, and lower environmental impact from manufacturing and disposal processes

Blockchain for Transparent Material Traceability - Reduced reliance on traditional materials, lower extraction-related environmental degradation, and minimized embodied carbon

On-Demand Additive Manufacturing Hubs - Drastic reduction in material waste, lower emissions from transportation, and reduced energy consumption compared to traditional manufacturing

Smart Returnable Packaging System - Decreased packaging waste and pollution, and reduced demand for traditional packaging materials

Machine Rental & Maintenance Subscription Service - Optimized machine usage, extended lifespan of machines, and lower production of new units due to shared usage

Circular Machine-as-a-Service Platform - Reduced waste generation and raw material extraction due to maximized reuse of components

Reverse Supply Chain for Components - Reduction in manufacturing emissions, raw material consumption, and waste from discarded components

Bio-Material Component Development Initiative - Substantial reduction in landfill waste and mitigation of microplastic pollution

Report from the design thinking workshop for the machine industry

Partner:	PP7 /TUKE
Participants (name and surname and company name):	PP7+APP+experts, as follows: TUKE-PP7 Faculty of Manufacturing Technologies TUKE Slovak Chamber of Commerce and Industry, Trenčín- APP Experts: Caspro, s.r.o. Wittmann, s.r.o. RMS-PT, s.r.o. Uniplast, s.r.o. Expedia, s.r.o. LPH, a.s. Rzeszow University of Technology, Poland
Date:	27.09.2024
Place:	SOPK, Vajanského 10, Prešov, Slovak Republic

Proposed solution(s) identification:
A collaborative creative design thinking workshop was organised to transform the machine industry towards circularity.
Short description of the proposed solution(s) (please upload photos if you have any):
The design thinking workshop is focused on finding innovative solutions in the engineering industry and is designed with circularity in mind.


The target group is technologists, experts in the plastics industry, key users and intermediaries, individuals, universities and regional innovation policy associations.

Solutions in the context of the machine's life cycle phases:

Design & Development	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	From the point of view of the proposed solution, we can contribute to increasing the ability to reuse and upgrade in several ways, mainly by creating products with modular components. This allows easy replacement or updating of individual parts, extending the life of the product. By recycling and reusing materials in the machine industry, we reduce waste and increase its ecological sustainability.
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	During the workshop, we focused on Eco-design and standardisation of parts. By recycling and reusing materials in the machine industry, we reduce waste and increase its ecological sustainability. The use of recycled materials in machinery for the plastics industry has many advantages and can contribute to the entire industry's sustainability.
What is the real potential of implementing this solution in real business models?	The proposed solution should be technically compatible with the company's existing systems and processes. The simpler the integration, the greater the likelihood of success. The solution should bring significant cost savings or increased revenue. If the return on investment (ROI) is high, businesses will be more interested in implementing it. During the workshop, we tried to address current problems and needs on the market directly to an expert group of manufacturing companies. If it becomes relevant and competitive, its implementation will be more in demand.

Additional comments:	No comment
Material Sourcing	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	• Recycled materials can be cheaper than new raw materials as input materials in the circular solution, resulting in lower production costs. • Companies that invest in recycled materials can gain a competitive advantage and create new business models. • Some recycled materials can offer the same or even better mechanical properties than new materials, increasing the quality of the final product. • Support of the circular economy
Which circular strategy does the solution best suit? (Use of Recycled Materials; Sustainable Material Sourcing; Closed-Loop Material Systems)	Recycled materials and Sustainable material sourcing
What is the real potential of implementing this solution in real business models?	Using recycled materials and sustainable material sourcing supports the concept of a circular economy, where materials are constantly reused and renewed, thus extending their lifespan.
Additional comments:	No comment
Manufacturing & Assembly	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	• Ensuring the availability of quality spare parts on the market is essential for an effective machine´s life cycle. • Implementation of scheduled manufacturing and assembly, which includes regular inspections and servicing, can prevent serious breakdowns and reduce downtime. • Using sensors and real-time machine performance monitoring systems can help identify problems before they become serious.
Which circular strategy does the solution best suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	Additive manufacturing/3D printing

What is the real potential of implementing this solution in real business models?	Additive technologies enable the production of complex geometric shapes that would be difficult or impossible to produce using traditional methods. This opens up new possibilities for design and innovation. Unlike conventional manufacturing processes, which often produce large amounts of waste, additive technologies use materials more efficiently, reducing costs and environmental impact. They enable mass personalisation of products, which means that companies can offer customised products tailored to individual customers.
Additional comments:	No comment
Distribution & Logistics	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	A key indicator within the workshop was the creation of systems for collecting, recycling, and reusing materials and products. This may include support programs for returning products and components that can be reworked or refurbished. Important from the point of view of distribution and logistics is the use of biodegradable, recyclable, or reusable packaging, which can reduce the environmental impact of distribution. In addition, it is important to optimise packaging sizes to minimise waste during transport.
Which circular strategy does the solution best suit? (Efficient Transportation; Local Production and Distribution; Reusable Packaging)	• Efficient Transportation • Support local production and distribution • Reusable packaging
What is the real potential of implementing this solution in real business models?	The priority will be to maximize the use of materials and products, which will lead to a significant reduction in waste. Collection and recycling systems allow resources to be reused. More efficient use of resources and materials can lead to lower raw materials costs and less waste disposal expenditures. The costs associated with transportation and storage are also reduced.
Additional comments:	No comment
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	• Using sensors and real-time machine performance monitoring systems can help identify problems before they become serious. • The ability to monitor and analyse problems remotely can speed up the repair process and reduce maintenance costs. • Ensuring that personnel are adequately trained in maintenance and repair increases efficiency and safety when handling machinery.

Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Predictive Maitenance
What is the real potential of implementing this solution in real business models?	Predictive maintenance identifies problems before a machine fails, minimising unplanned downtime and increasing productivity. Using data and sensor analysis, optimal maintenance times can be predicted, reducing the costs associated with excessive or insufficient maintenance. Regular and well-timed maintenance leads to a longer machinery and equipment life, increasing the return on investment. Implementing predictive maintenance requires data collection and analysis, leading to a better understanding of processes and machine performance. This information can be used for further optimisations.
Additional comments:	No comment
End-of-life Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	An important aspect is the strategic planning and execution of end-of-life activities. This process ensures sustainability, efficient resource use, and waste minimisation.
Which circular strategy does the solution best suit? (Recycling and Material Recovery; Reverse Logistics; Product-as-a-Service	• Recycling • Material recovery • Reverse engineering
What is the real potential of implementing this solution in real business models?	Recycling and reuse of materials increase resource efficiency and contribute to environmental protection. Businesses can save on raw materials and new machine manufacturing costs by implementing component recycling and recovery systems. End-of-life management enables the optimisation of processes within the supply chain. Properly planned disposal of end-of-life products reduces the time and costs associated with transportation and disposal.
Additional comments:	No comment
Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this	Reusing materials reduces the demand for new raw materials, which contributes to the protection of natural resources. Many

phase of the machine's life cycle:	businesses see economic benefits in the sale of used or refurbished products.
Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	• Component reuse
What is the real potential of implementing this solution in real business models?	Reusing materials promotes innovation in design and manufacturing processes. Businesses are motivated to develop products that are easily dismantled and renewable, leading to more efficient resource use. Businesses that focus on reusing materials can gain a better reputation and customer trust.
Additional comments:	No comment
Waste Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Waste management is a key aspect of ensuring sustainability and efficient waste management. It is the process of processing waste into new products or materials. Materials or components can be reused in the same or different applications without processing.
Which circular strategy does the solution best suit? (Zero Waste to Landfill; Biodegradable or Compostable Components; Material Recovery Facilities)	• Zero waste to landfill • Biodegradable or compostable components
What is the real potential of implementing this solution in real business models?	Efficient waste management and recycling reduce the need for new raw materials, which can lead to significant savings. Minimising the volume of waste that needs to be disposed of reduces the costs associated with waste removal and processing. Implementing waste management often leads to a review and optimization of production processes, which increases overall efficiency and productivity. Effective waste management minimises the amount of material in landfills and reduces environmental impact. Focusing on recycling and reuse of materials contributes to the sustainability and conservation of natural resources.
Additional comments:	No comment

<table>
<tr><th>If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:</th></tr>
<tr><td>We identified the following potential environmental impacts:

1. Reduction of carbon footprint
Using recycled materials reduces the demand for new plastics, which contributes to protecting natural resources.
Recycling plastics generally requires less energy than producing new plastics, reducing greenhouse gas emissions.
2. Increasing awareness and social responsibility
Using recycled materials shows a company's commitment to sustainability, which can strengthen the brand and attract environmentally-minded customers.
Many countries are introducing regulations to encourage using recycled materials, which can be an additional incentive for businesses.</td></tr>
</table>

Report from the design thinking workshop for the machine industry

Partner:	**PP10/CLUSTERO**
Participants (name and surname and company name):	-Leucuta Christina-Clustero -Dulgheru Ana-Clustero - Pirvu Gabriela-Clustero -Samoila Petrisor- ICMPP Iasi -Harabagiu Valeria-ICMPP Iasi -Dubanu Nicola- Arhipelago Iasi -Luca Romeo- EDIL INDUSTRY SRL -Ciolacu Diana-ICMPP Iasi -Grecu Ionela-ICMPP Iasi -Gociu Mioara-Breasla Constructorilor Cluster -Baltag Laurentiu- ICMPP -Condurache Bogdan-ICMPP -Barbu Catrina-Est Autoagroserv Srl -Fortuna Maria-ICMPP -Bele Adrian-ICMPP -Calamaz Octavian-Relians Corp Srl -Barzic Razvan-ICMPP -Haidautu Felix- Est Autoagroserv Srl -Grideroc Dragos-Venus Car System Srl -Lupu Vlad Marian-MSV Expert Construct Srl -Soreanu Gabriela- Technical University Iasi
Date:	19 September 2024
Place:	Institute of Macromolecular Chemistry „Petru Poni“ Iasi Romania

Proposed solution(s) identification:
The workshop facilitated a dialogue between experts and stakeholders for industry to explore innovative solutions capable of supporting the transition towards circularity in the plastic processing machinery sector. Through guided brainstorming sessions, the three teams have developed creative solutions to extend lifespan of machines and to improve their recycling.The platform MIRO was an essential tool used in this dedicated workshop facilitated collaboration and visual prototyping of solutions developed by the participants. **The team 1 offered solutions focused on making machines more efficient used in the purification and depolymerization of plastic materials**. In context of plastics processing, these solutions are essential for improving the performance of equipment used in recycling, in particular in terms of **solvent recovery and reuse**. The reduction of solvent consumption and their integration into new production cycles represent an innovative method to minimize costs and optimize industrial processes. The team also identified **opportunities for plastic reuse recycled in other industries (asphalt, furniture, equipment),** maximizing the duration life of materials and contributing to increasing circularity in industrial processes. These solutions can reduce the ecological footprint and generate significant savings in the exploitation of machinery. **The team 2 had as its main objective the reduction of energy consumption in industrial processes by optimizing and upgrading equipment intended for the processing of plastics. Their solutions focused on energy audits, process optimization and source integration renewable energy.**

The team 3 focused on improving the process of shredding plastic waste, one of the most critical steps in recycling the materials. Their innovative solutions such as **freezing materials plastics before chopping and breaking them down**, contributes to growth the energy efficiency of the equipment. These technologies are not just declining energy consumption, but also reduce wear and tear on machinery, which extends equipment life and increase productivity. In addition, the team proposed **combining chopping processes with biodegradation, a solution that would allow a more efficient and longer degradation of plastic, using chemical or biological methods.** This process integration could revolutionize the operation of equipment by recycling plastic, while reducing the ecological impact of the industry.

Short description of the proposed solution(s) (please upload photos if you have any):

The design thinking workshop is focused on finding innovative solutions in the plastic machine industry and is designed with circularity in mind.

Fig.1 solutions proposed by Team 1

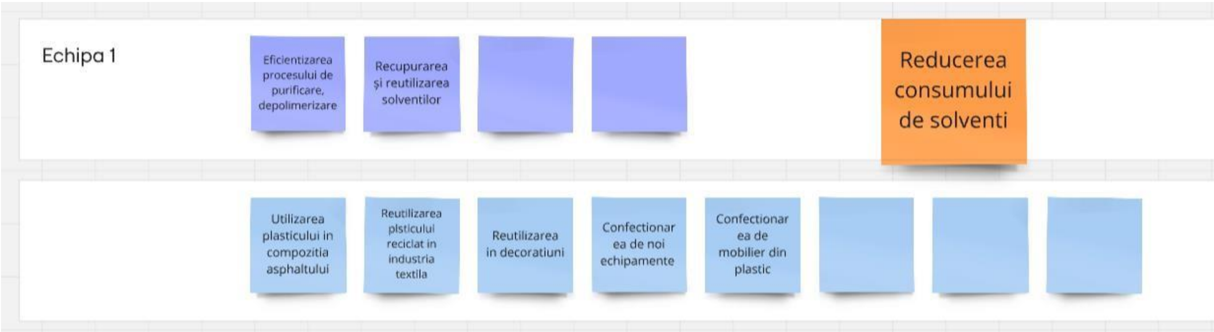


Fig. 2 solutions proposed by Team 2

Fig. 3 Graphic representation of the solutions proposed by Team 2

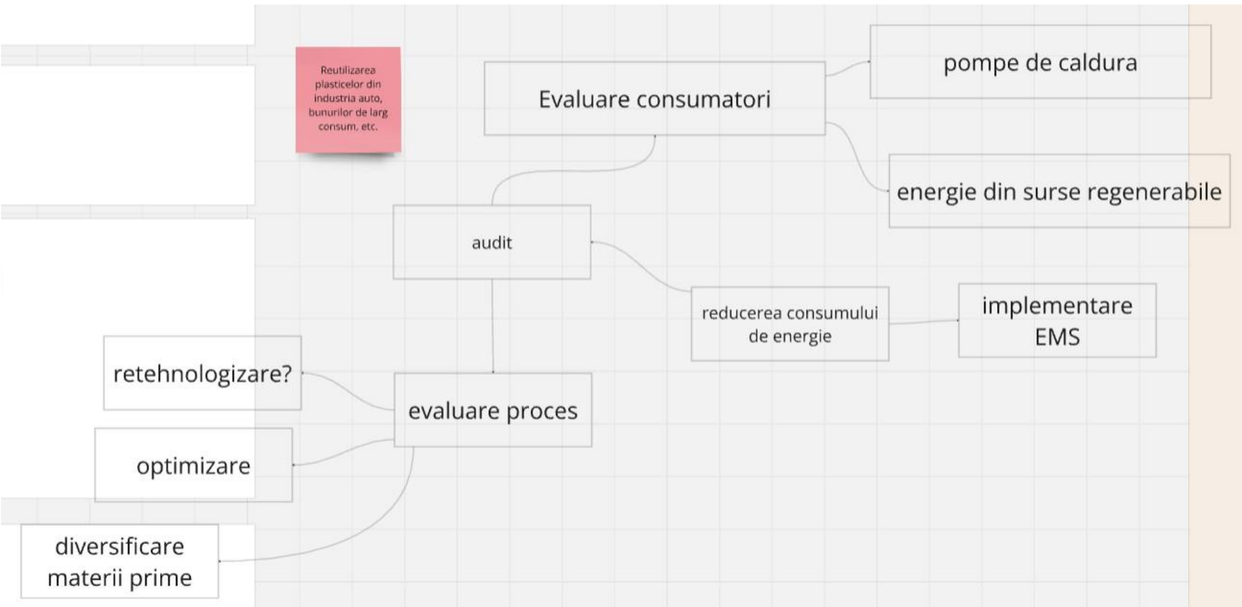
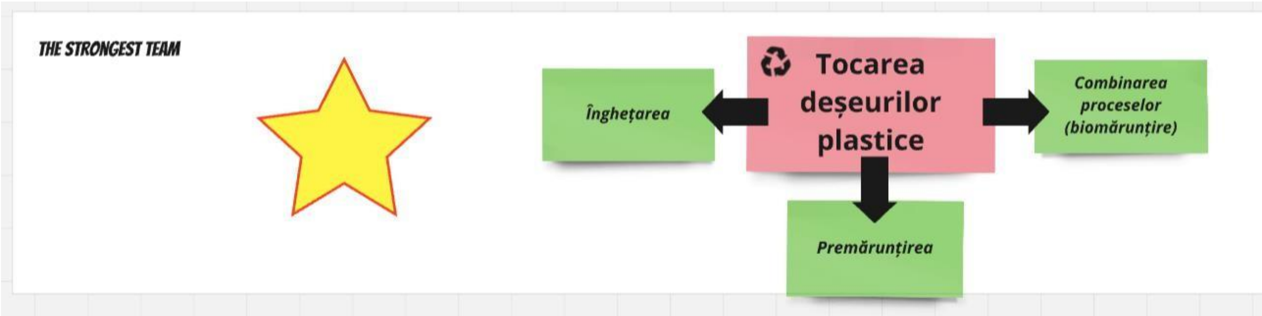
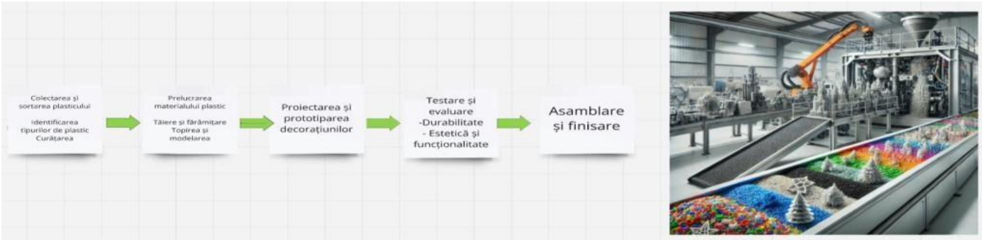


Fig. 4 solutions proposed by Team 3


Solutions in the context of the machine's life cycle phases:

Design & Development	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The proposed solutions within the workshop were multiple depending on the proposed objective. The strongest team no.3 focused on innovative solutions such as freezing materials plastics before chopping and breaking them down, contributes to growth the energy efficiency of the equipment. These technologies are not just declining energy consumption, but also reduce wear and tear on machinery, which extends equipment life and increase productivity. In addition, the team proposed combining chopping processes with biodegradation, a solution that would allow a more efficient and longer degradation of plastic, using chemical or biological methods. This process integration could revolutionize the operation of equipment by recycling plastic, while reducing the ecological impact of the industry.
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	The companies presented at the workshop considered the eco-design and standardization of parts as the best solutions for circularity. By recycling and reusing materials in the machine industry, we reduce waste and increase its ecological sustainability. The use of recycled materials in machinery for the plastics industry has many advantages and can contribute to the entire industry's sustainability.
What is the real potential of implementing this solution in real business models?	High, the expertise of companies EDIL INDUSTRY and Est Autoagroserv in circularity can serve as model for other companies and industries as well as for clusters.
Additional comments:	No comment
Material Sourcing	

Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The prototype developed by team 1 in the workshop highlights a complete process and sustainable for recycling and reusing plastics, focusing on optimizing the machinery that facilitates each stage of the life cycle of the material. This solution can be applied in an industrial framework to support the transition to a circular economy, maximizing equipment efficiency and reducing waste. **Fig.5 Prototype Team 1 – plastic processing and assembly recycled in a complete cycle** 
Which circular strategy does the solution best suit? (Use of Recycled Materials; Sustainable Material Sourcing; Closed-Loop Material Systems)	Recycled materials and sustainable material sourcing as well as closed-loop systems for reintroducing reprocessed plastics into manufacturing and thus reducing waste.
What is the real potential of implementing this solution in real business models?	High, by using recycled materials and sustainable material sourcing supports the concept of a circular economy where materials are constantly reused and renewed thus extending their lifespan.
Additional comments:	No comment
Manufacturing & Assembly	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The stages identified in the manufacturing and assembly of the prototype: 1. Collecting and sorting plastic The first stage includes the collection and sorting of plastic materials on types, followed by cleaning them to prepare them for recycling. The machines are optimized to identify and separate different types of plastic efficiently, ensuring proper processing. 2. Processing of plastic material In this phase, the equipment is designed to handle cutting, shredding and melting of plastic. The melting and molding process is an essential step to transform recycled plastic into new forms, thus reducing waste. 3. Design and prototyping of decorations After processing, the plastic material is used to make various prototypes products, such as decorations or new plastic components. This is it an innovative solution that expands the applicability of recycled materials in a creative and functional domain. 4. Testing and Evaluation

	Prototyped products undergo a testing process to evaluate their durability, aesthetics and functionality. This stage allows teams to verify product quality and performance before to move to mass production. 5. Assembly and Finishing The last phase involves assembling the components and finishing the products finals. The machines intended for this stage are optimized to ensure a fast and efficient completion of recycled products.
Which circular strategy does the solution best suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	Additive manufacturing/3D printing: Potential for customization and optimized resources use further supporting sustainable manufacturing.
What is the real potential of implementing this solution in real business models?	High potential, as additive techniques and 3D printing align with industry goals to minimize waste and improve resource efficiency. These approaches support companies commitment to high quality recyclate production and Plan C's goals for sustainable production.
Additional comments:	No comment
Distribution & Logistics	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The approach of EDIL Industry and Est Autoagroserv on logistics and distribution includes optimizing distribution networks to minimize emissions and enhance efficiency.
Which circular strategy does the solution best suit? (Efficient Transportation; Local Production and Distribution; Reusable Packaging)	**-**Efficient transportation -Local production and distribution -Reusable packaging
What is the real potential of implementing this solution in real business models?	High, by decreasing transportation distances and supporting local material processing, companies can realize cost savings, lower carbon emissions and strengthen regional supply chains.The costs associated with transportation and storage are also reduced.
Additional comments:	No comment

Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	An important solution was the retrofitting of old equipment, used in plastic processing to increase energy efficiency. This measure would include replacing obsolete components and introducing new technologies that consume less energy. Predictive maintenance extends machine life, ensuring consistent recycling quality. It’s very important to ensure well-trained personnel to maintenance to increase efficiency and safety when handling machinery.
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Predictive Maintenance Upgrading and retrofitting
What is the real potential of implementing this solution in real business models?	High potential as these strategies prevent frequent replacements and reduce downtime, aligning with the companies approach. Regular maintenance leads to a longer machinery and equipment life.
Additional comments:	No comment
End-of-life Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Machines could be designed for an easy disassembly, ensuring that components are recyclable and end-of-life. This process ensures sustainability, efficient resource use and waste management.
Which circular strategy does the solution best suit? (Recycling and Material Recovery; Reverse Logistics; Product-as-a-Service	Recycling and Material Recovery ensures components that can be reprocessed minimizing waste. Reverse Logistics that simplifies collection and recycling, fostering sustainable waste management. Product as a service for other companies.
What is the real potential of implementing this solution in real business models?	High, as they can serve as a model in the machine industry for managing end-of-life responsibility.
Additional comments:	No comment

Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	SC EDIL INDUSTRY SRL ,equipment could be refurbished allowing used machines and components to be restored and reused in different applications further aligning with circular economy goals.
Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	Component reuse Refurbishment programs
What is the real potential of implementing this solution in real business models?	High as EDIL INDUSTRY's commitment to resource efficiency supports the reuse and refurbishment of machinery, aligning with market demand for eco-friendly alternatives.
Additional comments:	No comment
Waste Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Waste management is a key aspect of ensuring sustainability and environment protection. Companies EDIL Industry and EST Autoagroserv minimize waste by implementing efficient sorting, processing and recycling technologies that repurpose a significaant part of materials into reusable ones.
Which circular strategy does the solution best suit? (Zero Waste to Landfill; Biodegradable or Compostable Components; Material Recovery Facilities)	Zero waste to landfill Materila Recovery Facilities
What is the real potential of implementing this solution in real business models?	High as zero waste to landfill targets and material recovery practices are becoming more desirable across industries. Focusing on recycling and reuse of materials contributes to the sustainability and conservation of natural resources.

Additional comments:	No comment

If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:
Workshop participants proposed and developed solutions viable for circularity in the plastics industry, including: -Tax breaks and incentives for adopting companies' circular technologies and recyclable plastics. -Improving recycling infrastructure through investments and partnerships public-private. -Increasing awareness and social responsibility (Romania introduced regulations to encourage using recycled materials, which can be an additional incentive for businesses; Romania has also a National Strategy for circular economy). -Regional collaborations for implementing solutions on a large scale, supporting innovation and adaptation to environmental regulations. Between October 10-11, 2024, the Conference "Clusters as drivers of Interregional value chains" took place in Chisinau, where at session III "The Role of clusters in the interregional cooperation" CLUSTERO presented the Plan C project, and at session VI Sustainable Development and Green Clusters were presented by ICMPP the results of Design Thinking Workshops to transform the plastics and machine industry towards circularity. The agenda of the Conference, the list of participants and photos are attached to the report.

Report from the design thinking workshop for the machine industry

Partner:	Czech Plastic Cluster (Plastr)
Participants (name and surname and company name):	Tomas Bata University Compuplast s.r.o. Zálesí a.s. Kasko s.r.o. Malza CZ s.r.o. Fortemix Produkce s.r.o. Plastika a.s. ASIO Tech s.r.o.
Date:	OCT-31, 2024
Place:	Zlin, Czech Republic

Proposed solution(s) identification:
The plastics processing industry is one of the most energy-intensive processes and in recent years in particular, sustainability and energy saving have become top priorities in the plastics industry - all types of polymers must be melted in the first phase so that their mixtures can be further homogenized and shaped into final products. And in the final phase, the plastic is cooled back to room temperature. Most of the heat is supplied to the melting and homogenization system by means of electric resistance heaters. Up to 60% of the heat is simultaneously radiated into the surroundings, and especially in the summer months it is not used at all, on the contrary it is emitted into the environment and forcibly removed. In other words : companies in the plastics industry an unrivalled range of particularly efficient plant and system technology. In view of the massive rise in energy prices and the Energy Efficiency Act passed last year, our range of services is in high demand. This means that plastics processors can find system technology from cooling systems to heat recovery, ventilation and clean room technology to dynamic mould temperature control, all geared towards the efficient and sustainable use of energy.
Short description of the proposed solution(s) (please upload photos if you have any):
Therefore, an initiative was created within the Association of Plastics Processors in the Czech Republic (Plastr) with the aim of defining technical and technological measures so that: a/ the use of heat supplied for the process itself is increased b/ the heat emitted by the technology is reused For this purpose, technical measures and the addition of energy-saving + recuperation units to the technologies were proposed. The proposed solutions are focused mainly on injection molding and extrusion technologies, which are the 2 most used and at the same time the most energy-intensive sub-technologies in the field of plastics processing.

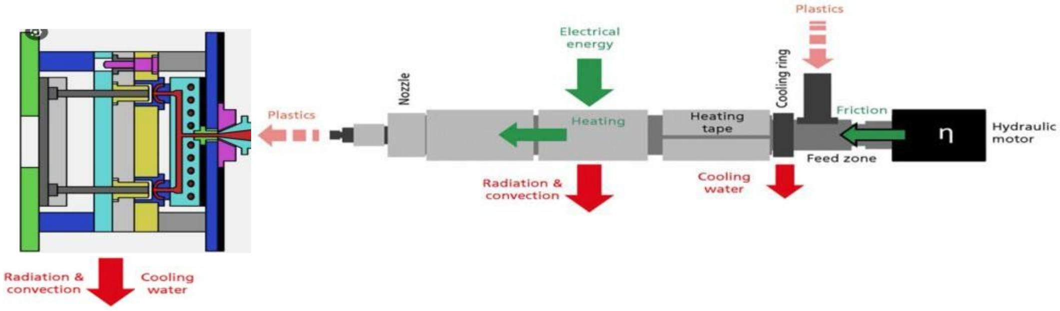
As part of the design thinking workshop, after discussion, 2 areas of energy loss were proposed, which will subsequently be given attention, and for which the following 2 groups of measures are proposed :

A/ Minimization of electrical energy losses intended for heating functional parts of technologies :

Typical convection heaters with heat loss of 40-70%

Energy saving (20-40%) heater for injection molding machine

B/ reuse of emitted warm air from technologies :



….illustration of typical heat losses within the injection molding process - it is similar for extrusion.

During the exhaust of hot-air the recovery of process heat can be achieved by the integration of a heat exchanger. Industrial exhaust air contains often valuable heat, which can be used for follow-up processes.

Solutions in the context of the machine's life cycle phases:

Design & Development	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Navrhované (a v budoucnu uplatňované) řešení bude mít vliv na snížení spotřeby elektrické energie pro tyto procesy až o 20% z celkové spotřeby. Podstatné je také to, že obě součásti řešení jsou přenositelné a stavebnicově využitelné pro jiné nebo obdobné nebo repasované technologie. jejich životnost tedy nesouvisí se samotnou technologickou životností konkrétního zařízení.
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	Eco-design is a fundamental indicator of the proposed solution, as stated above.
What is the real potential of implementing this solution in real business models?	It is clear that the application of the technological additions described above will clearly lead to energy cost savings and thus to a reduction in overall production costs and an increase in the competitiveness of the manufacturer. At the same time, it is a tool for reducing carbon emissions, which will be monitored from 2025 (for energies within SCOPE 1 and 2 in ESRS reporting) in all large and later medium-sized and small enterprises.
Additional comments:	
Material Sourcing	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The contribution of the proposed solution to achieving the goals of the circular industry lies in the area of reducing the energy intensity of production and thus in reducing CO_2 emissions calculated per unit of production. The proposed solution enables the long-term (even permanent) use of this technological innovation within the framework of long-term low-emission goals.
Which circular strategy does the solution best suit? (Use of Recycled Materials; Sustainable Material Sourcing; Closed-Loop Material Systems)	The proposed solution best fits the category of minimizing inputs to the production process - it is not on the material side, but on the energy side.
What is the real potential of implementing this	It is clear that the application of the technological additions described above will clearly lead to energy cost savings and thus to a reduction in overall production costs and an increase in the competitiveness of the manufacturer. At the same time, it is a

solution in real business models?	tool for reducing carbon emissions, which will be monitored from 2025 (for energies within SCOPE 1 and 2 in ESRS reporting) in all large and later medium-sized and small enterprises.
Additional comments:	
Manufacturing & Assembly	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	**N/A**
Which circular strategy does the solution best suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	**N/A**
What is the real potential of implementing this solution in real business models?	The same as above.
Additional comments:	
Distribution & Logistics	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The proposed solution will be tested on several model cases in companies. The benefits and actual efficiency will be quantitatively evaluated, including the calculation of the carbon footprint and the impact on the economics of operation/production.
Which circular strategy does the solution best suit? (Efficient Transportation; Local Production and Distribution; Reusable Packaging)	It is not necessary to seek local supplies and cooperation for this solution. However, the group that proposed this solution included representatives of technology manufacturers who promised cooperation not only in the area of verification, but also intend to serially apply the results and incorporate them into their business activities.
What is the real potential of implementing this solution in real business models?	If the designers and manufacturers (suppliers) of these technological units agree on a positive evaluation of the pilot projects, it can be assumed that they will benefit from the widespread supply of these units to many other interested parties in the future.
Additional comments:	

Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	N/A
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	N/A
What is the real potential of implementing this solution in real business models?	N/A
Additional comments:	-
End-of-life Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	N/A
Which circular strategy does the solution best suit? (Recycling and Material Recovery; Reverse Logistics; Product-as-a-Service	N/A
What is the real potential of implementing this solution in real business models?	N/A
Additional comments:	-
Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	The nature of the proposed solution allows for very long-term use not only within the installation of the given technology, but also within subsequent installations after the end of the service life of the first one. It can therefore be reused regardless of the condition and service life of the basic processing technology itself.

Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	It is not necessary to seek local supplies and cooperation for this solution. However, the group that proposed this solution included representatives of technology manufacturers who promised cooperation not only in the area of verification, but also intend to serially apply the results and incorporate them into their business activities.
What is the real potential of implementing this solution in real business models?	If the designers and manufacturers (suppliers) of these technological units agree on a positive evaluation of the pilot projects, it can be assumed that they will benefit from the widespread supply of these units to many other interested parties in the future.
Additional comments:	-
Waste Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	N/A
Which circular strategy does the solution best suit? (Zero Waste to Landfill; Biodegradable or Compostable Components; Material Recovery Facilities)	N/A
What is the real potential of implementing this solution in real business models?	N/A
Additional comments:	**-**

If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:
The proposed principle and solution clearly represent a positive environmental impact in terms of reducing the energy intensity of production. At the same time, they also contribute to increasing comfort in the workplace where this additional technology (measure) will be installed. Last but not least, it can be mentioned that, especially in large companies, the measure will have a positive effect on the overall working environment and employee awareness of real positive impacts on the environment.

<u>Report from the design thinking workshop for the machine industry</u>

Partner:	Innoskart
Participants (name and surname and company name):	Tamás Balogh, GÉPAUTOMATIKA Kft. Richárd Ecsődi, Fórum-Plusz Kft. Géza Ertsey, Fitting Metal Works Kft. Márton Gottschal, Go-Metall Kft. Attila Gurabi, Yield Kft. Zoltán Havasi, Mohanet Zrt. Katalin Hegedűs, Newed Kft. Csaba Jungmayer, Szerszám Technika Kft Zsolt Keresztúri, Innoskart Cluster Vilmos Kovács, Simplexion Informatikai Kft. János Ladányi, Elektronikai Kutatóközpont Kft. László Kaszó, Enco Software Kft. Attila Masa, Indeveyes Technologies Kft. Zsolt Meszlényi, Eff-System Kft. Zoltán Novák, Acélpartner Kft. Olivér Papp, CNC Média Kft. Éva Pető, Innoskart Cluster Dávid Péter, Rubin Informatikai Kft. Zoltán Rigó, Rigó Kft. Martin Soós, Innoskart Cluster Gábor Szabó, GF Machining Solutions SP Gábor Szabó, Gábor-pack Kft. Nóra Szirmai, innoskart Cluster Ádám Ferenc Tóth, European Conformity Check Kft. Edina Tóth, Innoskart Cluster Klára Tóth-Maródi Jenő Péter Török, Thematik Kft. Marcell Trembulyák, GO-Metal Kft Boglárka Ugrin, UgrinPack Kft Orsolya Ugrin, UgrinPack Kft. Balázs Weibel, Cubilog Kft. Gábor berkovich, Seacon Kft Imre Gotthárd, GIGA 2003 Kft. László Kovács, Budapest Technical University István Jánosi, Planimeter Kft. Tamás Pintér, Prémium S Kft.
Date:	19 November 2024
Place:	Budapest, Book Kitchen

Proposed solution(s) identification:
The goal of the workshop was to identify innovative solutions of circularity in the machine industry. Another goal is promoting cooperation among the stakeholders, including companies of the machine industry in order to map those areas of the value chain (design,

development, manufacturing, waste management, life-cycle extension) where circular practices can be integrated. The major challanges of circularity in machine industry are: - The acquisition and set-up of the industrial equipment is very expensive - In the case of an exchange, in addition to procurement, sometimes re-technologisation, testing and auditing are needed (increasing costs) - How do we serve our customers with a broken machine? - Secondary negative effects of machine stoppages (shifts, reorganization of logistics, heating, etc.) - Discarded machine as huge hazardous waste
Short description of the proposed solution(s) (please upload photos if you have any):
A detailed description of innovative solutions related to various life cycles wil be shown below. It can be stated though that most of the solutions are related to manufacturing, assembly, use and maintenance, as well as refurbishing and reuse. Distribution, logictics as well as material sourcing were not mentioned. A general remark is that most of the participated companies highlighted the importance of training , covering all life-cycle stages (therefore we did not mention it at each stage).

Solutions in the context of the machine's life cycle phases:

Design & Development	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	In relation to other life cycle phases, in the phase of design and development relatively few innovative solutions are used. Some companies make a survey before starting planning, development among machine manufacurers. In the planning phase it is really important to determine which maintenance strategy we use.
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	Design for longevity
What is the real potential of implementing this solution in real business models?	There are 3 different types of maintenance: - reactive - preventive - predictive In case a company sticks to predictive maintenance in the planning phase, further costs might be considerably reduced. Predictive maintenance is an equipment maintenance strategy that relies on real-time monitoring of equipment conditions and

	data to predict equipment failures. Advanced data models, analitics and machine learning can reliably access when and where failures are most likely to occur, includig which components are most likely to be affected. Openness of manufacturers is a questionmark.
Additional comments:	
Manufacturing & Assembly	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	One of the barriers to 3D printing is that the created surface is layered and therefore aesthetically does not meet the expectations of a final product.
Which circular strategy does the solution best suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	Additive manufacturing
What is the real potential of implementing this solution in real business models?	Use of a complex chemical process that can disrupt the surface of 3D printed models while smoothing them. The innovation is essentially a black box-like device and the post-treatment process that takes place inside it. This is postprocessing. By adjusting the parameters of the device, it is also possible to make the treated surfaces not only completely smooth, but also dense, air- and water-permeable, germ-proof and biocompatible, i.e. suitable for direct medical use.
Additional comments:	
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Optimisation of heat management. An often underestimated but effective strategy for lubrication and optimizing thermal management. Engines and gearboxes life of engines and motors can be significantly increased by keeping lubrication schedules and by monitoring of temperature fluctuations. Thermography and fluid analysis technologies help to detect overheating and lubrication problems in time, that are critical to long-term damage prevention.
Which circular strategy does the solution best	Predictive maintenance

suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	
What is the real potential of implementing this solution in real business models?	Time- consuming one-time investment but it can be easily managed.
Additional comments:	
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Monitoring of oil quality Monitoring oil quality allows us to track wear and tear and the optimal operation of lubrication systems. The presence of dirt or water can be a warning of leakage or spare part wear.
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Predictive maintenance
What is the real potential of implementing this solution in real business models?	Time- consuming one-time investment but it can be easily managed.
Additional comments:	
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Establishing AI based regional register for machine park. A regional/national/European wide register is needed for a better expolitation of existing operation time of machinery.
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Shared ownership Models

What is the real potential of implementing this solution in real business models?	In case of a machine park is not fully exploited and other regional companies might need them, by using AI, a more effective structure could be set up. Of course this solution has the main challange in the field of competition.
Additional comments:	
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Measuring of energy consuption. Why is is useful to measure ebergy consupmtion? - Use of energy becomes visible - Source of energy becomes visible - Transparency - Consumption peaks become visible → the whole factory becomes transparent
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Predictive manintenance
What is the real potential of implementing this solution in real business models?	Currently in Hungary there is a mandatory quarterly metering for all consumers above 50kW, which exceeds 1000 kWh on average over the three years preceding the year in question hours of operation. This refers only to the effective electricity (kWh) and its storage and conservation for a quarter of an hour. Measuring more than the mandatory regulation can have a real added vale by reducing costs.
Additional comments:	
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Timing based on cycle number or operation time Measuring of manufacturing time Counting cycles
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Predictive maintenance

What is the real potential of implementing this solution in real business models?	customisable production control system allows monitoring of diverse machine fleets up to hundreds of machines.
Additional comments:	
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Optimisation of lifecycle of tools - monitoring of shifting speed - monitoring of loading of spindle
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models; Upgrading and Retrofitting)	Predictive manintenance
What is the real potential of implementing this solution in real business models?	customisable production control system allows monitoring of diverse machine fleets up to hundreds of machines.
Additional comments:	
Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Planning of maintaining of heavy machine blocks otherwise rejectable. In several cases the electric part of the machinery goes wrong, the machine frame could be easily refurbished.
Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	Refurbishment programmes, Marketplaces for Used Machines)
What is the real potential of implementing this solution in real business models?	The planning should be coordinated on global and sectoral level.
Additional comments:	Level of cooepration (company culture) has to be considerably increased for such a joint coordination.

Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Adopt used machines! Using already existing market place for second-hand machinery such as https://www.machineseeker.com/ https://www.surplex.com/hu/ https://www.eurobots.net/ https://www.metalindustry.hu/
Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	Marketplaces for Used Machines)
What is the real potential of implementing this solution in real business models?	The planning should be coordinated on global or national level.
Additional comments:	Level of cooperation (company culture) has to be considerably increased for such a joint coordination.

If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:
During the workshop various positive environmental inpacts were mentioned: - less waste and emission - reduction of cycle time and accessories - refurbishing of machinery is much better from environmental aspect than building a new machine - less energy consumption - training of staff has a positive impact on awareness

Report from the design thinking workshop for the machine industry

Partner:	Technology Center Horb
Participants (name and surname and company name):	Dr. Fabian Lüth, Vogt Plastic Martin Mühlen, ARBURG GmbH & Co. KG Alexander Brock, cirp GmbH Matthias Gindele, Gindele GmbH Jörg Vetter, Hermann Hauf GmbH Udo Eckloff, HoliMaker Jörg Hansen, jomahan Consulting + Kunststoff Susanne Nestle, ProPlas GmbH Stephan Klumpp, ProPlas GmbH Constanze Mihr, Technologiezentrum Horb Assia Buchmann, Technologiezentrum Horb Janet Rosenberger, INNONET Kunststoff Thomas Reber, alkus GmbH & Co. KG
Date:	30/09/2024
Place:	Rheinfelden (Baden), Germany

Proposed solution(s) identification:
The workshop emphasized the development of adaptable, energy-efficient machinery for recycling mixed plastic waste, specifically from the Yellow Bag system. Key solutions included sorting technologies, modular machine designs, and strategies to reduce emissions through renewable energy and closed-loop systems.
Short description of the proposed solution(s) (please upload photos if you have any):
Creation of highly adaptable machines with modular components that can be reconfigured for various types of plastic waste, particularly those found in mixed collection streams. This modularity allows for machine upgrades and retrofits without replacing the entire system, significantly extending the machinery’s lifespan and enhancing resource efficiency

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Solutions in the context of the machine's life cycle phases:

Design & Development	
Briefly describe the innovative circular solution that fits this	Vogt Plastic already incorporates innovative machine designs aimed at reducing emissions and conserving resources. Extending this approach, machines could be modular, allowing

phase of the machine's life cycle:	for component upgrades based on material processing needs. This would enable efficient management of diverse plastic types and adapt to future advancements, keeping Vogt's technology at the forefront of mechanical recycling.
Which circular strategy does the solution best suit? (Design for Longevity; Design for Disassembly; Eco-design; Standardization of Parts)	• Design for Longevity: Vogt's machines are engineered to endure, minimizing the need for frequent replacements. • Eco-design and Standardization: By standardizing parts, repairs are simplified, and machinery lifespan is extended, reducing waste.
What is the real potential of implementing this solution in real business models?	High, as Vogt Plastic's expertise and market leadership can serve as a model. By adopting modular, standardized components, they enhance durability, thereby making recycling more cost-effective and aligning with the broader goals of Plan C for a climate-neutral Europe.
Additional comments:	
Material Sourcing	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Vogt Plastic sources recycled materials to create high-quality regrinds and granulates, reintroducing these into the production cycle. By ensuring purity in its recycled output, Vogt facilitates closed-loop cycles that minimize reliance on virgin materials..
Which circular strategy does the solution best suit? (Use of Recycled Materials; Sustainable Material Sourcing; Closed-Loop Material Systems)	• Use of Recycled Materials: Vogt prioritizes recyclates in the production process. • Closed-Loop Systems: Reprocessed plastics are reintroduced into manufacturing, reducing waste.
What is the real potential of implementing this solution in real business models?	High, as more companies prioritize sustainable material sources. Vogt Plastic's high-quality recycled products offer an appealing alternative to virgin materials, supporting industry shifts towards circular practices.
Additional comments:	
Manufacturing & Assembly	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Lean manufacturing and precision machining ensure that each component produced by Vogt Plastic is tailored for efficiency. By reducing material waste, they conserve resources while enabling efficient assembly suited to diverse plastics.
Which circular strategy does the solution best	• **L**ean Manufacturing: Vogt minimizes waste by producing only essential components.

suit? (Additive Manufacturing - 3D Printing; Lean Manufacturing; Remanufacturing)	• Additive Manufacturing (3D Printing): Potential for customization and optimized resource use, further supporting sustainable manufacturing
What is the real potential of implementing this solution in real business models?	High potential, as lean and additive techniques align with industry goals to minimize waste and improve resource efficiency. These approaches support Vogt's commitment to high-quality recyclate production and Plan C's goals for sustainable production.
Additional comments:	
Distribution & Logistics	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Vogt Plastic's approach to logistics includes optimizing distribution networks to minimize emissions and enhance efficiency. TRECO, a strategic partner, plays a critical role in this phase by supporting local infrastructure and material repurposing needs, creating efficient pathways for material redistribution and reuse within regional networks.
Which circular strategy does the solution best suit? (Efficient Transportation; Local Production and Distribution; Reusable Packaging)	• Efficient Transportation: By consolidating distribution efforts with TRECO, Vogt Plastic reduces transportation distances and environmental impact. • Local Production and Distribution: TRECO's local support facilitates shorter distribution loops and boosts regional material sourcing and processing, promoting sustainable logistics.
What is the real potential of implementing this solution in real business models?	This local and efficient logistics model is highly scalable for other businesses, especially those with circular economy goals. By decreasing transportation distances and supporting local material processing, companies can realize cost savings, lower carbon emissions, and strengthen regional supply chains.
Additional comments:	TRECO enhances Vogt Plastic's logistics sustainability by supporting local circularity hubs. This model not only exemplifies eco-efficient distribution but also strengthens community-based recycling efforts, setting a standard for how logistics in the recycling industry can integrate local networks to reduce environmental impact.
Use phase & Maintenance	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Vogt Plastic designs machines for longevity and ease of maintenance. Predictive maintenance systems could be integrated to preemptively address wear, extending the lifespan of machinery.
Which circular strategy does the solution best suit? (Predictive Maintenance; Shared Ownership Models;	• Predictive Maintenance: Extends machine life, ensuring consistent recycling quality. • Upgradeability: Machines can be retrofitted as needed, reducing waste and enhancing efficiency.

Upgrading and Retrofitting)	
What is the real potential of implementing this solution in real business models?	High potential, as these strategies prevent frequent replacements and reduce downtime, aligning with Vogt Plastic's efficient, resource-conscious approach.
Additional comments:	
End-of-life Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Machines from Vogt Plastic could be designed for easy disassembly, ensuring that components are recyclable at end-of-life. Reverse logistics can be employed to collect parts and components for responsible disposal or reprocessing.
Which circular strategy does the solution best suit? (Recycling and Material Recovery; Reverse Logistics; Product-as-a-Service	• Recycling and Material Recovery: Ensures components can be reprocessed, minimizing landfill waste. • Reverse Logistics: Simplifies collection and recycling, fostering sustainable waste management.
What is the real potential of implementing this solution in real business models?	Very high, particularly for Vogt Plastic, as they can serve as a role model in the machine industry for managing end-of-life responsibly.
Additional comments:	
Refurbishment & Reuse	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	• Vogt Plastic's equipment could be refurbished, allowing used machines and components to be restored and reused in different applications, further aligning with circular economy goals.
Which circular strategy does the solution best suit? (Component Reuse; Refurbishment Programs; Marketplaces for Used Machines)	• Refurbishment Programs: Extends machine lifespan, making Vogt's solutions more cost-effective and sustainable. • Secondary Markets: Offers resale options for refurbished machines.
What is the real potential of implementing this solution in real business models?	High, as Vogt Plastic's commitment to resource efficiency supports the reuse and refurbishment of machinery, aligning with market demand for eco-friendly alternatives.
Additional comments:	

Waste Management	
Briefly describe the innovative circular solution that fits this phase of the machine's life cycle:	Vogt Plastic minimizes waste by implementing efficient sorting, processing, and recycling technologies that repurpose a significant portion of materials into reusable regrinds and granulates. By focusing on material purity and waste reduction, Vogt reduces dependency on landfills and mitigates the environmental impact of plastic waste.
Which circular strategy does the solution best suit? (Zero Waste to Landfill; Biodegradable or Compostable Components; Material Recovery Facilities)	• Zero Waste to Landfill: Vogt Plastic's processes are designed to recycle nearly all incoming materials, reducing landfill waste. • Material Recovery Facilities (MRFs): The company's recycling facilities act as MRFs by sorting, cleaning, and reprocessing materials directly from mixed waste, enabling high recovery rates for plastics.
What is the real potential of implementing this solution in real business models?	High potential, particularly as zero-waste-to-landfill targets and material recovery practices are becoming more desirable across industries. Vogt Plastic's role as both a recycler and materials provider offers an operational model that other companies could adopt to achieve similar waste management goals.
Additional comments:	Vogt Plastic's success in recycling approximately 10% of Germany's Yellow Bag waste highlights their commitment to circularity. Their closed-loop approach, combined with material recovery expertise, aligns with broader industry goals to reduce environmental impact, setting a benchmark for sustainable waste management practices.

If you have managed to identify the potential environmental impacts of one or more developed innovative circular solutions, please briefly describe the effect below:
By implementing these solutions, Vogt Plastic could further reduce emissions and conserve valuable resources. Their self-developed recycling processes already eliminate the need for energy-intensive chemical treatments. Extending this with energy-efficient, modular machines powered by renewable energy will reduce the carbon footprint and bolster Plan C's vision for climate-neutral circular production. These efforts showcase Vogt Plastic as a pioneer in sustainable recycling, already recycling 10% of Germany's Yellow Bag waste and demonstrating the future of a circular plastics industry. Vogt Plastic, although not formally part of Plan C, exemplifies its objectives through practice. Their advanced, efficient recycling and material reintroduction methods demonstrate what sustainable manufacturing looks like in real-world applications. Through partnerships like INNONET Kunststoff, Vogt Plastic can further showcase and expand these circular economy efforts, helping drive Europe's shift towards a climate-neutral, resource-efficient economy.