Interreg Danube Region

Co-funded by the European Union

Plan-C

Strategy Development for Transformation Roadmaps for the Machine Industry

Deliverable D.3.2.2

Responsible Partner: Business Upper Austria

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1 Introduction

The plastics industry is at a critical turning point, facing mounting environmental and economic challenges that require a shift from the traditional linear model of production, use, and disposal to a circular economy. Circularity in plastics means designing products and systems that prioritize reuse, recycling, and long-term value retention, reducing waste and conserving resources. This transformation is not only essential for sustainability but also for compliance with evolving regulations, such as the EU target to recycle 50% of plastic packaging by 2025.

Despite these ambitions, many countries in the Danube Region struggle with weak recycling infrastructure, outdated waste systems, and gaps in technical expertise. Regulatory pressures, consumer expectations, and oversight from international bodies add complexity, while economic uncertainties, such as fluctuating markets, tariffs, and geopolitical risks, disrupt supply chains. Additionally, technological barriers, including inefficient recycling processes and contamination issues, hinder the progress.

Embracing circular principles offers significant benefits. Environmentally, they reduce plastic pollution and conserve natural resources. Economically, they lower production costs and create new business opportunities through innovative models such as recycling, remanufacturing, and product-as-a-service systems. These approaches not only minimize waste but also generate continuous revenue streams and strengthen competitiveness. Initiatives such as Plan-C demonstrate the feasibility of circularity, providing practical solutions and fostering collaboration across sectors to drive a sustainable industrial development.

This deliverable explores how strategy development and transformation roadmaps can guide plastics processors toward circularity, outlining key challenges, regional differences, and actionable measures to achieve a resilient and resource-efficient plastics value chain.

1.1 Plan-C project

Moving Plastics and mAchine iNdustry towards Circularity (Plan-C) is an ambitious initiative aimed at transforming the plastics and machinery industries in the Danube Region towards a circular economy. The project brings together 14 partners from countries including Germany, Austria, Czechia, Slovakia, Hungary, Serbia, Bosnia and Herzegovina, Romania, and Moldova.

By fostering transnational cooperation among plastics processors, producers, and the machine industry, Plan-C seeks to develop innovative solutions that emphasize reuse, recycling, and long-term value retention. The core objectives of Plan-C include:

- Co-creating circular plastic solutions through collaboration and design thinking, resulting in practical prototypes and guidelines for SMEs.

- Redesigning machinery for reuse and recycling, covering the entire lifecycle and exploring digital opportunities.
- Developing a transnational action plan that aligns with EU regulations and national strategies, ensuring long-term impact through policy integration and SME support.

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

1.2 Objective

The goal of the workshops was to accelerate the transition of the plastics and machinery sectors in the Danube Region toward a circular economy by identifying barriers to circularity and co-creating practical solutions. They aimed to engage stakeholders in a collaborative process to map critical lifecycle stages, uncover systemic hurdles, and propose actionable "lifts" that enable circular practices. This included fostering cross-sector dialogue between machine producers and plastics processors to ensure holistic solutions.

The scope of the workshops covered the entire product lifecycle—from design and production to operation, maintenance, end-of-life, and reuse—addressing technical, economic, and regulatory challenges. The methodology emphasized regional diversity, ensuring that insights reflect local realities while contributing to a unified transnational strategy.

The ultimate aim was to generate knowledge and strategies that feed into the Plan-C transformation roadmap and transnational action plan, providing a foundation for policy recommendations, investment priorities, and collaborative projects that support circularity across the plastics value chain.

2 Methodology

The workshops were designed as interactive sessions to identify hurdles and opportunities for circularity within the plastics and machinery sectors. The approach followed a structured yet collaborative format, encouraging participants to actively engage in problem-solving and idea generation. At the outset, participants were divided into two groups—one representing machine producers and the other plastics processors—regardless of their actual roles. This role-play method fostered empathy and cross-sector understanding.

The sessions began with a brief introduction to the Plan-C project and an icebreaker to create an open and creative atmosphere. Participants then mapped the key lifecycle stages of a product, such as production, operation, end-of-life, and repurposing, and ranked these stages by importance. This exercise provided a clear framework for identifying where circularity faces the greatest resistance.

Next, participants brainstormed specific hurdles within these stages, documenting them on notes. Through the “Note Game,” the hurdles were shared and discussed, promoting dialogue and deeper insight into systemic challenges. After ranking the importance of each lifecycle stage, the groups switched tables to review the other group’s hurdles and propose potential solutions—referred to as “lifts.” This step encouraged collaborative thinking and generated a wide range of ideas, from practical measures to visionary concepts.

Where time allowed, the feasibility and usefulness of proposed solutions were assessed, helping prioritize actions for future implementation. All results were documented through photos and written summaries, forming the basis for comparative analysis across workshops. These insights will feed into the transnational action plan, ensuring that identified hurdles and lifts translate into concrete measures and projects aimed at accelerating the transition to a circular economy.

3 Strategy development for plastics producers

For the development of a joint strategy for machine producers, a series of transnational workshops were organized under the PLAN-C project. These workshops brought together stakeholders from Austria and Germany (Baden-Württemberg), Bosnia and Herzegovina with Hungary and the Republic of Serbia, the Czech Republic with the Slovak Republic, and Moldova with Romania. The purpose was to collaboratively map key lifecycle stages of machinery influencing circularity, identify existing hurdles within each stage, and evaluate their relative importance to guide future strategic actions.

3.1 AT|Austria / DE|Germany, Baden-Württemberg

The workshop for machine producers, organized by Business Upper Austria, AWS, and Technology Center Horb during the K-Fair in Düsseldorf, focused on identifying hurdles that prevent circularity in machinery and exploring solutions to overcome them. Participants examined the entire product lifecycle and prioritized four key sections: production, operational procedures and management, repair and maintenance, and logistics. Among these, production and operational management were identified as the most critical stages for enabling circularity.

In production, design and technical challenges dominate. Machines are often not designed for recyclability, lacking modularity and incorporating mixed materials that complicate reuse. Technical hurdles include the need to process recycled materials with varying properties such as moisture, contamination, and viscosity. Integrating advanced technologies like sensors and AI adds complexity, while achieving energy efficiency remains difficult. Regulatory compliance further complicates production, creating barriers to market access and certification.

Operational procedures and management present strategic challenges. Transitioning to circular processes requires significant investment and workflow redesign, as most systems still follow linear models. Certification and compliance processes are complex and time-consuming, limiting access to sustainability labels and regulated markets.

Repair and maintenance issues stem from poor machine modularity, limited spare parts availability, and high costs for repairing older machines. Technical expertise for handling new materials and technologies is often lacking, and regulatory documentation requirements add further burden. These factors encourage replacement over repair, undermining lifecycle extension.

Logistics hurdles include high transport and storage costs for old machines, lack of take-back systems, and incompatibility with circular supply chains. Regulatory requirements for traceability and compliance increase complexity and cost.

Participants concluded that production and operational management are the most important areas to tackle first, as they set the foundation for circularity. Production involves numerous interconnected problems, technical, design-related, and regulatory, that must be solved together. Operational management issues, though fewer, are strategically critical for embedding circular principles into company culture and workflows. Repair and logistics, while important, depend heavily on decisions made in production and management.

The workshop emphasized that overcoming these hurdles requires a combination of design innovation, investment readiness, and regulatory alignment, supported by new business models for repair and reuse. Addressing these challenges will unlock practical circularity, reduce waste, and create opportunities for sustainability and competitiveness in the machine manufacturing sector.

3.2 BiH|Bosnia and Herzegovina / HU|Hungary/ RS|Republic of Serbia

The online workshop held on 20 November 2025 brought together machine producers from Serbia, Hungary, and Bosnia and Herzegovina to identify hurdles to circularity and propose solutions for transforming the plastics value chain. Participants examined five critical lifecycle stages: Product Design & Material Selection, Manufacturing & Production, Use & Maintenance, End-of-Life & Refurbishment, and Waste Management & Reverse Logistics.

Design & Material Selection was highlighted as the most influential stage, as decisions on modularity, reparability, and material efficiency determine the long-term circular potential of machines. Poor design choices lock in inefficiencies, making repair and recycling difficult. Participants stressed the need for modular tooling, standardised components, and integration of recycled or bio-based materials.

In Manufacturing & Production, challenges include outdated equipment, high energy consumption, and limited adoption of clean technologies. Many companies lack resources for process optimisation, digital twins, or renewable energy integration. Valuable materials such as nickel and copper are often lost due to inadequate recovery systems.

The Use & Maintenance phase was identified as the second most critical stage. Machines without sensors or predictive maintenance systems experience frequent breakdowns, leading to higher energy use and shorter lifespans. Retrofitting older machines with automation and monitoring technologies was seen as a key solution.

End-of-Life & Refurbishment faces hurdles such as non-standardised components, poor design for disassembly, and limited take-back schemes. These issues result in premature scrapping and missed opportunities for remanufacturing. Similarly, Waste Management & Reverse Logistics suffers from a lack of organised networks for scrap exchange and insufficient recovery systems, causing recyclable materials to be discarded or sold cheaply.

Participants identified several systemic barriers: low customer willingness to pay for sustainable solutions, limited funding for innovation, regulatory restrictions on renewable energy, and gaps in collaboration and knowledge. Skills shortages and lack of awareness further slow the transition to circular practices.

Proposed solutions included retrofitting older machines with sensors and energy-efficient upgrades, implementing predictive maintenance and AI-based monitoring, introducing modular design and standardised components, and closing resource loops through metal recovery and water reuse systems. Switching from hydraulic to electric machinery and improving energy efficiency were also considered strategic priorities. These actions scored high in feasibility and usefulness, offering immediate environmental and economic benefits.

The workshop concluded that achieving circularity requires a combination of design innovation, digitalisation, and collaborative networks supported by policy incentives and funding mechanisms. By addressing these hurdles, machine producers can enable plastics processors to reduce waste, lower costs, and strengthen competitiveness across the entire value chain.

3.3 CZ|Czech Republic / SK|Slovak Republic

The workshop held on 10 October 2025 at Hotel Kontakt in Stará Lesná, Slovakia, brought together machine manufacturers and plastics processors from the Czech Republic and Slovakia to identify hurdles to circularity and propose solutions for enabling sustainable transformation. Participants prioritized five key lifecycle stages: design, construction, production, use, and recycling, ranking construction and design as the most critical areas for achieving circularity.

Discussions revealed several major hurdles. In the design phase, limited access to raw materials and insufficient integration of resource-efficient technologies were highlighted as key barriers. Poor design choices reduce recyclability and lock in inefficiencies, making future circular loops difficult to implement. Construction challenges included competitiveness pressures and gaps in expert knowledge, which hinder innovation and adoption of circular principles. Production faced technical limitations, while use phase issues centered on the shortage of qualified machine operators and the high cost of machines. In recycling, technical feasibility and cost constraints, combined with societal attitudes toward recycling, were identified as significant obstacles.

Participants also noted systemic challenges such as EU legislative complexity and a shortage of skilled professionals. These issues slow down the transition to circular practices and limit the ability of companies to meet sustainability targets.

Proposed solutions focused on functional engineering and design improvements, development of less resource-intensive technologies, and raising awareness of recycling benefits. Support for technical education, including dual education systems and lifelong learning programs for technicians and machine operators, was considered essential.

Active participation in EU legislative processes and marketing initiatives to promote circularity were also recommended.

Feasibility and usefulness were assessed on a 0–5 scale. The highest-rated solutions included functional engineering and design (5:5), technical education support (5:5), and awareness campaigns (5:5). Development of less resource-intensive technologies scored slightly lower on feasibility but was still considered highly useful. Urgent priorities identified were legislative measures, improved design practices, and training programs for qualified operators.

The workshop concluded that achieving circularity requires a combination of design innovation, technical education, and policy engagement, supported by collaborative efforts between machine producers and plastics processors. By addressing these hurdles, the region can strengthen competitiveness, reduce resource dependency, and advance toward a sustainable, circular plastics value chain.

3.4 MD|Moldova/ RO|Romania

The workshop held on 30 October 2025 in Târgoviște, Romania, gathered machine producers, SMEs, research institutions, and business support organizations from Romania and Moldova to identify hurdles to circularity and propose solutions for enabling sustainable transformation in the plastics machinery sector. Participants mapped five key lifecycle stages: Design & Development, Material Sourcing, Use Phase & Maintenance, Repair & Reuse, and Waste Management, ranking Repair & Reuse and Design & Development as the most critical for achieving circularity.

Discussions revealed several major hurdles. Low energy efficiency during machine operation was identified as a significant barrier, increasing costs and environmental impact. Lack of information about materials, particularly plastics used in machine components, limits traceability and compatibility with recycled inputs. A shortage of specialists in repair and maintenance and lack of spare parts availability were highlighted as systemic issues that lead to premature disposal and reduced machine lifespan. Finally, absence of infrastructure for component reuse prevents functional parts from being reintegrated into production cycles, resulting in material loss and higher reliance on virgin resources.

Participants noted that these hurdles create additional challenges during the transition to circularity, including high investment costs for upgrading equipment, resistance to change, and fragmented collaboration networks. Regulatory gaps and insufficient quality assurance for refurbished components further slow adoption of circular practices.

Proposed solutions focused on automation and digitalization, including smart sensors, predictive maintenance tools, and remote diagnostics to improve energy efficiency and reduce downtime. Standardized identification systems such as labeling and digital passports were recommended to ensure material traceability. Training and professional development programs were considered essential to address the shortage of skilled technicians and operators. Improved after-sales services, modular machine design, and optimized spare parts inventories were also suggested to facilitate repair and reuse. Fiscal incentives, public-private partnerships, and collaborative networks were proposed to support investments in circular technologies and infrastructure.

Feasibility and usefulness were assessed, with automation scoring the highest overall (Feasibility: 10, Usefulness: 10), followed by training and professional development and enhanced after-sales services. These measures were seen as critical for reducing energy consumption, extending machine lifespan, and enabling circular maintenance strategies.

The workshop concluded that achieving circularity in the machinery sector requires a combination of design innovation, digitalization, and collaborative ecosystems, supported by policy incentives and financial instruments. By addressing these hurdles, machine producers can significantly reduce waste, improve resource efficiency, and strengthen competitiveness across the plastics value chain.

4 Comparison

The machinery-focused workshops identified similar lifecycle stages as important across all regions but revealed clear differences in where the main constraints arise, how challenges are understood, and which solutions are seen as feasible. These differences are linked to variations in industrial structures, infrastructure availability, regulatory frameworks, and market conditions.

4.1 Design as a Strategic Entry Point vs. a Constrained Lever

Design was identified as a critical stage in all regions, but its role differed in emphasis and operational framing.

- AT/DE and CZ/SK discussed design primarily in relation to technical feasibility, modularity, and compliance, linking design decisions directly to recyclability, repairability, and system integration. Design was treated as a lever that can be acted upon within existing engineering and production processes.

- BiH/HU/RS and MD/RO also ranked design highly, but discussions focused more on design deficits as inherited constraints, such as non-standardized components, poor disassembly, or missing material information. Design improvements were often linked to the need for standardization, external support, or regulatory guidance rather than immediate in-house implementation.

Across regions, design was consistently recognized as important; however, workshop discussions positioned it either as an immediately actionable element or as one that is closely tied to broader system conditions.

4.2 Production and Operation: Optimization vs. Capability Gaps

The workshops showed that there are differences in how production and operational phases are discussed.

- In AT/DE, production and operational management were framed as strategic coordination challenges, involving energy efficiency, regulatory compliance, integration of digital technologies, and workflow redesign.

- CZ/SK discussions linked production challenges to knowledge and competitiveness pressures, highlighting the need for functional engineering, cost efficiency, and skilled operators.

- In BiH/HU/RS and MD/RO, production and operation were discussed more in terms of capability gaps, such as outdated equipment, high energy consumption, lack of sensors, and limited digitalization, which restrict optimization potential.

Across all workshops, production was identified as a critical stage, but discussions varied between improving existing processes and addressing identified technical or organizational gaps.

4.3 Repair, Maintenance, and Use Phase as Differentiating Factors

The use, repair, and maintenance phases played different roles across regions.

- In AT/DE and CZ/SK, repair and maintenance were discussed mainly in relation to design choices, modularity, standardization, and cost considerations. Repair was often described as economically challenging or inefficient due to design complexity or lack of modular components.

- In BiH/HU/RS and MD/RO, discussions emphasized practical barriers to repair and refurbishment, including limited spare parts availability, skills shortages, and missing infrastructure for organized repair or refurbishment activities.

These patterns show that repair and maintenance are constrained less by technical limits and more by design choices, market incentives, and service ecosystems.

4.4 End-of-Life, Reverse Logistics, and Resource Recovery

Clear contrasts emerged in how end-of-life and reverse logistics were discussed.

- AT/DE and CZ/SK workshops referred to logistical complexity, take-back systems, and regulatory traceability as challenges, but assumed the existence of basic recovery pathways.

- BiH/HU/RS and MD/RO emphasized the absence or fragmentation of reverse logistics, limited recovery of valuable metals, and lack of organized reuse or refurbishment networks.

As a result, end-of-life discussions focused either on improving and coordinating existing systems or on establishing more structured recovery and exchange mechanisms.

4.5 Technology Adoption Pathways

Technology was viewed as essential across all workshops, but its role differed by context.

- AT/DE discussions focused on upgrading existing systems through incremental measures such as sensors, AI-supported monitoring, and energy-efficiency improvements.
- CZ/SK linked technological measures closely with education, applied research, and skills development, emphasizing alignment between technical solutions and workforce capability.
- BiH/HU/RS and MD/RO framed advanced technologies mainly in relation to prerequisites such as funding access, skills development, and infrastructure improvements, often prioritizing retrofitting and efficiency improvements.

This suggests that technological solutions are perceived either as **scalable enhancements** or as **longer-term enablers**, depending on absorptive capacity.

4.6 Systemic Enablers: Skills, Regulation, and Collaboration

Systemic enabling factors were addressed with different levels of emphasis.

- CZ/SK placed strong emphasis on education, dual training systems, and specialist availability, treating skills as a binding constraint.
- AT/DE discussed skills mainly in relation to regulatory compliance and technology uptake, not as a primary bottleneck.
- BiH/HU/RS and MD/RO emphasized awareness, collaboration gaps, funding access, and regulatory clarity, indicating that coordination and institutional support are central concerns.

These discussions indicate that skills, regulation, and collaboration are relevant across regions, but their perceived role and urgency differ.

4.7 Comparative Implication

Taken together, the workshops show that circularity in the machinery sector is discussed through different focal points and constraints across regions. In some cases, discussions centered on improving coordination and efficiency within existing systems, while in others they emphasized addressing technical, organizational, or infrastructural gaps identified during the workshops. These differences suggest that transnational strategies for machinery producers should combine knowledge exchange and technical guidance with targeted support measures, reflecting the specific challenges and priorities articulated in each regional context rather than applying uniform assumptions.

5 Conclusion

The machinery-focused workshops conducted within the Plan-C project provide a consistent basis for comparing how circularity is addressed across regions. Across all workshops, participants identified similar lifecycle stages—design, production, use and maintenance, and end-of-life—as relevant for circularity in the machinery sector. At the same time, the discussions showed clear differences in how challenges were articulated, which stages were emphasized, and which measures were considered feasible within each regional context.

Design and production were highlighted as critical stages in all workshops, though their role was discussed differently. In some workshops, design-related aspects such as modularity, material selection, and compliance were linked directly to recyclability, repairability, and system integration. In other workshops, design was discussed primarily in relation to existing constraints, including non-standardized components, limited disassembly options, and insufficient material information. Similarly, production and operational phases were consistently identified as important, with discussions ranging from energy efficiency, regulatory compliance, and digital integration to technical limitations, outdated equipment, and organizational constraints.

Repair, maintenance, and use phases were generally discussed as dependent on upstream design and production decisions. Across regions, participants linked limited repair and refurbishment to factors such as lack of modularity, availability of spare parts, skills constraints, cost considerations, and the absence of organized service or refurbishment structures. End-of-life and reverse logistics were also addressed in all workshops, with discussions focusing either on improving existing take-back, traceability, and recovery processes or on the need to establish more structured systems for material recovery, reuse, and refurbishment.

Technology was recognized as an important enabler in each workshop, though its role was discussed in relation to feasibility within existing conditions. Participants referred to incremental upgrades, retrofitting, automation, and digital tools, often linking their adoption to factors such as skills availability, infrastructure conditions, regulatory requirements, and access to funding. Education, training, and collaboration were repeatedly identified as supporting elements, though the specific needs and priorities varied across workshops.

Taken together, the workshop results show that circularity in the machinery sector is discussed through a combination of design-related, technical, organizational, and system-level challenges. The differences observed across regions reflect variations in the issues emphasized during the workshops rather than differences in overall objectives. These findings provide an evidence-based foundation for developing transnational strategies that reflect the challenges and priorities identified in each regional context and for aligning future actions with the specific conditions discussed by workshop participants.

6 Annex

Strategy development with transformation roadmaps with machine producers

Deliverable D.3.2.2 - RECORD SHEET: Business Upper Austria

AWS – Austria Business Service

Technology Center Horb

All interregional groups are responsible for evaluating and completing this check list, which contains individual parameters that should be evaluated and recorded during workshop D.3.2.2. In some cases, short statements are sufficient; in other cases, please provide an evaluation comment, upload files, photo documentation, etc.

Involved Partners:	TZH / Business Upper Austria/ AWS
Participants:	8 Participants
Date of proceeding:	10.10.2025
Place of proceeding:	Messe K Düsseldorf

Proposed Workshop topic:
Hurdles & Lifts - Machine producers identify hurdles in the circularity of their products. - Each Participant then seeks a way to "lift" plastics processors over their hurdles.
Short description of the workshop, possible images, photos, etc.:
The workshop was centered on determining key struggles of plastics processors as well as ways for them to help machine producers become more circular.

Results and discussion of the Workshop step-by-step:

<table>
<tr><td>Step 1.
Identifying 5 track sections for machine producers
What sections during a products lifetime are the most important for circularity?</td></tr>
<tr><td>- 1. Production
- 2. Operational procedures/Management
- 3. Repair and maintenance
- 4. Logistics

- The sections are sorted by their importance.</td></tr>
<tr><td>Step 2.
Identifying hurdles on the track

What keeps a product / process from becoming circular?
What problems arise during the transformation towards circularity?</td></tr>
<tr><td>1. Production
- Design Aspects
    o Machines are not always designed for recyclability (e.g., lack of modularity, mixed materials).
- Technical Aspects
    o Machines must handle recycled materials with varying properties (e.g., moisture, contamination, viscosity).
    o Integration of new technologies such as sensors and AI is challenging.
    o Energy efficient machines are not always easy to create
- Regulatory Aspects
    o Compliance with technical and environmental standards can be a problem.
2. Operational Procedures / Management
- Economic Aspects
    o Transition to circular processes requires investments and new resources.
- Design Aspects
    o Most workflows and processes follow a linear design, making reuse and recycling difficult.
- Regulatory Aspects
    o Complexity of certifications and standards.
3. Repair & Maintenance
- Economic Aspects
    o Spare parts availability for older machines or recycled components is costly.
    o Repair instead of replacement requires new business models and approaches.
- Design Aspects
    o Machines are often not modular or accessible enough for easy repair.</td></tr>
</table>

- **Technical Aspects**
    - Lack of expertise for repairing machines with new materials or technologies.
- **Regulatory Aspects**
    - **Documentation and compliance requirements for repair/reuse activities.**

4. Logistics

- **Economic Aspects**
    - Transport and storage of old machines are more complex and expensive.
    - Take-back systems require upfront investment**.**
- **Design Aspects**
    - Current logistic processes make it difficult for components to be returned and reused.
- **Regulatory Aspects**
    - Traceability and compliance with transport and storage regulations.

Step 3.
Assigning problems to track sections

At which point in a product's lifetime does each hurdle occur?
What are the consequences of each hurdle?

The hurdles identified across production, operations, repair & maintenance, and logistics all represent significant barriers to transitioning toward a circular economy. Whether due to technical limitations in handling recycled materials, high investment costs, or complex regulatory requirements, these hurdles collectively hinder the ability to close material loops and extend product lifecycles. Instead of enabling reuse, repair, and recycling, they reinforce linear practices—resulting in inefficiencies, increased waste, and missed opportunities for sustainability and innovation

1. Production

- **Design Aspects**
  Consequences:
    - Difficulties in recycling or repairing machines and products
    - Increased waste and reduced circularity
    - Higher costs for end-of-life processing
- **Technical Aspects**
  Consequences:
    - Inefficient processing of recycled materials
    - Increased machine downtime and maintenance needs
    - Limited adoption of advanced technologies due to complexity
- **Regulatory Aspects**
  Consequences:
    - Barriers to market access or certification
    - Potential fines or reputational damage

2. Operational Procedures / Management

- **Economic Aspects**
  Consequences:
    - High upfront costs for transitioning to circular models

- Delayed implementation due to budget constraints
- Missed opportunities for long-term savings

- **Design Aspects**

  Consequences:
  - Inefficiencies in material reuse and recycling
  - Resistance to change within teams
  - Lack of integration with circular supply chains
- **Regulatory Aspects**

  Consequences:
  - Complex and time-consuming compliance procedures
  - Limited access to sustainability labels or certifications
  - Reduced competitiveness in regulated markets

3. Repair & Maintenance

- **Economic Aspects**

  Consequences:
  - Increased operational costs due to spare part scarcity
  - Financial pressure to replace rather than repair
  - Missed potential for lifecycle extension
- **Design Aspects**

  Consequences:
  - Difficult or impossible repairs
  - Increased downtime and waste
  - Reduced machine lifespan
  - "Designed for the Dump"
- **Technical Aspects**

  Consequences:
  - Inadequate repair capabilities
  - Need for specialized training or external support
  - Higher risk of machine failure
- **Regulatory Aspects**

  Consequences:
  - Barriers to circular certification

4. Logistics

- **Economic Aspects**
- **Consequences:**
  - Higher transport and storage costs
  - Inefficient material flows
  - Reduced profitability of circular logistics
- **Design Aspects**

  Consequences:
  - Incompatibility with circular supply chains
  - Limited ability to recover and reuse components
- **Regulatory Aspects**

  Consequences:
  - Limited traceability of recycled materials
  - Potential legal and reputational risks

Step 4.

Determining importance of track sections Which sections are the most important to tackle? Do these sections have many problems that need to be solved or little problems that are very important? Include a graphic representation of the importance (photograph of flipchart or processed data)
Which sections are the most important to tackle? - Production and Operational Procedures / Management are the most important to tackle first. - Production sets the technical and design foundation for circularity. If machines and processes can't handle recycled materials or aren't energy-efficient, circularity is blocked from the start. - Operational Procedures / Management determines whether circular principles are embedded in the company's strategy, workflows, and culture. Without this, even well-designed production systems won't be used effectively. **Do these sections have many problems that need to be solved or few problems that are very important?** - Production has many interconnected problems—technical, design-related, and regulatory. These must be solved in combination to enable circular manufacturing. The complexity is high but solving them unlocks practical circularity. - Operational Procedures / Management has fewer problems, but they are strategically very important. Issues like investment readiness, workflow redesign, and certification complexity are fewer in number but critical for enabling and sustaining circular transformation across the organization. - Repair & Maintenance and Logistics are also important, but they depend heavily on decisions made in production and management. Their problems are more operational and can be addressed more effectively once the foundational issues are resolved.

Fill out this part only after completing “Step 9” of the Workshop Concept:

Step 5. **Considering the hurdles of plastics processors** What are their most important hurdles? Which hurdles can we as machine producers help them overcome? And how?
- **What are their most important hurdles?** - **Which hurdles can we as plastics processors help them overcome? And how?**
Step 6. **How feasible are these solutions? How useful would overcoming this hurdle be? (score of 1-10 for each)** Which lifts have the highest score overall? Include a picture of the Feasibility/Usefulness scale (photograph or processed data)
- **Which lifts have the highest score overall?** - **Include a picture of the Feasibility/Usefulness scale (photograph or processed data)**

Strategy development with transformation roadmaps with machine producers

All interregional groups are responsible for evaluating and completing this check list, which contains individual parameters that should be evaluated and recorded during workshop D.3.2.2. In some cases, short statements are sufficient; in other cases, please provide an evaluation comment, upload files, photo documentation, etc.

Involved Partners:	Serbia, Hungary, Bosnia and Herzegovina
Participants:	1. Nedeljko Milosavljević, ICMF 2. Tamara Čolić Milosavljević, ICMF 3. Kristina Stevanović Damiš, ICMF 4. Tibor Tarcsay, DBH InnoHub 5. Sumeja Kovačević Glibanović, FITT 6. Biljana Smajić, FITT 7. Edina Toth, Innoskart 8. Zsolt Kereszturi, Innoskart 9. Hanka Hadžić, Plastoflex d.o.o. 10. Vedad Elesković, Centar za robotiku, DKR 11. Vernes Bešić, Plamingo d.o.o. 12. Veselinka Perović, KREMAKO 13. Miloš Pavlović, Hydrocor 14. Marko Prošić, UTVA AVIO DOO 15. Luka Stankovski, UTVA AVIO DOO 16. Nenad Dragović, PKS 17. Mikó Valentin, Drink System Ltd. 18. Kaszó László, EN-CO Software cPlc.
Date of proceeding:	20.11.2025.
Place of proceeding:	Online workshop

Proposed Workshop topic:
Hurdles & Lifts - Machine producers identify hurdles in the circularity of their products. - Each Participant then seeks a way to “lift” plastics processors over their hurdles.
Short description of the workshop, possible images, photos, etc.:
The workshop was centered on determining key struggles of machine producers, as well as ways for them to become more circular and help the whole plastics value chain with efficient circular transformation and adaptation.

Results and discussion of the Workshop step-by-step:

Step 1. **Identifying 5 track sections for machine producers** What sections during a products lifetime are the most important for circularity?
- **Identify 5 track sections for machine producers** - **What sections during a products lifetime are the most important for circularity?** 1. Product Design & Material Selection This stage defines the entire circular potential of a machine. Decisions on modularity, reparability, durability, material efficiency, and incorporation of recycled or bio-based materials directly affect the number of future resource loops a product can accommodate. Participants highlighted the need for designs with fewer raw materials, greater standardisation of parts, and modular tooling, particularly in mould manufacturing. 2. Manufacturing & Production Processes The way machines and tools are produced strongly affects resource use and waste generation. This includes energy consumption, machining efficiency, water-loops, reuse of scrap metals, use of digital twins for process optimisation, and integration of clean technologies such as solar power. Processes such as preventive maintenance during manufacturing and implementation of zero-waste approaches were emphasised. 3. Use Phase, Operation & Maintenance The longest stage of the machine's life has significant impact on circularity. Predictive maintenance, AI-supported failure detection, retrofitting older machines with new sensors, and improving energy efficiency were identified as essential. 4. End-of-Life, Repair, Refurbishment & Remanufacturing Participants emphasised that circularity cannot be achieved without a strong system for repairing, remanufacturing, and upgrading equipment. The availability of spare parts, design for disassembly, recovery of valuable materials (nickel, copper, stainless steel), and introducing take-back schemes are crucial. 5. Waste Management, Material Recovery & Reverse Logistics Companies recognised the importance of closed-loop systems that capture valuable materials instead of sending them to waste. This includes recycling of aluminium and plastics, recovery units for metals from wastewater, reuse of process water for heating and cooling, and establishing networks to strengthen cross-company visibility of available scrap and secondary raw materials.
Step 2. **Identifying hurdles on the track** What keeps a product / process from becoming circular? What problems arise during the transformation towards circularity?

- **What keeps a product / process from becoming circular?**
- **What problems arise during the transformation towards circularity?**

Participants collectively identified a range of hurdles, combining technological, economic, behavioural, and regulatory challenges faced in Serbia, Hungary, and Bosnia and Herzegovina. These barriers prevent the full implementation of circular practices throughout the lifecycle of machinery.

First, customers often dictate product requirements, leaving little room for integrating circular solutions, such as modular structures or recycled materials. Many buyers are unwilling to pay a higher price for sustainable products, which reduces the motivation of companies to invest in circular transformation. Low awareness of circularity among both producers and consumers aggravates the issue.

Secondly, technological constraints persist. Many companies still operate older machinery lacking sensors, automation, or predictive maintenance capabilities, which limits the potential for efficiency improvements and lifetime extension. Retrofitting is possible but not always systematically implemented. A lack of standardisation in machine components further complicates repair and disassembly.

Economic and funding barriers are also significant. Insufficient financial support, limited grants, and regulatory restrictions, such as limits on the use of solar energy or inefficient incentive systems, slow down the adoption of circular solutions. Some companies lack funds to invest in new technologies, recovery units, or advanced monitoring systems.

Participants also recognised gaps in collaboration and information exchange. There is no coordinated registry or network to match producers of scrap materials with companies that could reuse them. As a result, valuable materials such as nickel, copper, and stainless steel are often sold cheaply as waste rather than integrated into secondary loops.

Finally, time and skill limitations emerged as persistent barriers. Circular processes require trained staff, interdisciplinary cooperation, and new competencies. Without sufficient knowledge of eco-design, LCA, maintenance optimisation, or circular business models, companies continue relying on linear practices.

Step 3.
Assigning problems to track sections

At which point in a product's lifetime does each hurdle occur?
What are the consequences of each hurdle?

- At which point in a product's lifetime does each hurdle occur?
- What are the consequences of each hurdle?

In the Design & Material Selection stage, limited customer acceptance of circular solutions results in machines that are not modular, difficult to repair, and made from non-recyclable or resource-intensive materials. Poor design choices lock in inefficiencies for decades, making future circular loops harder to implement.

Within Manufacturing & Production, older equipment, insufficient automation, and lack of funds for innovation hinder energy efficiency and waste reduction efforts. Valuable materials such as nickel and copper are lost due to inadequate recovery processes. Strict regulations on renewable energy usage restrict opportunities to reduce carbon footprint.

In the Use & Maintenance phase, machines without sensors or AI-based predictive systems experience more frequent breakdowns, resulting in higher energy use, shorter lifetimes, and increased demand for new products. Without good maintenance practices or retrofitting, the operational phase becomes a driver of unnecessary resource consumption. Repair, Refurbishment & End-of-Life challenges include unavailable spare parts, non-standardised components, and poor design for disassembly. These issues lead to premature scrapping, lost material value, and missed opportunities for remanufacturing. Companies that do not participate in take-back schemes or material recovery lose access to valuable secondary raw materials. In Waste Management and Reverse Logistics, the lack of organised networks for exchanging scrap, limited awareness, and insufficient recovery systems result in recyclable materials being sold cheaply or discarded. This not only increases environmental burdens but also raises production costs due to unnecessary reliance on virgin materials.
Step 4. **Determining importance of track sections** Which sections are the most important to tackle? Do these sections have many problems that need to be solved or little problems that are very important? Include a graphic representation of the importance (photograph of flipchart or processed data)
- **Which sections are the most important to tackle?** - **Do these sections have many problems that need to be solved or little problems that are very important?** - **Include a graphic representation of the importance (photograph of flipchart or processed data)** After extensive discussion, participants concluded that the Design & Material Selection stage is the single most important section to address. This stage determines the long-term circularity potential of every machine and influences repairability, disassembly, modularity, lifetime extension, and recovery of materials. Many challenges identified in later stages can be prevented entirely by better design choices. The Use & Maintenance phase was identified as the second most critical, because this is where machines consume the majority of energy and where lifetime can be extended or shortened depending on maintenance practices. Problems in this phase are not numerous, but the importance of addressing them is extremely high since improvements have direct environmental and economic impacts. The Manufacturing & Production section also contains significant challenges, particularly related to energy efficiency, technological gaps, and inefficient material management. Although many problems at this stage are solvable through investment and improved processes, their combined effect is substantial. The End-of-Life & Recovery section contains fewer barriers than the earlier stages, but the consequences of unresolved issues are large, as they determine whether materials re-enter

the loop or become waste. Better standardisation, take-back systems, and reverse logistics would really improve outcomes.

Finally, Waste Management & Reverse Logistics was viewed as an area with moderate complexity but high potential for impact. With appropriate networking platforms, recovery systems, and incentives, the sector could significantly reduce material loss and lower reliance on virgin resources.

Fill out this part only after completing “Step 9” of the Workshop Concept:

Step 5. **Considering the hurdles of plastics processors** What are their most important hurdles? Which hurdles can we as machine producers help them overcome? And how?
- **What are their most important hurdles?** - **Which hurdles can we as plastics processors help them overcome? And how?** Plastics processors face several major hurdles that limit their ability to operate circularly. These include variability in material quality, high energy consumption, lack of standardisation in tools and components, dependence on water-intensive cooling systems, and limited predictability of machine performance. Processors also struggle with high waste rates, difficulties in reusing materials, and high operational costs due to inefficient or outdated machinery. Machine producers can help plastics processors overcome these hurdles in several ways: First, by designing more modular and energy-efficient machines, producers can directly reduce energy consumption during plastics processing. Switching from hydraulic to electric machines, improving process automation, and integrating digital twins support processors in achieving greater stability and lower waste. Next, machine producers can offer predictive maintenance tools that improve uptime, reduce failures, and prevent material loss. AI-based monitoring systems, machine vision for defect detection, and early failure prediction all increase efficiency along the plastics processing line. Producers can also support water-loop circularity by offering improved cooling technologies, enabling processors to reuse water for heating or reintegrate it into a closed-loop system. Shared practices, such as using waste heat for facility heating, can be incorporated into machine design. Through standardisation of parts and design for disassembly, machine producers can help processors achieve smoother maintenance and reduce downtime. Such standardisation also simplifies recycling and end-of-life management. Finally, machine producers can facilitate access to secondary raw materials by developing take-back schemes, cooperating on recovery units, or connecting processors to networks for exchanging scrap materials. This strengthens the overall ecosystem and reduces costs for all actors.
Step 6. **How feasible are these solutions? How useful would overcoming this hurdle be? (score of 1-10 for each)** Which lifts have the highest score overall? Include a picture of the Feasibility/Usefulness scale (photograph or processed data)

- **Which lifts have the highest score overall?**
- **Include a picture of the Feasibility/Usefulness scale (photograph or processed data)**

1. Retrofitting older machines with sensors, automation, and energy-efficient upgrades:
This solution scored very high in both feasibility and usefulness because it allows companies to extend machine lifetime at relatively low cost while reducing energy consumption and improving process stability. Retrofitting is more affordable than replacing machinery and has immediate environmental and financial benefits.

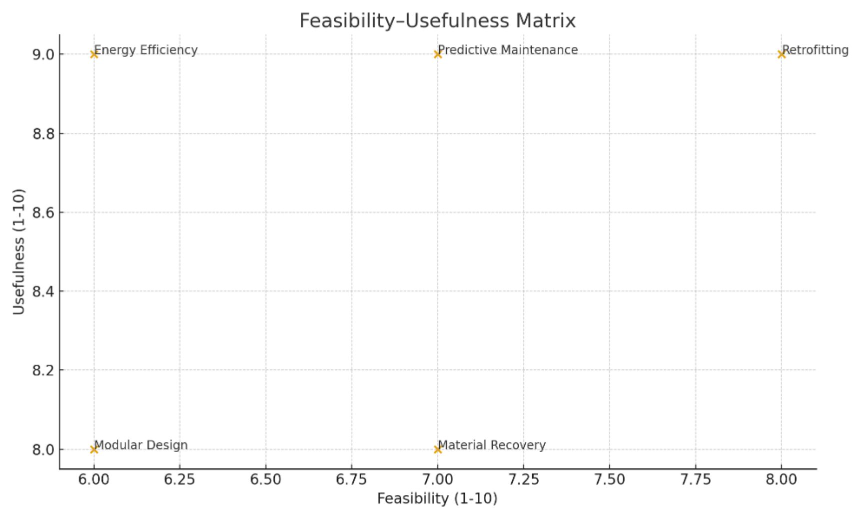
2. Implementing predictive maintenance and AI-based monitoring systems:
Participants rated this as highly useful due to its potential to significantly reduce downtime, prevent failures, and reduce waste. Since many companies are already investing in digitalisation, feasibility is also high.

3. Introducing modular design and standardised components for easier repair and disassembly:
While this requires changes in design practices, it is highly useful for processors and strongly supports circularity. The long-term impact on maintenance efficiency, materials recovery, and lifetime extension is substantial.

4. Closing resource loops through improved recovery of metals and reuse of process water:
Technologies such as nickel recovery units, circular water-cooling systems, and secondary material filtration were considered both feasible and highly impactful because they reduce waste, lower costs, and diminish environmental burden.

5. Switching from hydraulic to electric machinery and increasing overall energy efficiency:
This lift scored high in usefulness due to the strong link between energy use and carbon footprint. Its feasibility varies by company, but participants agreed it is a strategic shift with transformative long-term gains.

Additional high-potential actions included collaboration platforms for scrap exchange, unified component sizing, and expanding the use of solar energy where legislation allows.



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Strategy development with transformation roadmaps with machine producers

Deliverable D.3.2.2 - RECORD SHEET

SPK, TUKE, UTB, Plastr

All interregional groups are responsible for evaluating and completing this check list, which contains individual parameters that should be evaluated and recorded during workshop D.3.2.2. In some cases, short statements are sufficient; in other cases, please provide an evaluation comment, upload files, photo documentation, etc.

Involved Partners:	TUKE, SPK, UTB, Plastr
Participants:	33 participants
Date of proceeding:	10.10.2025
Place of proceeding:	Hotel Kontakt, Stará Lesná 180, 059 52, Slovakia

Proposed Workshop topic:
Hurdles & Lifts - Machine producers identify hurdles in the circularity of their products. - Each Participant then seeks a way to “lift” plastics processors over their hurdles.
Short description of the workshop, possible images, photos, etc.:
Description: The workshop organized with **two target groups** – machine manufacturers and plastic processors included the following procedures/steps. **The target group** consisted of participants from the university sector, from production (small and medium-sized companies), research representatives. In terms of age composition and male and female representatives, it was balanced, which has a great impact on defining and solving obstacles. The participants came from both the Czech Republic and the Slovak Republic. The official language of the workshop was Slovak, the participants presented and discussed in their national languages. **In the introduction**, the project content, project outputs and results, the workshop objective and the timeframe were presented. All participants **introduced themselves** (name, job position, organization, and were supposed to identify themselves with some part of the product cycle (within the circular economy). It was necessary to have enough **didactic materials ready** for the workshop (flip papers, markers, colored sticky notes). The essence of the Roud map method and the possibilities of its use were presented. Both groups reviewed key EU documents on the circular economy and at the same time some key points from the Circular Economy Action Plan in the Slovak Republic were selected. **Subsequently, methodological procedures were carried** out: defining areas - sections within the product cycle (especially for plastics and especially for machines), 5 areas were determined for each cycle and prioritization was carried out. Subsequently, obstacles in the given sections and proposed solutions were determined. The groups moved 2 times - when defining obstacles (they were supplemented by the second group - the second view) and when solving obstacles (the view of the second group was supplemented). The structure was also presented within the workshop Action Plan *(general)* and methodological

connection of individual parts of the Action Plan with the outputs of the Roadmaps method. Therefore, the groups continued with further activities, added to individual solutions for usefulness and feasibility.
Subsequently, the groups changed again, and points from 1-3 were assigned for the time frame (need for speed of implementation). To implement the solutions, the group also proposed evaluation criteria for the proposed solution to be implemented.

At the end of the workshop, a summary was made for each group (plastics processors and machine manufacturers), and a map was presented - the path of transferring outputs to the Action Plan and tasks to be solved in accordance with the action plan.
All workshop participants provided **oral feedback on the workshop** - methodology, outputs, and the meaning of using the Roud map method for planning in accordance with the action plan.
All procedures were **implemented in each group on 2 flipchart papers.**
The workshop **lasted 4.5 hours,** including a break.

Results and discussion of the Workshop step-by-step:

Step 1.
Identifying 5 track sections for machine producers
What sections during a products lifetime are the most important for circularity?

- **Identify 5 track sections for machine producers**
- **What sections during a products lifetime are the most important for circularity?**

The group selected the **5 most important sections** (areas) within the cycle, drew a table on another flipchart paper and listed only the 5 most important sections (areas) within their product cycle in the left part (see).
In the next step, the importance of the sections of the route was determined. Each participant could assign **6 points to all sections**. (They could assign points to any sections, divide them into several sections or assign all points to one section if they considered it particularly important.)
The sections were then ranked by importance - according to the total number of points. Each participant added the points themselves. They did not have to discuss them with their colleagues in advance, but they can discuss them later. It is advisable for each participant to take a marker and assign their points for the individual sections. The points were finally tallied.

Section	Importance
design	7 ● ● ● ● ● ● ●
construction	12 ● ● ● ● ● ● ● ● ● ● ● ●
recycling	6 ● ● ● ● ● ●
use	..... 5 ● ● ● ● ●
production *(for example, injection molding machine)*	.... 6 ● ● ● ● ● ●

Step 2. **Identifying hurdles on the track** What keeps a product / process from becoming circular? What problems arise during the transformation towards circularity?
1.Competitiveness of the machine manufacturer 2.Expert knowledge 3.Raw material resources 4.Technical feasibility of recycling - Cost of recycling 5.Society's attitude towards recycling 6.Technical limitations 7.Qualified users/qualified machine operators 8.Final machine price
Step 3. **Assigning problems to track sections** At which point in a product's lifetime does each hurdle occur? What are the consequences of each hurdle?

Construction	Design	Recycling
1. Competitiveness of the machine manufacturer 2.Expert knowledge	Raw material resources	1.Technical feasibility of recycling - Cost of recycling 2.Society's attitude towards recycling

Production *(for example, injection molding machine)*	Use
Technical limitations	1.Qualified users/qualified machine operators 2.Final machine price

The consequences of the obstacles were not precisely defined. In the following steps, the time horizons - the urgency of the solution - were defined.

Step 4. **Determining importance of track sections** Which sections are the most important to tackle? Do these sections have many problems that need to be solved or little problems that are very important? Include a graphic representation of the importance (photograph of flipchart or processed data)
In the previous steps (1-3) as well as in the summary description of the whole workshop, it is stated that **5 key sections/areas** were selected within the design, construction, production, use and recycling of machines. All the problems that the group participants named could be assigned to these 5 key sections/areas of the "path" = the circularity

cycle. In step 4, the obstacles and sections that were identified as the most important were selected.

Construction	**Design**
1. Competitiveness of the machine manufacturer 2.Expert knowledge	Raw material resources

Recycling	**Production *(for example, injection molding machine)***
1.Technical feasibility of recycling - Cost of recycling 2.Society's attitude towards recycling	Technical limitations

Step 5.

Considering the hurdles of plastics processors

What are their most important hurdles?

Which hurdles can we as machine producers help them overcome? And how?

The most important hurdles regarding machine manufacturers and plastics processors were in the design and recycling sections.

Recycling	**Design**
defined hurdles	defined hurdles
1. Technical feasibility of recycling - Cost of recycling 2. Society's attitude towards recycling	Raw material resources
proposed solutions	proposed solutions
1.1 Research and automation 1.2 Recycling support and incentives 2. Awareness of the benefits of recycling	Development of less resource-intensive technologies

At the same time, **common and very important problems (hurdles) were defined**, which should be solved together.

1) EU legislation

2) Quality and sufficiency of human resources

proposed solutions

1) active participation in the comment procedure for European legislation
2) support for the dual education system in secondary schools,
support for the active participation of students in solving company tasks,
provision of various forms of education for professional employees (technicians, designers) within the framework of lifelong learning.

Step 6. **How feasible are these solutions? How useful would overcoming this hurdle be? (score of 1-10 for each)** Which lifts have the highest score overall? Include a picture of the Feasibility/Usefulness scale (photograph or processed data)
The group participants were asked to define the usefulness and feasibility of each proposed solution. **A shorter scale was chosen, from 0 to 5**. The participants from each group took colored post-its and assigned a record to each solution, where **the first number indicated feasibility and the second number indicated usefulness** (on a scale from 0-5). In the record it then looked like e.g. 4:5 (where 4 was the feasibility of the solution and 5 indicated usefulness.) <u>The following proposed solutions achieved the **best ratio** of feasibility and utility for machinery producers:</u> • Functional engineering and design 5:5 • Support for technical education (including machine operator training) 5:5 • Awareness of the benefits of recycling 5:5 <u>The following proposed solutions received the **lowest scores** in terms of feasibility</u> • Development of technologies that are less resource-intensive 4:5 • State demand 3:5 <u>From the perspective of the **urgency of solving the problems**, the following solutions were selected as urgent:</u> a) Legislative measures, improvement procedures, marketing procedures, functional construction and design - **the problem of competitiveness** b) Development of technologies less demanding on raw materials - **the problem of raw materials resources** c) Training of technicians, operators who operate machines - **the problem of qualified employees/machine operators**

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Strategy development with transformation roadmaps with machine producers

Deliverable D.3.2.2 - RECORD SHEET

CLUSTERO

ICMPP

SORINTEX

All interregional groups are responsible for evaluating and completing this check list, which contains individual parameters that should be evaluated and recorded during workshop D.3.2.2. In some cases, short statements are sufficient; in other cases, please provide an evaluation comment, upload files, photo documentation, etc.

Involved Partners:	ROMANIA (ICMPP & CLUSTERO) / REPUBLIC OF MOLDOVA (Sorintex)
Participants:	14 Participants
Date of proceeding:	30.10.2025
Place of proceeding:	Targoviste, Romania

Proposed Workshop topic:
Hurdles & Lifts - Machine producers identify hurdles in the circularity of their products. - Each Participant then seeks a way to “lift” plastics processors over their hurdles.
Short description of the workshop, possible images, photos, etc.:
The workshop focused on identifying the main challenges (“hurdles”) encountered by machine producers in their transition toward circularity. Participants first mapped the key stages in the lifecycle of plastics-processing machines, then identified specific hurdles linked to each stage. Finally, they explored potential “lifts”—opportunities, measures, or support mechanisms that could help overcome these barriers. The session encouraged open dialogue between participants, highlighting interdependencies across the value chain and strengthening cooperation toward circular solutions.

Results and discussion of the Workshop step-by-step:

Step 1. Identifying 5 track sections for machine producers
- **Identify 5 track sections for machine producers** During the workshop, participants collaboratively identified five key lifecycle stages that have the strongest influence on the circularity of machines used in plastics processing. These stages shape decisions that affect repairability, material recovery, resource efficiency, and end-of-life options: • **Design & Development** • **Material Sourcing** • **Use Phase & Maintenance** • **Repair & Reuse** • **Waste Management** These five sections were selected because they cover the full value chain of machinery—from conceptualization and material inputs to operation, end-of-life management, and reintegration into the cycle. - **What sections during a products lifetime are the most important for circularity?** Participants ranked the five stages according to their potential to drive circularity improvements across the machinery sector: 1. **Repair & Reuse -** This stage focuses on restoring functionality through repair and reusing components. It is essential for minimizing waste generation and maximizing the lifetime value of machines. 2. **Design & Development -** This phase defines the machine's structure, material selection, and level of modularity. Decisions made at this stage determine repairability, durability, ease of upgrading, and end-of-life recyclability. 3. **Use Phase & Maintenance -** Operation and maintenance practices play a major role in extending machine lifespan. Proper servicing, energy-efficient operation, and skilled maintenance reduce early replacement needs and support circular use. 4. **Material Sourcing -** The choice of raw materials and components affects spare part availability, compatibility with recycled inputs, and the overall environmental footprint of production. 5. **Waste Management -** The end-of-life phase—including disassembly, recycling, and energy recovery—determines how much material can be reintegrated into the production cycle versus lost as waste.
Step 2. Identifying hurdles on the track
- **What keeps a product / process from becoming circular?** Participants analyzed the main factors that currently prevent machines in the plastics sector from becoming fully circular. The discussion highlighted several critical barriers that limit repairability, reuse, and efficient resource management throughout a product's lifecycle. The following **hurdles** were identified as key obstacles to circularity:

1. **Low energy efficiency** - Many existing machines operate with high energy consumption, increasing operational costs and environmental impact. This reduces the competitiveness and sustainability of production systems.
2. **Lack of information about the type of plastic used -** Missing, incomplete, or unclear data regarding the type of plastic or components used limits recyclability and traceability. Without proper labeling, it is difficult to integrate secondary materials or design compatible components.
3. **Shortage of specialists in repair and maintenance** - The lack of trained technical personnel results in longer downtimes, more frequent failures, reduced equipment lifetime, and increased waste generation.
4. **Lack of spare parts availability -** Difficulty in sourcing replacement components prevents timely repair and encourages premature disposal of machines, which undermines circular maintenance strategies.
5. **Lack of infrastructure for component reuse -** The absence of dedicated collection, inspection, and refurbishment systems leads to the disposal of parts that could otherwise be reused.

- **What problems arise during the transformation towards circularity?**

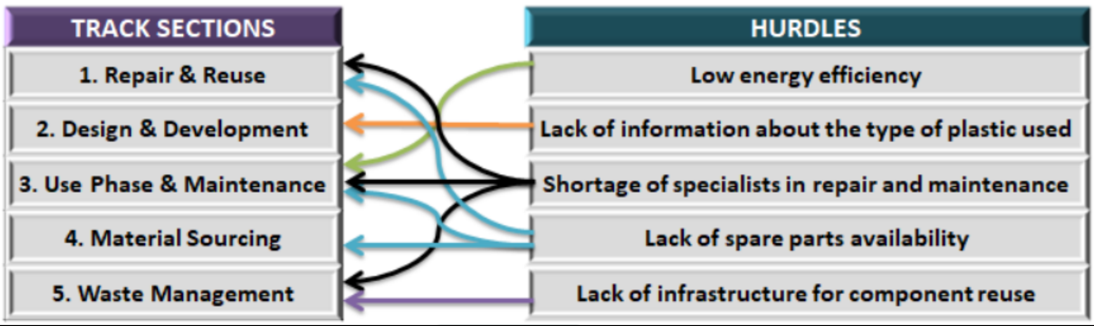
Given the **five hurdles** identified during the workshop, the transition from linear to circular models becomes particularly challenging. These barriers not only **limit current circularity** but also **create additional systemic difficulties** during the transformation process.

Companies face ***high transition costs*** for upgrading equipment, training staff, and adjusting processes, while ***resistance to change*** can arise when the benefits of circularity are not immediately visible. The ***lack of standardized protocols*** for repairability, modularity, and recycling further complicates implementation across the value chain. In addition, a ***fragmented industrial ecosystem*** and *a* ***limited market for refurbished components***—combined with ***low customer trust*** and ***insufficient quality assurance***—restrict the development of effective reuse loops. ***Regulatory gaps*** related to waste management and secondary materials also slow down adoption. Altogether, the five hurdles amplify the challenges encountered throughout the shift toward a fully circular system.

Step 3.
Assigning problems to track sections

- **At which point in a product's lifetime does each hurdle occur?**
- **What are the consequences of each hurdle?**

To better understand where circularity breaks down in the lifetime of a machine, each hurdle identified during the workshop was assigned to the track section(s) where it most commonly occurs:



This step clarifies both **when** the problem appears and **how** it affects the transition toward circularity:

1. Low energy efficiency → Assigned to: **Use Phase & Maintenance**

a) Where in the product's lifetime?

This hurdle occurs during machine operation, where high energy consumption directly affects performance and sustainability.

b) Consequences:

- Higher energy costs and increased greenhouse gas emissions.
- Reduced competitiveness and alignment with sustainability goals.
- Maintains resource-intensive production, limiting circularity potential.

2. Lack of information about the type of plastic used → Assigned to: **Design & Development**

a) Where in the product's lifetime?

This hurdle originates during the design stage, when documentation, labeling and material information are not properly established.

b) Consequences:

- Poor traceability makes reuse and recycling difficult.
- Restricts circular design strategies and the use of recycled materials.
- Reduces collaboration across the value chain due to lack of transparency.

3. Shortage of specialists in repair & maintenance → Assigned to: **Use Phase & Maintenance / Repair & Reuse**

a) Where in the product's lifetime?

This hurdle manifests during the machine's operational life, particularly in the phases requiring servicing, troubleshooting or refurbishment.

b) Consequences:

- Longer downtimes and increased operational costs.
- Premature disposal of machines that could be repaired.
- Reduced machine lifespan and lower resource efficiency.

4. Lack of spare parts availability → Assigned to: **Material Sourcing / Use Phase & Maintenance / Repair & Reuse**

a) Where in the product's lifetime?

The issue appears throughout the machine's life, but is most critical:

- during **sourcing**, when compatible parts are not available
- during **maintenance**, when parts are needed to repair faults
- during **repair & reuse**, when parts determine whether equipment can be refurbished

b) Consequences:

- Repairs are delayed or impossible → full machine replacement.
- Circular maintenance strategies cannot be implemented.
- Increased reliance on external suppliers, raising costs and waste.

5. Lack of infrastructure for component reuse → Assigned to: **Waste Management (End-of-Life)**

a) Where in the product's lifetime?
This hurdle appears at the end-of-life stage, when machines or components are discarded and there is no system to collect, refurbish or reintegrate usable parts.
b) Consequences:

- Functional components are discarded instead of reused.
- Material recovery is limited, reducing circularity.
- More virgin materials must be produced → higher environmental impact and costs.

Step 4.
Determining importance of track sections

- **Which sections are the most important to tackle?**

To determine the importance of each track section, participants' votes on the five hurdles were summed and redistributed based on the section(s) to which each hurdle belonged. This allowed the hurdle-level prioritization to be translated into a section-level prioritization.
By summing the prioritization votes for the hurdles within each section, the **Use Phase & Maintenance** emerged as the most critical section to address, followed by **Repair & Reuse**, **Material Sourcing**, **Waste Management**, and **Design & Development**.

- **Do these sections have many problems that need to be solved or little problems that are very important?**

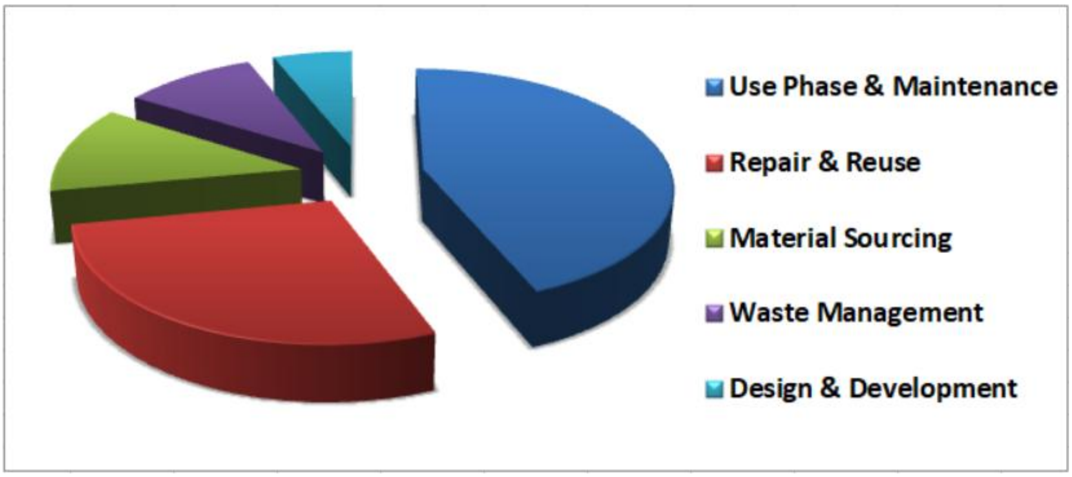
- **Use Phase & Maintenance** concentrates several high-impact hurdles—low energy efficiency, shortage of specialists, and lack of spare parts availability. Although not the section with the highest number of distinct problems, the **impact** of these problems is very strong, affecting machine lifespan, and directly influencing energy consumption, machine reliability, and lifespan.
- **Repair & Reuse** includes fewer hurdles, yet these are strategically important because they determine whether machines can be restored instead of discarded.
- **Material Sourcing** is affected by the availability of spare parts, a single but highly influential issue that affects maintenance and repair across the entire lifecycle.
- **Waste Management** includes one hurdle—lack of reuse infrastructure—whose importance lies in enabling circularity at the end of the product lifecycle.
- **Design & Development**, although linked to fewer hurdles, influences long-term circularity by enabling material traceability and better design documentation.

Overall, the findings show that **impact outweighs quantity**: sections with fewer hurdles may still be critical because their problems have strong systemic effects across the entire lifecycle.

- **Include a graphic representation of the importance (photograph of flipchart or processed data)**

Track section Importance (Pie Chart)

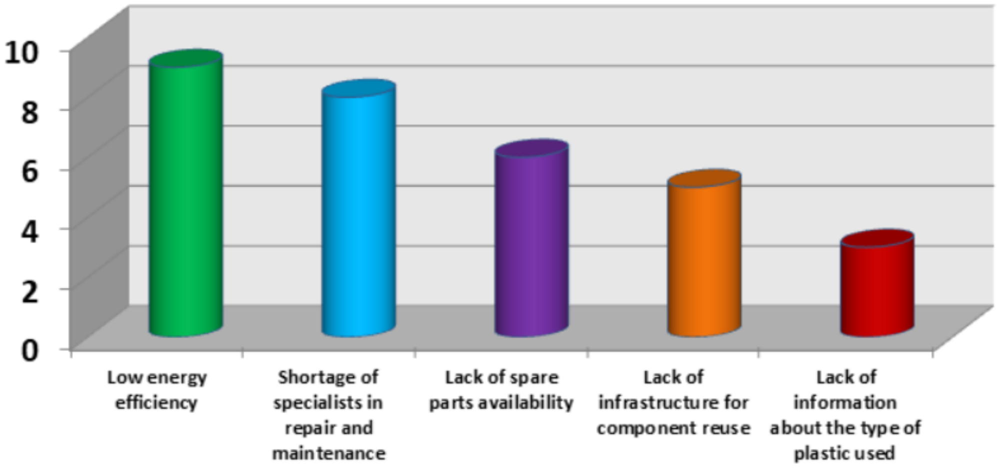
This chart presents the aggregated importance of the five track sections, based on the votes attributed to the hurdles connected to each section.



Step 5.
Considering the hurdles of machine manufacturers

- **What are their most important hurdles?**

Hurdle Prioritization (Bar Chart) : This chart illustrates the prioritization scores assigned to each hurdle by the participants.



Based on the prioritization results (as shown in the bar chart), the most important hurdles identified by participants are:

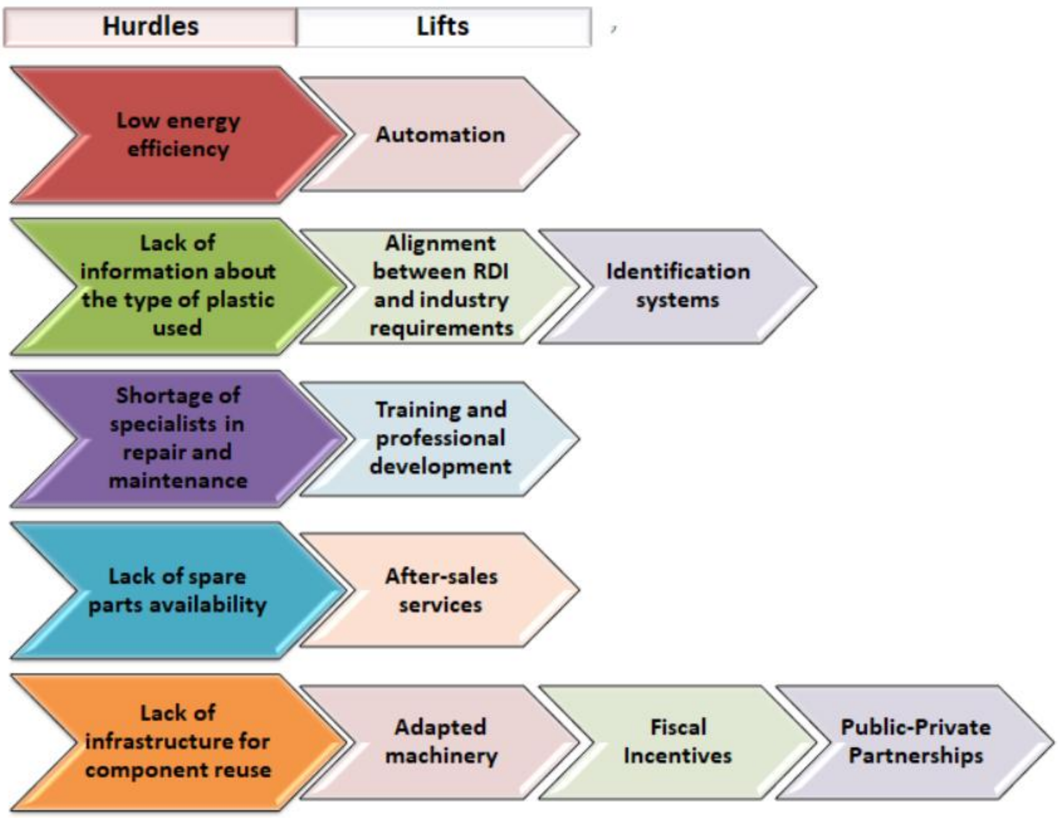
1. **Low energy efficiency**
   This hurdle strongly influences production costs, sustainability performance, and overall circularity potential during the use phase.
2. **Shortage of specialists in repair and maintenance**
   Also highly ranked, this hurdle affects both the operational performance of machines and the ability to extend their lifespan through repair, refurbishment, and reuse.

3. **Lack of spare parts availability**
   Although slightly lower in ranking, it remains a major constraint, as it directly determines whether equipment can be repaired or must be prematurely replaced.
4. **Lack of infrastructure for component reuse**
   Moderately important, this hurdle affects end-of-life options and limits the reintegration of functional components into new production cycles.
5. **Lack of information about the type of plastic used**
   While having the lowest score, it still remains a strategically relevant hurdle, as it impacts traceability, design, and compatibility with circular materials.

These priorities reflect both the **frequency** of operational challenges and their **systemic impact** across the machinery lifecycle.

- **How can be this hurdles overcomed?**

During the workshop, participants proposed several **cross-cutting solutions** to address the identified hurdles. The suggestions focus on technological innovation, skill development, improved service systems, and stronger collaboration between research, industry, and policy, as graphically shown below:



6.1.1.1 1. Automation

- Implementing automated monitoring, control, and diagnostic systems to improve energy efficiency and reduce dependency on specialized technicians.
- Using smart sensors and predictive maintenance tools to prevent failures and optimize machine performance.

6.1.1.2 2. Better alignment between RDI (Research, Development & Innovation) and industry requirements / Identification systems

- Introducing standardized identification systems (e.g., labeling, digital passports) to ensure clear information about materials and components.
- Strengthening collaboration between research institutes and industrial actors to develop solutions tailored to real operational needs.

6.1.1.3 3. Training and professional development

- Developing specialized training programs to increase the number of skilled technicians in repair, maintenance, and circular operations.
- Enhancing continuous learning for operators to improve machine use, maintenance quality, and energy-efficient practices.

6.1.1.4 4. Improved after-sales services

- Expanding technical support, maintenance agreements, and remote diagnostics to ensure timely assistance.
- Ensuring better spare parts availability through optimized inventories, modular components, and service partnerships.

6.1.1.5 5. Adapted machinery/ Fiscal incentives / Public-Private Partnerships

- Designing machines with modularity, easy disassembly, and compatibility with refurbished components.
- Facilitating upgrades instead of replacements to extend equipment lifespan.
- Encouraging investments in energy-efficient technologies, reuse systems, and training through tax reductions or subsidies.
- Supporting companies adopting circular models through targeted financial instruments.
- Creating collaborative networks between public authorities, industry, and research organizations to develop shared repair, reuse, and recycling infrastructure.
- Supporting pilot projects that demonstrate the viability of circular practices in machinery production and usage.

Step 6.
How feasible are these solutions? How useful would overcoming this hurdle be? (score of 1-10 for each)

- **Which lifts have the highest score overall?**

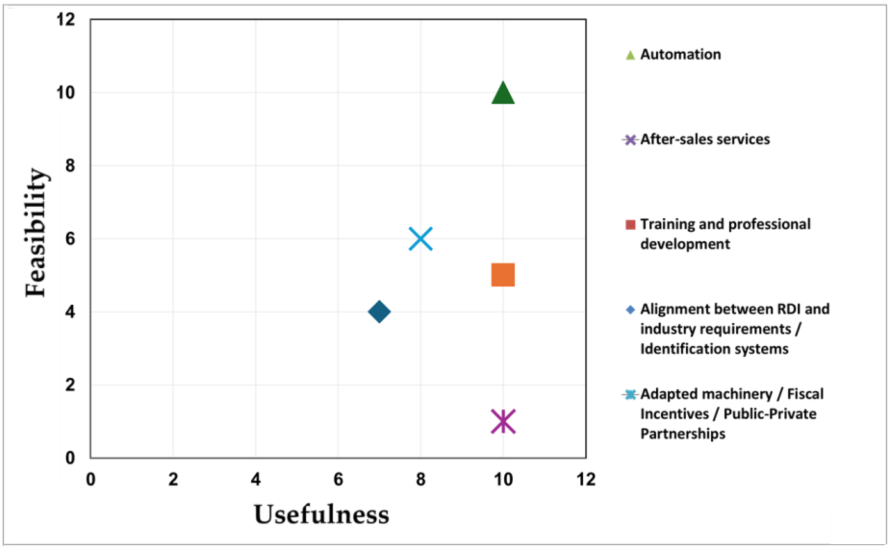
The lift with the highest overall score is:

1. **Automation** (Feasibility: 10, Usefulness: 10) with an **Overall Score of 20**.

The next highest-scoring lifts are:

2. **Training and professional development** (Feasibility: 5, Usefulness: 10) with an **Overall Score of 15**.
3. **After-sales services** (Feasibility: 8, Usefulness: 6) with an **Overall Score of 14**.

- **Include a picture of the Feasibility/Usefulness scale (photograph or processed data)**


Feasibility
Usefulness
0
2
4
6
8
10
12
Automation
After-sales services
Training and professional development
Alignment between RDI and industry requirements / Identification systems
Adapted machinery / Fiscal Incentives / Public-Private Partnerships