GUIDELINE – DEMO FACTSHEET no.1

Pillar I : RECYLABILITY

Deliverable D.1.2.5

Proposed solution identification – based on DTWs :
The processing and recycling of waste plastics generates a lot of waste sludge, which contains plastic parts and various contaminants. At present, this sludge is specified as hazardous waste and its disposal represents a significant expense for the operators of recycling lines. **As part of the demonstration and prototyping phase, we focused on the possibilities of using this waste, which is generated during the recycling of plastics.**
Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase :
• Material (waste of waste) is currently exclusively landfilled is reused within the proposed solution. • The proposed and pre-tested solution significantly increases the period of use of the material originally obtained from fossil sources; at the same time, it was verified in pilot production that the technology is reliable and effective.

Prototyping and Demonstration step-by-step :

Step 1. - Understand your idea
Goal & Purpose of the Prototype The aim is to verify the very principles and possibilities of processing such materials that are a secondary (waste) product in plastic recycling. **What problem is the prototype meant to solve?** Using appropriate sludge treatment technologies, polymer particles can be separated and processed into a recyclable form. The waste material could be used for the production of e.g. building elements (tiles, blocks, etc.) or grass grates. By selecting the appropriate composition of the final primary or secondary sludge-based composite mixture, durable and reliable structural components can be produced. **Who is the target audience?** Recycling production plants focused on PE and PP post-consumer waste, as well as many manufacturers, especially of technical plastic parts **Which hypotheses are to be tested?** In particular, the composition of such materials must be verified as well as their processability; including that recommendations for final products should be defined
Step 2. - Functionality & Features
What are the core functions? The key functional parameters are : properties suitable for technical applications, harmlessness and sufficient service life **Which features are necessary to achieve the goal?** - processability using conventional technologies – - compactness and mechanical properties of products made from this material - last but not least, aesthetic acceptability. **Which functions could be added later?**

Step 3. - Technology & Materials & other Inputs needed

What technologies, platforms, or tools will be used?
Laboratory and test plastics technologies were used for prototyping - crushing, sorting, compounding, extrusion and injection molding :

If it's a physical prototype: What materials are suitable?
Real materials from recycling plants were used for prototyping and demonstrating the process - that is, the very materials whose use for the proposed products is the subject of this assignment :

Step 4. - Type of Prototype
Low-Fidelity (low detail level): Sketches, wireframes, paper models
High-Fidelity (high detail level): Interactive mockups, functional models
(Written detailed description ; prevent intellectual property infringement)

The final prototype within the solution are models of semi-final products with real production and commercial value. However, several phases/stages took place within the prototyping process, which can be characterized separately by individual prototyping phases and outputs:

↓

Step 5. - Testing Strategy
How will the prototype be tested? Basic tests of mechanical properties, accelerated aging and application behavior will be performed on prototype samples. **Which metrics or feedback methods will be used?** In the first phase of testing the properties, the standards and requirements that apply to the incriminated products made from primary raw materials will be used. It is likely that the target customer will then have the opportunity to modify these parameters and reduce the requirements with regard to the nature of the material used - this will mainly concern properties related to durability.
Step 6. - Iteration and Development Process
What steps follow after the first prototype? - property evaluation - business evaluation by marketing - comparison with existing products - economic calculations and product costing **How will the feedback be integrated?** An economic study and a feasibility study will be prepared in terms of availability and securing of resources. In parallel, a marketing evaluation will be carried out using prototypes by contacting key customers and discussing the topic with them.

Step 7. **Circularity** How does the prototype impact circularity/sustainability/requirements of circular economy?
The proposed solution allows for the treatment of otherwise unusable waste, which is currently classified as hazardous and ends up in landfills, or at best in incinerators. **That means the main impact is in :** • **use of recycled material = reduction in consumption of primary raw materials** • **reduction of landfilling and incineration = reduction of GWP, reduction of risk of ecotoxicological impact and human toxicity, reduction of energy consumption**

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GUIDELINE – DEMO FACTSHEET no.2

Pillar II : RECY-BIO CONTENT

Deliverable D.1.2.5

Proposed solution identification – based on DTWs :
Natural composite materials from industrial hemp
Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase :
Given that industrial hemp is a crop with very high potential and application possibilities and represents a species suitable for growing on the territory of the Republic of Serbia (especially in Vojvodina), the focus is on the processing different plant parts with the aim of obtaining the final products that can replace plastic and plastic parts in certain industries. The final conceptual solution is natural composite materials created by processing natural resin and natural fibers of industrial hemp, which can potentially replace plastic parts and plastic products, primarily in the automotive and packaging industries. So the idea is that instead of traditional plastic parts and plastic packaging, a process of transformation towards a more sustainable model will take place, including parts and packaging containing the highest percentage of industrial hemp.

Prototyping and Demonstration step-by-step :

Step 1. **Understand your idea** Goal & Purpose of the Prototype What problem is the prototype meant to solve? Who is the target audience? Which hypotheses are to be tested?
What problem is the prototype meant to solve? The prototype aims to address one of the most pressing environmental challenges today — the overwhelming presence of single-use plastics in the packaging industry. Conventional plastic packaging, especially trays used for food, electronics, cosmetics, and other consumer products, is typically produced using fossil-based polymers that are neither biodegradable nor easily recyclable. These materials persist in the environment for centuries, contributing to land and ocean pollution, harming ecosystems, and exacerbating the climate crisis through their carbon-intensive production processes. This prototype responds to these issues by offering a natural, circular, and biodegradable alternative — a molded tray made from industrial hemp fibers and natural resins. It provides a realistic and sustainable replacement for plastic trays, especially those used for short-lifecycle applications, such as protective packaging, transport trays, and single-use containers. It not only targets environmental degradation caused by plastic waste but also aims to reduce the resource consumption associated with conventional packaging manufacturing, such as water use, high energy demand, and chemical inputs. In the context of Serbia, this prototype also responds to the national need for more sustainable industrial practices. Serbua has a significant agricultural base, especially in Vojvodina, where industrial hemp can be cultivated with minimal environmental impact. This makes the solution not only ecologically good but also locally viable and economically promising, potentially contributing to rural development, green innovation, and alignment with European Union circular economy strategies.

Who is the target audience? The target audience for this prototype includes several groups. First, it addresses companies in the packaging industry, especially those seeking to transition from plastic to sustainable materials. These may include manufacturers of consumer goods (such as electronics, cosmetics, or food products) who are under pressure to reduce their environmental impact, particularly companies exporting to the EU where environmental regulations are stricter. Second, the prototype is designed for eco-conscious startups and SMEs in Serbia and the broader Balkan region that are interested in embedding sustainability into their core business models. These companies are likely to be more agile in testing and adopting innovative materials. Third, the target audience includes public institutions, NGOs, and policymakers involved in promoting circular economy strategies. They may view this prototype as a tool to advance national and regional goals related to waste reduction, resource efficiency, and environmental protection. Lastly, this solution speaks to end consumers — indirectly — by responding to the growing demand for sustainable, compostable, and plastic-free products. It provides companies with a tangible way to meet the expectations of a market that increasingly values environmental responsibility. **Which hypotheses are to be tested?** • Hemp-based composites can match or outperform certain plastic parts in durability and mechanical strength. • These materials are economically viable to produce in Serbia with existing or adapted infrastructure. • The solution is environmentally superior to plastic in terms of carbon footprint, recyclability, and biodegradability. • Users (e.g., automotive manufacturers) will accept and integrate these parts into existing production lines.
Step 2. **Functionality & Features** What are the core functions? Which features are necessary to achieve the goal? Which functions could be added later?
Necessary features (core functions): • High mechanical performance: strength, flexibility, and wear resistance. • Moldability: Ability to be shaped into parts using existing industrial methods (e.g., injection molding or compression molding). • Biodegradability or recyclability: Under specified industrial or natural conditions. • Lightweight structure: Important for automotive and packaging efficiency. • Thermal and moisture resistance: Especially for packaging and interior automotive applications. Features to add later: • Color and texture customization for aesthetic or branding needs. • Smart additives (e.g., biodegradable antimicrobial agents or traceability markers). • Fire retardancy for automotive interiors. • Modular component design for easier repair/upgrade.
Step 3.

Technology & Materials & other Inputs needed What technologies, platforms, or tools will be used? If it's a physical prototype: What materials are suitable?
To develop this prototype, a combination of low-tech and medium-tech tools will be used, depending on the available resources and production capacity. In the initial prototyping stage, compression molding is the preferred technology. This technique involves placing a mixture of hemp fibers and natural resin into a heated mold where it is pressed into shape under pressure and temperature. Compression molding is well-suited for shaping composite biomaterials and is commonly used in the production of trays, panels, and structural components. The prototype may also benefit from thermoforming processes, especially in later stages when working with thin, pre-formed sheets made of hemp bioplastics. For smaller-scale or early testing, hand pressing, manual mold shaping, and small heated presses may be used in workshops or maker labs. In terms of materials, the solution is centered around industrial hemp fibers — derived from the stalks of the plant. These fibers are known for their high tensile strength, light weight, and renewability. They can be processed into mats or loose fibers suitable for mold pressing. The binding agent, or matrix, is a natural resin, such as a starch-based or lignin-modified biopolymer, which allows the tray to retain its form while being fully biodegradable and compostable. In some formulations, recycled natural fibers or biodegradable additives can be included to improve flexibility or surface finish. All materials chosen are non-toxic, biodegradable, and sourced locally, reducing the environmental footprint and supporting regional agricultural and processing economies.
Step 4. **Type of Prototype** Low-Fidelity (low detail level): Sketches, wireframes, paper models High-Fidelity (high detail level): Interactive mockups, functional models (Written detailed description ; prevent intellectual property infringement)
Sketch: Low-Fidelity Prototype of Hemp-Based Packaging Container    The prototype is a biodegradable, molded packaging tray, roughly the size and shape of a standard electronics or food tray, with shallow compartments designed to hold individual items securely. Its form is created through a custom mold that defines the structure and texture of the final product. The tray is made of compressed layers of industrial hemp fibers that are bonded using a natural, plant-based resin. These materials are mixed into a

semi-dry blend that is inserted into a mold, heated, and pressed until the desired form is achieved.
The final tray has a natural, fibrous texture, possibly with a slightly matte, grainy surface finish that reflects its organic origin. It is lightweight yet durable enough to protect products during transport. Depending on the use case, the tray can be designed to be stackable, modular, or form-fitting to different product types (e.g., phone accessories, food items, cosmetics).
This tray is fully compostable under industrial or home composting conditions, and if disposed of in natural environments, it will biodegrade without releasing microplastics or toxins. It can also be thermally processed or ground down into raw material for low-grade composites, enabling circular reuse within the production cycle.

Step 5.
Testing Strategy
How will the prototype be tested?
Which metrics or feedback methods will be used?

The testing process for this prototype involves both laboratory assessments and real-world performance evaluations. In the lab, the first step is to test the mechanical strength of the tray, including compression resistance, tensile strength, and flexibility. These tests ensure the tray can support the weight of typical products and withstand stacking during shipping or storage.
The tray will also undergo moisture resistance and temperature tolerance testing, particularly if it is intended for packaging food or products exposed to humidity. These tests help determine whether additional coatings or design adaptations are necessary for specific environments.
Another crucial test is biodegradability — conducted under controlled composting conditions to assess how long it takes for the tray to break down and whether it leaves any residue. The prototype's thermal insulation and flame resistance will also be assessed if it is intended for high-risk environments.
In real-world settings, pilot testing will be conducted with packaging companies. They will be asked to integrate the tray into existing packaging processes and provide feedback on ease of handling, customer perception, durability, and logistics compatibility. These pilot users will also assess stackability, fit with secondary packaging (like boxes), and transport efficiency.
Feedback from these users will be systematically gathered through interviews, observation, and structured evaluation checklists.

Metrics & Feedback:
- Comparative data vs. traditional plastics.
- Stakeholder feedback from:
  - Local producers (cost, machinery compatibility).
  - End users (performance, aesthetics).
  - Environmental organizations (biodegradability validation).
- LCA (Life Cycle Assessment) to compare environmental impact.

Step 6.
Iteration and Development Process
What steps follow after the first prototype?
How will the feedback be integrated?

Once the initial prototype has been tested and feedback has been collected, the development team will analyze the results to identify both strengths and areas for improvement. For example, if users report that the tray lacks water resistance, the next iteration might explore the use of biodegradable coatings or surface treatments. If the mold design proves inefficient for mass production, geometry modifications or tooling upgrades may be made to improve throughput and reproducibility. The team will also refine the fiber-to-resin ratio, explore different molding techniques, and test alternative hemp processing methods (e.g., length of fibers, direction of layup) to optimize strength and flexibility. In parallel, cost analyses will be performed to ensure the solution is commercially viable, especially for manufacturers operating on thin margins. Further steps include collaborations with research institutions or technical faculties, especially those focusing on materials science, green chemistry, and circular economy. This will support the development of higher-performance versions and allow for validation according to international standards. Eventually, if the second-stage prototype meets expectations, a small-batch production run can be initiated in partnership with some packaging company operating in Serbia, and the product can be piloted on the market.

Step 7. **Circularity** How does the prototype impact circularity/sustainability/requirements of circular economy?
This prototype is designed to fulfill the core principles of the circular economy. First, it prioritizes biological materials — hemp fibers and natural resins — that are renewable, regenerative, and non-toxic. By sourcing these materials locally, it supports shorter supply chains, reduces transport emissions, and promotes rural green economies, particularly in Serbia's agriculturally rich regions (Vojvodina). Second, the tray is fully biodegradable, which addresses the end-of-life problem of traditional plastic packaging. Rather than becoming waste, the tray returns to the soil — literally — when composted, thus closing the material loop in a regenerative way. Third, the prototype encourages resource efficiency because hemp cultivation requires minimal water, no synthetic pesticides, and improves soil health. Manufacturing the tray consumes less energy compared to petrochemical plastics, and waste fibers from other hemp industries (e.g., textiles, construction) can be upcycled into this product, creating opportunities for industrial symbiosis. Additionally, the product is designed with reuse potential in mind. It can be used multiple times if desired, and certain design modifications could allow for modularity or upgradeability in packaging systems. If mechanically recycled, the tray's materials can serve as feedstock for lower-grade composite materials such as insulation, filling, or secondary packaging. Ultimately, the prototype demonstrates how circular transformation is not only possible in Serbia's plastics sector but also beneficial — environmentally, economically, and socially. It reduces dependency on imported raw materials, decreases waste, and aligns with European sustainability and environmental standards/regulations.

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GUIDELINE – DEMO FACTSHEET no.3

Pillar II : RECY-BIO CONTENT

Deliverable D.1.2.5

Proposed solution identification – based on DTWs :
We selected the packaging sector for our prototyping case study because in Hungary, the share of recycled and sustainable materials in packaging is only 26%, which falls significantly behind the EU average of 46%. Meeting the EU's 2030 target of 55% will be a major challenge for the national plastics industry. A key issue is the management of polymer foams used as protective packaging materials. These foams have a high volume-to-weight ratio, making waste collection and transportation inefficient. In addition, residual chemical blowing agents in post-consumer foams hinder thermal reprocessing, making it difficult to produce homogeneous recycled products and maintain stable processing parameters. Another common problem is the poor design of packaging solutions, often leading to overprotection—the use of unnecessarily large amounts of material to protect products. This results in excessive use of raw materials, increased packaging size, and more end-of-life waste. To address these challenges, we are developing a mycelium-based foam prototype as a sustainable alternative to fossil-based foams. The material is grown in custom molds using different fungal species (e.g., Trametes, Pleurotus ostreatus, Fomes fomentarius, Ganoderma applanatum) with a substrate of agricultural by-products such as rice husks, wheat hulls, or cotton seeds. The result is a lightweight, porous, biodegradable foam suitable for protective packaging applications, designed with material efficiency and circularity in mind.

Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase :
Several aspects have already proven to be particularly relevant during the early stages of the prototyping phase. First, the production of mycelium-based foam is feasible under small-scale conditions, making it accessible for experimental development. Second, the agricultural by-products used as substrates—such as rice husks or wheat hulls—are readily available in Hungary, supporting the local implementation of circular economy principles. Third, the properties of the mycelium material, such as density and energy absorption, can be tailored by adjusting growth conditions and raw material composition, which opens the possibility for application-specific optimization in protective packaging.

Prototyping and Demonstration step-by-step :

Step 1. **Understand your idea** Goal & Purpose of the Prototype What problem is the prototype meant to solve? Who is the target audience? Which hypotheses are to be tested?

Goal & Purpose of the Prototype:
The goal of the prototype is to develop a sustainable, biodegradable cushioning foam for protective packaging applications, based on mycelium grown on agricultural waste substrates. The prototype aims to demonstrate that such materials can serve as a viable alternative to fossil-based polymer foams used in the packaging industry.

What problem is the prototype meant to solve?
The prototype addresses multiple problems: the low use of recycled and sustainable materials in Hungarian packaging, the challenges in managing polymer foam waste, and the frequent overdesign of protective packaging, which leads to excessive material use and waste generation.

Who is the target audience?
The target audience includes packaging manufacturers, logistics companies, sustainability-focused product designers, and stakeholders in the bio-based materials sector, particularly those looking for eco-friendly alternatives to expanded polystyrene (EPS) or polyethylene (PE) foams, which are commonly used in cushioning packaging systems.

Which hypotheses are to be tested?
- Mycelium-based foams can be tailored to meet the cushioning and mechanical needs of protective packaging.
- Locally available agricultural by-products can be effectively used as growth substrates.
- The resulting material can provide adequate protection during the transportation of different goods while reducing environmental impact compared to conventional polymer foams.

Step 2.

Functionality & Features
What are the core functions?
Which features are necessary to achieve the goal?
Which functions could be added later?

What are the core functions?
The core function of the prototype is to provide shock absorption and mechanical protection for fragile goods during transport. It must act as a cushioning element that mitigates impact forces, similarly to conventional polymer foams like EPS or PE foam.

Which features are necessary to achieve the goal?

- Sufficient compressive strength and energy absorption to protect products from damage during handling or dropping.
- Shape conformity, i.e. the ability to grow into mold-defined forms to match specific packaging needs.
- Low density, to reduce material usage and shipping weight.
- Biodegradability, ensuring environmental benefits at end-of-life.
- Use of locally available, renewable feedstocks (e.g. agricultural residues) to enhance sustainability.

Which functions could be added later?

- Moisture resistance or surface coating, to improve performance under humid conditions or extended storage.
- Fire retardancy through natural additives.
- Integration with other packaging components, such as corrugated paperboard backings for combined mechanical stability.
- Coloring or branding options, if desired for product presentation or marketing.

Step 3.
Technology & Materials & other Inputs needed
What technologies, platforms, or tools will be used?
If it's a physical prototype: What materials are suitable?

What technologies, platforms, or tools will be used?
The prototype will be developed using standard laboratory tools suitable for preparing substrates, inoculating fungal cultures, and shaping the material. Controlled-environment equipment—such as incubators or humidity-controlled chambers—is required to maintain optimal temperature and humidity during the growth phase. For post-growth processing, tools for demolding, cutting, and low-temperature drying (e.g. drying ovens) will be used to stabilize the final product.

If it's a physical prototype: What materials are suitable?

- Mycelium cultures of selected saprotrophic fungal species (e.g. Pleurotus ostreatus, Trametes versicolor, Fomes fomentarius, Ganoderma applanatum).
- Agricultural by-products as growth substrates (e.g. rice husks, wheat hulls, sawdust, cotton seeds).
- Natural binding agents (e.g. flour or starch) to support initial colonization where needed.
- Low-cost, reusable molds made from materials such as plastic, paperboard, or wood.

- Plastic wrap or breathable film to maintain moisture and allow air exchange during incubation.

Step 4.
Type of Prototype
Low-Fidelity (low detail level): Sketches, wireframes, paper models
High-Fidelity (high detail level): Interactive mockups, functional models
(Written detailed description ; prevent intellectual property infringement)

This prototype is classified as High-Fidelity, as it results in a functional physical model intended to demonstrate the real material behavior, structure, and applicability of mycelium-based foam in protective packaging.

The prototype is grown directly into shape using custom-made molds, simulating the final form of a protective packaging product. The growth process follows the actual intended method for future industrial-scale production, including incubation, drying, and basic finishing steps. The prototype is made using the actual materials intended for real-world application, allowing the functional and mechanical performance to be realistically evaluated.

While the form and dimensions of the prototype are tailored to lab-scale testing, the process replicates the conditions and sequence expected in real-life production, making it suitable for evaluating cushioning performance, moisture sensitivity, and material consistency.

The design avoids the inclusion of any protected industrial designs or patented mold structures, ensuring freedom to operate and share results within the project framework.

Step 5.
Testing Strategy
How will the prototype be tested?
Which metrics or feedback methods will be used?

<u>How will the prototype be tested?</u>
The prototype will undergo mechanical testing focused on its compressive behavior and cushioning performance, both under static and dynamic loading conditions. Laboratory-drop tests will be conducted in accordance with the ASTM D-1596 standard to evaluate how well the material absorbs impact forces and how this performance changes with repeated loading. The tests will help determine the prototype's suitability for protecting fragile goods during transport.

<u>Which metrics or feedback methods will be used?</u>

- Cushion curves will be recorded based on ASTM D-1596 methodology, with separate analysis of the first drop and subsequent repeated drops (2nd–5th).
- In addition to standard testing, curve-fitting estimation methods will be applied to predict cushioning behavior across different drop heights and material thicknesses. This enables the evaluation of impact-absorbing performance under a wide range of conditions, while reducing the number of required tests.
- This approach allows packaging engineers to select appropriate cushioning height for a given product weight and drop energy, and to compare the performance of the mycelium-based foam with conventional fossil-based foams such as EPS or PE.

Further measurements will include:

- Static compressive strength tests, to determine the material's resistance to compressive loads.
- Creep testing, to evaluate how much the cushioning height is reduced during prolonged storage under load.
- Bulk density determination by measuring outer dimensions and mass, as well as hydrostatic density measurements for cross-validation.
- Humidity sensitivity testing, to assess how moisture affects the cushioning performance and structural stability of the foam.

These tests collectively provide a clear understanding of the material's behavior under realistic packaging conditions, supporting both performance evaluation and material comparison.

Step 6.
Iteration and Development Process
What steps follow after the first prototype?
How will the feedback be integrated?

What steps follow after the first prototype?
Following the first prototype, we will analyze the results of mechanical and environmental tests to identify areas for improvement in both material performance and process stability. Based on these findings, new prototype iterations will be prepared with modified parameters—such as fungal species, substrate composition, growth duration, mold geometry, and post-treatment conditions (e.g. drying temperature or optional pressing).

These iterations aim to improve key properties like compressive strength, resilience under repeated loading, moisture resistance, and dimensional accuracy.

How will the feedback be integrated?
All performance data from the testing phase will be compiled and evaluated to identify the most critical limiting factors. Feedback will be used to:

- Optimize growth conditions (e.g. temperature, humidity, incubation time).
- Fine-tune the substrate formulation and binding additives.
- Adjust the prototype geometry to enhance structural performance without unnecessary overdesign.
- Explore potential surface treatments or hybrid structures (e.g. integration with corrugated board) to address moisture sensitivity or improve mechanical integrity.

The iteration process will be documented step-by-step, ensuring traceability of improvements and supporting the development of practical guidelines for packaging designers interested in applying mycelium-based foam solutions.

Step 7. **Circularity** How does the prototype impact circularity/sustainability/requirements of circular economy?

The mycelium-based packaging foam prototype contributes to circularity and sustainability in several meaningful ways. First and foremost, it is produced from bio-based, locally available raw materials, such as agricultural residues (e.g. rice husks, wheat hulls, or cotton seeds), which would otherwise go unused or be treated as waste. This not only reduces dependence on fossil-based resources but also shortens supply chains and lowers the environmental footprint associated with material transport. **The production process itself is low-energy and non-toxic, relying on natural fungal growth under controlled temperature and humidity, without the need for high-temperature extrusion, chemical blowing agents, or complex machinery typically required for synthetic foam manufacturing.** **Importantly, the resulting material is fully biodegradable and compostable, allowing for natural decomposition at the end of its life cycle—unlike conventional packaging foams such as EPS or PE, which are difficult to recycle and often end up in landfills or as environmental pollutants.** **By replacing problematic fossil-based foams with a regenerative alternative, the prototype helps reduce packaging-related plastic waste and supports the transition towards a circular economy, where materials are sourced responsibly, used efficiently, and returned safely to natural systems after use.** **However, several challenges remain before full-scale application is feasible. Mycelium foams are typically less resilient under repeated impact loads, and their compressive stiffness is lower compared to traditional closed-cell foams, which may lead to deformation under static load during long-term storage. In many cases, achieving the required mechanical performance demands higher material density, which increases the size and weight of the packaging. Furthermore, the foam is sensitive to moisture, and its performance can vary significantly depending on environmental humidity. These aspects must be carefully considered in packaging design, and further iterations will aim to improve durability, consistency, and environmental resistance.**

GUIDELINE – DEMO FACTSHEET

no.4

Pillar II : RECY-BIO CONTENT

Deliverable D.1.2.5

Proposed solution identification – based on DTWs :
1. Bioplastic Components in Automotive Manufacturing 2. Bioplastics for 3D Printing 3. Bioplastic Grippers in Robotics
Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase :
1. Bioplastic Components in Automotive Manufacturing Significance: • Lightweighting for Fuel Efficiency: Bioplastics are significantly lighter than traditional metals and some conventional plastics, leading to better fuel efficiency and lower CO_2 emissions. • Sustainability in Production: Many bioplastics (such as PLA, PHA, or bio-based polyamides) have a lower carbon footprint compared to petroleum-based plastics. • End-of-Life Benefits: Some bioplastic materials are biodegradable or compostable, reducing automotive waste and landfill accumulation. Importance for Prototyping: • Material Testing: Bioplastics must be tested for mechanical properties like impact resistance, heat tolerance, and durability to ensure they can replace traditional materials in car interiors, dashboards, or structural reinforcements. • Process Optimization: Injection molding or thermoforming techniques need to be assessed to determine whether bioplastics can meet the demands of mass automotive production. 2. Bioplastics for 3D Printing Significance: • Customization and Flexibility: 3D printing allows for rapid prototyping of complex shapes and geometries, which is useful for automotive parts, medical applications, and industrial tooling. • Reduced Waste: Unlike traditional manufacturing, 3D printing with bioplastics generates minimal material waste, supporting circular economy goals. • Wide Application Potential: Bioplastics in 3D printing can be used in industries ranging from medical (prosthetics, implants) to consumer goods (packaging, customized products). Importance for Prototyping: • Material Selection: Identifying which bioplastic filaments (PLA, bio-based PET, or PHA blends) work best for different applications. • Performance Evaluation: Bioplastics need to be tested for layer adhesion, strength, and printability to ensure they match the quality of petroleum-based alternatives. • Sustainability Metrics: Measuring biodegradability, recycling potential, and energy consumption in 3D printing processes. 3. Bioplastic Grippers in Robotics Significance: • Weight Reduction for Efficiency: Using bioplastics in robotic grippers can reduce overall weight, which lowers energy consumption in robotic arms and increases their speed and agility. • Alternative to Traditional Materials: Many industrial grippers use metals or petroleum-based plastics, which can be replaced with high-strength bioplastic composites.

- Sustainability in Automation: The use of biodegradable or bio-based polymers in robotic tooling contributes to eco-friendly automation.

Importance for Prototyping:

- Material Strength and Durability Testing: Bioplastics must be tested for their ability to withstand mechanical stress, repetitive motion, and grip forces.
- Customization with 3D Printing: Bioplastic grippers can be 3D-printed, allowing for rapid prototyping and design iterations.
- Thermal and Chemical Resistance: Ensuring bioplastics can resist high temperatures and exposure to industrial chemicals in robotic applications.

Due to the core business of Foundation ITT, we will continue describing the usage of bioplastics in robotics, including designing tools, structural components, cables and insulation, actuators, housing and casings etc.

Prototyping and Demonstration step-by-step :

Step 1.
Understand your idea
Goal & Purpose of the Prototype
What problem is the prototype meant to solve?
Who is the target audience?
Which hypotheses are to be tested?

1. Goal & purpose of the prototype

The bioplastics in robotics prototype aims to:

- Reduce the environmental impact of robotics manufacturing by replacing conventional plastics with bioplastics.
- Lighten robotic components, improving energy efficiency and performance.
- Showcase the feasibility of bioplastics in industrial applications, such as grippers, structural casings, and soft robotics.

2. What problem is the prototype meant to solve?
   - High carbon footprint of petroleum-based plastics in robotics.
   - Heavyweight materials that increase energy consumption in robotic systems.
   - Limited sustainability in robotic manufacturing.
   - Challenges in end-of-life disposal and recyclability of robotic components.

3. Who is the target audience?
   - Robotics manufacturers looking for sustainable materials.
   - Automotive and industrial robotics sectors aiming to reduce weight and improve efficiency.
   - R&D teams exploring bioplastics in automation.
   - Policymakers & sustainability advocates supporting the circular economy.

4. Which hypotheses are to be tested?
   - Material Performance Hypothesis
     - Analyze the strength, durability, and flexibility of various bioplastics (e.g., PLA, PHA, or reinforced composites) compared to conventional materials. Conduct experiments under industrial conditions, including robotic movement at different speeds, varying temperatures, and impact stress. Perform fatigue testing to evaluate long-term mechanical stability.

- Weight Reduction Hypothesis
    - Assess the performance of bioplastic grippers in the tool coordinate system by analyzing payload effects, speed, acceleration, and braking/stopping cycles. Compare against standard materials to quantify weight reduction and evaluate its impact on robotic joint longevity and energy efficiency.
- Sustainability Hypothesis
    - Conduct a long-term study on the durability of bioplastic components under industrial use. Compare wear resistance, deformation, and mechanical integrity against traditional materials. Analyze potential degradation risks such as moisture absorption, UV exposure, and temperature fluctuations.
- End-of-Life Management Hypothesis
    - Test the biodegradability and end-of-life processing of bioplastic components under various conditions, including industrial composting, soil degradation, and mechanical recycling. Compare the disposal impact of bioplastics vs. petroleum-based plastics to ensure a truly circular economy approach.

Step 2.
Functionality & Features
What are the core functions?
Which features are necessary to achieve the goal?
Which functions could be added later?

1. What are the core functions?
    - Lightweight Structure – Reduces payload, improves energy efficiency.
    - High Durability & Flexibility – Ensures the gripper or component withstands industrial use.
    - Mechanical Strength – Provides necessary grip force for object handling.
      Eco-Friendly & Biodegradable – Supports circular economy & sustainable manufacturing.
2. Which features are necessary to achieve the goal?
    - Precision Engineering – The gripper must maintain accuracy in handling objects.
    - Compatibility with Existing Robots – Must fit standard robotic arms (e.g., KUKA, FANUC, ABB).
    - Chemical & Temperature Resistance – Avoids degradation from industrial conditions.
    - Modular Design – Allows for part replacements instead of full re-manufacturing.
2. Which functions could be added later?
    - Smart Material Integration – Bioplastics infused with nano-materials for extra strength.
    - Self-Healing Bioplastics – Materials that repair minor damage over time.
    - Embedded Sensors – For pressure, temperature, or wear monitoring.
    - Recycling & Reusability System – Designed for easy reprocessing into new components.

Step 3.
Technology & Materials & other Inputs needed
What technologies, platforms, or tools will be used?
If it's a physical prototype: What materials are suitable?

1. What technologies, platforms, or tools will be used?

- Robotic Simulation Software (RoboDK, ROS, KUKA.Sim, FANUC ROBOGUIDE) – To program the robot movement with various parameters (speed, acceleration, braking) to test bioplastic components in a real environment.
- 3D Printing (FDM, SLA, SLS) – For rapid prototyping and part customization.
- CAD/CAM Software – To design, simulate, and optimize bioplastic components.
- Finite Element Analysis (FEA – Ansys, COMSOL) – To test material stress, flexibility, and durability.
- Material Testing Equipment (Tensile Testers, Thermal Analyzers, Impact Testers) – For evaluating bioplastic properties under stress.

2. If it's a physical prototype: What materials are suitable?

- Bioplastic Options (Based on Strength & Flexibility Needs):
  - PLA (Polylactic Acid) – Easy to 3D print but brittle under stress.
  - PHA (Polyhydroxyalkanoates) – Biodegradable with better flexibility than PLA.
  - PBS (Polybutylene Succinate) – Good balance of flexibility, durability, and biodegradability.
  - Reinforced Bioplastics (e.g., PLA + Carbon Fiber, PHA + Nanocellulose) – For added strength in robotic applications.
  - Thermoplastic Starches & Bio-Polyurethanes – Flexible, but need reinforcement for industrial use.

Step 4.
Type of Prototype
Low-Fidelity (low detail level): Sketches, wireframes, paper models
High-Fidelity (high detail level): Interactive mockups, functional models
(Written detailed description ; prevent intellectual property infringement)

1. Low-Fidelity Prototype

- Hand-drawn sketches of grippers, casings, or structural parts made of bioplastics
- Prepare a model to be used in simulation software to test sizing and adaptability to the robot system

2. High-Fidelity Prototype

- 3D Printed Bioplastic Parts: Use FDM or SLA printing with PLA, PHA, PBS, or reinforced composites (e.g., PLA+carbon fiber)
- Component-Level Integration: Mount on robotic manipulator (KUKA, ABB, FANUC) to simulate industrial use (gripping, load, cycles)
- Test the robot in a real environment, check for wearing, payload impact etc.

Step 5.
Testing Strategy
How will the prototype be tested?
Which metrics or feedback methods will be used?

1. How Will the Prototype Be Tested?

- Design & Material Validation: Validate initial design concepts and evaluate baseline material properties.
  - Use tensile testers, hardness testers, and impact resistance machines on sample parts made from PLA, PHA, PBS, and reinforced composites.
  - Conduct moisture, UV, and temperature exposure tests to simulate harsh industrial environments.
  - 3D Fit & Form Testing: Assemble printed parts on robotic arm to check tolerances, assembly time, and fit with standard robot arm interfaces.
- Functional Testing in Robotic Environment: Evaluate the prototype's mechanical, environmental, and sustainability performance in near-real use conditions.
  - Dynamic Robotic Testing:
    - Attach bioplastic components (e.g., grippers or casings) to robotic manipulator
    - Program repetitive motion cycles: gripping, lifting, rotation, acceleration/deceleration, braking.
  - Payload & Energy Analysis:
    - Measure motor strain, power usage, and torque under different payloads to evaluate weight reduction benefits.
  - Durability Testing:
    - Run high-cycle tests (e.g., 10,000+ movement cycles) to monitor material fatigue, warping, and mechanical failure.
  - End-of-Life Testing:
    - Assess biodegradability in controlled composting and natural soil conditions.
    - Run mechanical recycling simulations to check reusability and material breakdown quality.

2. Which Metrics or Feedback Methods Will Be Used?

- Metrics
  - Mechanical Performance: Tensile strength, elasticity, impact resistance, fatigue cycle limit
  - Weight Reduction: Part weight (g), robot payload capacity (% used), energy consumption per movement cycle
  - Fit & Compatibility: Assembly success rate, tolerance deviation (mm), interface compatibility score
  - Thermal/Chemical Resistance: Deformation point (°C), UV resistance rating, chemical exposure tolerance (qualitative)
  - Durability: Number of operation cycles before failure, wear rate (% per cycle), failure mode analysis
  - Sustainability: Biodegradation rate (% over time), recyclability score (qualitative & mass retained %)
  - Stakeholder Feedback: Structured interviews with engineers, user surveys, usability scores
  - Simulation Validation: Deviation between simulated and real-world test results (%)
- Feedback
  - Observation Logs: During robotic testing cycles

- Lab Reports: From material and environmental testing labs
- Engineering Evaluation Sheets: For each test round
- Photo/Video Documentation: For before/after analysis and failure modes

Step 6.
Iteration and Development Process
What steps follow after the first prototype?
How will the feedback be integrated?

1. What Steps Follow After the First Prototype?

- Step 1: Initial Prototype Testing
  - Conduct testing through the experiment
  - Collect performance data (mechanical strength, durability, degradation).
  - Document any issues related to part fit, material failure, or usability in robotic systems.
- Step 2: Analyze Results
  - Review testing metrics, simulation discrepancies, and feedback from engineers and stakeholders.
  - Identify areas for improvement:
  - Material weaknesses (e.g., cracking, warping)
  - Compatibility issues with robot arms or tooling
  - Sustainability or weight reduction goals not achieved
- Step 3: Redesign & Optimize
  - Use insights to update:
    - Component geometry (thickness, reinforcement ribs, joint design)
    - Material selection (switching from PLA to PHA, or adding nanocellulose for strength)
    - Surface finish or post-processing steps to improve durability
  - Update CAD models and simulation files.
- Step 4: Produce Next Iteration
  - 3D print the improved version using selected bioplastic materials.
  - Re-run simulation tests to validate improvements.
  - Conduct selective re-testing (not full cycle) to confirm fixes.
- Step 5: Stakeholder Review
  - Present updated version to:
    - Robotics engineers for functional feedback
    - Sustainability experts for material/environmental validation
    - End users or industry reps for usability review
  - Collect feedback via interviews, evaluation sheets, and performance comparisons with previous versions.
- Step 6: Final Refinement
  - Apply final design changes based on stakeholder feedback.
  - Conduct a small-scale pilot (e.g., run component on real robotic arm in demo environment or real-world task).
  - Document final performance and sustainability indicators.

- Step 7: Preparation for Scaling or Knowledge Transfer
    - Prepare a technical dossier: material specs, CAD files, testing results, design files.
    - Develop a knowledge pack: use cases, sustainability impact data, user manual for replication.

2. How will the feedback be integrated?
    - Test results & metrics: Used to adjust dimensions, material selection, joint design
    - Engineer/Technician input: Integrated into CAD redesigns & stress point optimization
    - Simulation data: Used to refine structural geometry, thickness, and contours
    - Environmental testing data: Adjust material formulations or add protective coatings

Step 7.
Circularity
How does the prototype impact circularity/sustainability/requirements of circular economy?

- Material Substitution
    - Replaces traditionally used materials with bioplastics (e.g., PLA, PHA, PBS) that are renewable, biodegradable, and less carbon-intensive.
    - Reduces dependence on finite fossil resources, aligning with circular economy principles of regenerative materials.
- Eco-Design & Lightweight
    - Designs robotic components to be lighter, which decreases energy consumption during robotic operation (especially in motors and joints).
    - Lighter components mean lower operational emissions, contributing to overall sustainability across the product lifecycle.
- End-of-Life Management
    - The prototype includes materials designed for industrial composting, soil degradation, or mechanical recycling.
    - Testing for biodegradability ensures the parts won't end up as long-term waste, unlike traditionally used materials that persist in landfills.
    - Supports closed-loop material cycles — components can either return to the biosphere or be reprocessed into new parts.
- Data-Driven Material Optimization
    - Through testing and feedback, the prototype informs which bioplastic formulations perform best in industrial settings — paving the way for optimized, long-lasting circular materials that don't sacrifice functionality.
- Awareness & Knowledge Transfer
    - The project demonstrates the viability of circular materials in robotics, a field that has been slow to adopt sustainable solutions.
    - Can inspire policy change, supplier shifts, and educational efforts toward eco-design in industrial automation.

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GUIDELINE – DEMO FACTSHEET no.5

Pillar II : RECY-BIO CONTENT

Deliverable D.1.2.5

Proposed solution identification – based on DTWs :
FOGGARA is a smart watering can that revolutionizes the watering process for indoor plants. Thanks to an innovative combination of sensor technology, sustainable design and intuitive use, watering becomes a well-thought-out ritual that not only optimally cares for the plants, but also involves the user in the process. FOGGARA combines state-of-the-art technology with an elegant, timeless design to create a product that is both functional and aesthetically pleasing. The market launch will take place via a targeted crowdfunding campaign, which will not only serve to finance the first production series, but will also create a community of early adopters. Direct sales via the company's own web shop and marketplaces such as Amazon represent the next stage of growth before the product is scaled up in the long term via design and smart home retailers. **Demonstration Process**: Foggara V3
Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase :

1. NFC Sticker System & Automated Watering – Core Functional Challenge
• The NFC sticker system is a key differentiator and must work flawlessly.
• Testing must confirm that NFC tags reliably store and transmit plant-specific watering needs.
• Water dispensing must be precise—neither too much nor too little—requiring fine-tuning of the flow control mechanism.
Prototyping Priority: Early testing should focus on **sensor accuracy, NFC compatibility with different plant types, and real-world usability.**
 	
2. Material Selection & Manufacturing Feasibility
• The choice of **recycled plastic** aligns with sustainability goals but needs to be tested for:
    o **Durability** (resistance to cracks, UV exposure, and frequent use).
    o **Waterproofing** (to prevent electronic damage).
    o **Weight & balance** (for comfortable handling).
• The **blow molding process** is ideal for lightweight and robust construction but requires validation for cost-efficiency in smaller production runs.
Prototyping Priority: Material performance tests should be conducted to ensure a balance between sustainability, durability, and user comfort.
 	
3. User Experience & Ergonomic Design
• The watering can should be intuitive to use, even for users unfamiliar with smart home devices.
• Key user-experience (UX) factors to validate in the prototype:
    o **Ease of handling:** Comfortable grip, easy refilling, and well-balanced weight distribution.
    o **User interaction with NFC tags:** Simple and seamless scanning process without needing precise alignment.
    o **Feedback mechanisms:** LED indicators, audio cues, or a small display to confirm successful watering.

Prototyping Priority: Rapid low-fidelity prototypes (mockups, 3D-printed handles, wireframe interactions) should be tested with target users early.

4. Functional Testing – Water Flow & Efficiency

- Water flow regulation is critical to prevent overwatering or leaks.
- The **pump and flow system** must be tested to handle different soil absorption rates.
- A self-cleaning mechanism or filtration may be necessary to prevent blockages over time.

Prototyping Priority: A working high-fidelity prototype should undergo **watering cycle tests on various plant types** to ensure precision and efficiency.

5. Scalability & Circularity Considerations

- The design should facilitate **disassembly for recyclability** at the product's end-of-life.
- Future product iterations might integrate **IoT features** (e.g., app connectivity), so modularity is essential.
- Crowdfunding and direct online sales require a **cost-effective, scalable prototype** that can be easily manufactured in small batches before full production.

Prototyping Priority: The **assembly process should be optimized** for ease of manufacturing and recycling, ensuring a smooth transition to production.

Prototyping and Demonstration step-by-step :

Step 1.
Understand your idea
Goal & Purpose of the Prototype
What problem is the prototype meant to solve?
Who is the target audience?
Which hypotheses are to be tested?

Goal & Purpose of the Prototype
The prototype is designed to validate the concept of a **smart watering can** that automates plant care by recognizing each plant's water requirements. It ensures precise and resource-efficient watering while being easy to use and sustainable.

Problem the Prototype Solves
- Overwatering or underwatering of houseplants due to lack of knowledge or attention.
- Complex plant care routines that require manual tracking of watering needs.
- The need for sustainable and smart home solutions that reduce water waste.

Target Audience
- Plant owners, especially beginners who struggle with plant care.
- Smart home enthusiasts looking for automated solutions.
- Environmentally conscious consumers seeking sustainable home products.

Hypotheses to Be Tested
1. The NFC-based communication system effectively identifies plant watering needs.
2. Users find the automated watering process easier and more convenient than manual watering.
3. The use of **recycled plastic** from the Yellow Bag meets both sustainability and durability requirements.

Step 2.
Functionality & Features
What are the core functions?
Which features are necessary to achieve the goal?
Which functions could be added later?

Core Functions
- **NFC sticker system:** Each plant has an NFC sticker that stores watering needs.
- **Automated watering:** The watering can reads the NFC sticker and dispenses water accordingly.
- **Sustainable material:** Made from **recycled plastic** to ensure environmental friendliness.
- **Ergonomic & stylish design:** Combines aesthetics with ease of use.

Necessary Features to Achieve the Goal
- **Built-in sensor & NFC reader** to detect plant type and watering schedule.
- **Water level indicator** to show when refilling is needed.
- **Battery or rechargeable power source** for portability.
- **User-friendly interaction** (visual or audio cues to confirm watering).

Future Features (to be added later)
- **App integration** to track watering history and receive reminders.
- **Smart home connectivity** (e.g., compatibility with Alexa or Google Home).
- **Customizable watering profiles** for more complex plant care needs.

Step 3. **Technology & Materials & other Inputs needed** What technologies, platforms, or tools will be used? If it's a physical prototype: What materials are suitable?
Technologies, Platforms & Tools • **NFC sensor technology** to read plant information. • **Embedded microcontroller** to process watering logic. • **Water pump & flow control mechanism** for precise dispensing. • **Wireless communication (optional)** for future app connectivity. **Suitable Materials for Prototyping** • **Recycled plastic** from the Yellow Bag for the water tank and base (lightweight & durable). • **Silicone seals** for waterproofing the electronic compartment. • **Sustainable electronics** with energy-efficient components.
Step 4. **Type of Prototype** Low-Fidelity (low detail level): Sketches, wireframes, paper models High-Fidelity (high detail level): Interactive mockups, functional models (Written detailed description ; prevent intellectual property infringement)
Low-Fidelity Prototype (Early Stage) • **Sketches and wireframes** of the watering can design and user interaction flow. • **3D-printed models** to explore ergonomic handling. • **Paper or cardboard models** to visualize size and form factor. **High-Fidelity Prototype (Functional Stage)** • **Working NFC sticker system** to test plant recognition. • **3D-printed or blow-molded prototype** made from recycled plastic. • **Basic electronic components** integrated for water dispensing automation.
Step 5. **Testing Strategy** How will the prototype be tested? Which metrics or feedback methods will be used?
Prototype Testing Approach • **User testing:** Provide prototype to plant owners for real-world testing. • **Technical testing:** Validate NFC recognition, water dispensing accuracy, and battery life. • **Sustainability testing:** Assess recyclability and durability of materials. **Metrics & Feedback Methods** • **User satisfaction surveys** (ease of use, reliability, aesthetic appeal). • **Water efficiency measurement** (amount of water dispensed per cycle). • **Durability tests** (drop tests, water resistance evaluation).
Step 6. **Iteration and Development Process** What steps follow after the first prototype? How will the feedback be integrated?

Steps After the First Prototype

1. **Analyze user feedback** to identify usability and functionality issues.
2. **Refine the NFC recognition system** for more precise water dispensing.
3. **Optimize material selection** based on durability and sustainability tests.
4. **Develop a second prototype** with improved features and robustness.
5. **Pilot production batch** for extended real-world testing.

Integration of Feedback

- Implement design adjustments based on user insights.
- Improve sensor accuracy and watering precision.
- Address any usability concerns before moving to full-scale production.

  FOGGARA has already developed an initial measuring station that can then collect and send data. This means that values such **as soil moisture, temperature, brightness and humidity can be precisely monitored** and then later processed using algorithms and serve as a database with which the irrigation data can be compiled. In future, **Hohenheim University** could also set up various test series and help with data collection. This will further support the scientific basis

Step 7.
Circularity
How does the prototype impact circularity/sustainability/requirements of circular economy?

Circularity & Environmental Impact

- **Use of recycled materials:** The can is produced from post-consumer plastics, supporting a closed-loop recycling system.
- **Waste reduction:** Precise watering minimizes water waste and prevents unnecessary plant damage.
- **Recyclable design:** The product components can be easily disassembled for material recovery.
- **Energy-efficient technology:** Low power consumption and rechargeable batteries for sustainable use.

The FOGGARA smart watering can integrates **innovative sensor technology, sustainable materials, and user-friendly automation** to solve common plant care issues. Through **iterative prototyping, real-world testing, and sustainable production methods**, the product is positioned as a **resource-efficient, smart home solution** that aligns with circular economy principles.

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GUIDELINE – DEMO FACTSHEET no.6

Pillar III : REUSE

Deliverable D.1.2.5

Proposed solution identification – based on DTWs :
Proposed solution: 3D printing support used extruder for plastic materials. Recyclability and remanufacturing of plastics are key to reducing the plastic industry's ecological footprint. These approaches help extend equipment life, reduce costs, and promote sustainability throughout manufacturing.
Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase :
• Recycled materials can be cheaper than new raw materials, 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 • The use of recycled materials supports the concept of a circular economy, where materials are constantly reused and renewed, thus extending their lifespan. • Reverse Engineering and transforming waste into raw materials helps reduce the amount of waste in landfills

Prototyping and Demonstration step-by-step :

Step 1. **Understand your idea** Goal & Purpose of the Prototype What problem is the prototype meant to solve? Who is the target audience? Which hypotheses are to be tested?
It is important to provide options such as remanufacturing or refurbishing critical components that can be cost-effective and environmentally friendly. Remanufacturing machines and components can be designed to process recycled materials, thus promoting their reuse. These approaches can significantly increase the ability of products to be reused or upgraded, therefore contributing to a more sustainable economy. The target audience: the plastics industry, machine industry researchers, research institutions, and stakeholders. Important testing will focus on input materials, extrusion processes, and 3D printing of new products from recycled materials.
Step 2. **Functionality & Features** What are the core functions? Which features are necessary to achieve the goal? Which functions could be added later?

From the proposed solution's perspective, 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 product's life. Recycling and reusing materials reduce waste and increase ecological sustainability.

Step 3.

Technology & Materials & other Inputs needed

What technologies, platforms, or tools will be used?

If it's a physical prototype: What materials are suitable?

Regarding the proposed technologies, we used the Extruder. The EX2 Extruder Setup is a device that opens up new opportunities in 3D printing by enabling effective plastic recycling and innovative use of plastics. It provides a small-scale solution to a significant environmental challenge and makes sustainable production accessible.


The input materials are thermoplastics materials, e.g. PLA, PETG, PVB. This device is used for granulate processing to fabricate filament from recycled granulates. The filament production itself begins when the pellets are poured into the pellet's hopper, and then the pellets are fed into the extrusion screw. The pellet extruder has several heating zones; in the first part of the extrusion screw, the temperature is usually higher to ensure uniform material melting.

Step 4.

Type of Prototype

Low-Fidelity (low detail level): Sketches, wireframes, paper models

High-Fidelity (high detail level): Interactive mockups, functional models

(Written detailed description ; prevent intellectual property infringement)

The EX2 Extruder -A filament preparation extruder is a device used to produce custom 3D printing material (filament) from plastic pellets. This process is important in cases where specific material properties or filament costs need to be achieved. Filament preparation extruders allow filament production tailored to particular printing requirements, such as diameter, colour, hardness, or other mechanical properties.

The step-by-step process:

1. Heating the material

The plastic pellets are first fed into the extruder, which is heated to the desired temperature. This step is crucial because each material has a specific melting point.

2. Extruding the material

Once heated, the material moves through the extruder and is forced through a nozzle. The nozzle determines the final diameter of the filament, which can be adjusted as needed. 3. Cooling and shaping After extruding the material, the filament is immediately cooled, often with water or air, to maintain its shape and prevent warping. This step ensures that the filament acquires the desired strength and flexibility. 4. Winding the filament The finished filament is wound onto a spool at the end of the process, ready to be used in the 3D printer. The filament must be wound evenly to avoid printing problems such as jamming or cracking.
Step 5. **Testing Strategy** How will the prototype be tested? Which metrics or feedback methods will be used?
Material testing using extruder and 3D printing is a modern and effective way to investigate the properties of different materials that can be used for printing in various applications. Based on the results of the initial tests, 3D printing settings such as : print speed, temperature, sample design -can be optimised or material selection can be adjusted. Subsequent testing can help ensure the material meets requirements before being widely used.
Step 6. **Iteration and Development Process** What steps follow after the prototype? How will the feedback be integrated?
Preparing a plastic material extrusion through iteration and development is a key step in producing quality filament for 3D printing. This process involves several phases that can be repeated (iterated) until the desired results are achieved. Developing and optimising a plastic material extrusion requires a professional approach, precision, and testing on multiple levels—the main steps and aspects of this process are the following: 1. Material selection 2. Preparation of the material /granulate 3. Setting extrusion parameters/temperature, Tm (Melting Temperature), extrusion speed, cooling, filament diameter 4. First extrusion test and evaluation 5. Optimization process and iteration/temperature adjustment, changing the extrusion speed, testing different ingredient ratios, cooling adjustment

Step 7.
Circularity
How does the prototype impact circularity/sustainability/requirements of circular economy?

1. Sustainability and reduction of carbon footprint
   - Using recycled materials reduces the demand for new plastics, which contributes to protecting natural resources.
   - Recycling plastics requires less energy than producing new plastics, reducing greenhouse gas emissions.
2. Circular economy impact and 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.
   - Introducing regulations to encourage using recycled materials can be an additional incentive for businesses.

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GUIDELINE – DEMO FACTSHEET

no.7

Pillar III : REUSE

Deliverable D.1.2.5

Proposed solution identification – based on DTWs:
Modular Insulation Panel System Made from Recycled and Reusable Plastic
Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase:
A modular insulation panel system made from recycled plastic, designed to improve the energy efficiency of buildings. The panels can be configured according to specific building needs and are intended to be durable, easy to install, reusable, and straightforward to disassemble at the end of their lifecycle. By using recycled plastic, this system aims to reduce reliance on traditional building materials (such as concrete and wood) and encourage the reuse of plastic.

Prototyping and Demonstration step-by-step :

Step 1. **Understand your idea** Goal & Purpose of the Prototype What problem is the prototype meant to solve? Who is the target audience? Which hypotheses are to be tested?
The goal of the digital prototype is to demonstrate the feasibility and effectiveness of the modular insulation panels as a sustainable and innovative solution for the construction industry. The purpose of creating this digital prototype is to validate the design concept, test its functionality through simulations, and gather feedback from stakeholders without the need for physical production. By focusing on a digital format, we can efficiently refine the design, address potential issues, and ensure that the panels meet the required standards for durability, thermal insulation, and ease of installation before moving forward with any physical development. The digital prototype is designed to address several critical problems in the construction and environmental sectors. One of the main issues is the significant amount of plastic waste generated by the construction industry, which often ends up in landfills or the environment. By using recycled plastic as the primary material, the prototype aims to reduce plastic waste and promote a circular economy. Additionally, many buildings suffer from poor insulation, leading to high energy consumption for heating and cooling. The prototype seeks to improve energy efficiency by providing a high-performance insulation solution that reduces heat loss and lowers energy costs. Another problem is the limited availability of sustainable building materials, which are often expensive or difficult to source. The digital prototype offers an affordable and eco-friendly alternative to traditional insulation materials, making sustainable construction more accessible. Finally, traditional insulation materials can be complex and time-consuming to install. The modular design of the prototype aims to simplify the installation process, reducing labor costs and construction time. The target audience for the digital prototype includes a wide range of stakeholders who would benefit from or be involved in the adoption of the modular insulation panels. Construction professionals, such as contractors and builders, are key users of the panels. They are interested in durable, easy-to-install, and cost-effective materials that can improve

the efficiency of their projects. Architects and designers play a crucial role in specifying building materials and are interested in the aesthetic appeal, flexibility, and sustainability of the panels. Building owners and developers are focused on reducing energy costs and improving the long-term value of their buildings. They are interested in the panels' energy efficiency, durability, and potential return on investment. Environmental experts and NGOs are interested in the panels' contribution to reducing plastic waste and promoting circular economy practices. Investors are focused on the market potential of the panels, including their competitive advantage, scalability, and potential for profitability. Several key hypotheses will be tested through the development and evaluation of the digital prototype. The first hypothesis is that the panels will withstand harsh environmental conditions, including extreme temperatures, humidity, and UV exposure, while maintaining their structural integrity and insulation properties. This will be tested through digital simulations and virtual stress tests. The second hypothesis is that the panels will significantly reduce energy consumption in buildings by providing superior thermal insulation compared to traditional materials. This will be tested through energy efficiency simulations and virtual performance monitoring. The third hypothesis is that the modular design and simplified connection mechanism will reduce installation time and labor costs compared to traditional insulation materials. This will be tested by creating virtual installation scenarios and gathering feedback from construction professionals. The fourth hypothesis is that the use of recycled plastic will reduce the carbon footprint of the panels and contribute to a circular economy. This will be tested through a digital lifecycle assessment to quantify the environmental benefits. The final hypothesis is that the panels will be well-received by the target audience, including construction professionals, architects, building owners, and environmental experts. This will be tested through stakeholder feedback and virtual market research. By clearly defining the goal and purpose of the digital prototype, identifying the problems it aims to solve, understanding the target audience, and outlining the hypotheses to be tested, the project is set on a solid foundation. This clarity ensures that the digital prototype will be developed with a clear focus on meeting the needs of the market and achieving the project's sustainability and innovation objectives. With these elements in place, the next steps of design refinement, virtual testing, and stakeholder engagement can proceed with confidence, paving the way for future physical development if needed.
Step 2. **Functionality & Features** What are the core functions? Which features are necessary to achieve the goal? Which functions could be added later?
The core functions of the digital prototype for the modular insulation panel system are designed to address the primary goals of sustainability, energy efficiency, and ease of installation. The first core function is to provide high-performance thermal insulation, which is essential for reducing energy consumption in buildings. The second core function is modularity and ease of installation, which allows the panels to be quickly and efficiently assembled in various configurations. The third core function is environmental sustainability, achieved by using recycled plastic as the primary material. To achieve the goal of creating a sustainable and innovative insulation solution, several necessary features must be incorporated into the digital prototype. One essential feature is the textured surface of the panels, which not only enhances durability but also improves thermal insulation performance. Another critical feature is the galvanized steel frame, which provides structural support and ensures the panels remain rigid and durable over time. The connection mechanism, designed with specialized screws and grooves, is another necessary feature that ensures a secure and efficient installation process.

While the core functions and necessary features are prioritized for the initial digital prototype, there are several additional functions that could be added later to further enhance the system. One potential addition is the integration of smart technology, such as sensors that monitor temperature and humidity levels within the building. This could provide real-time data on the panels' performance and help optimize energy efficiency. Another possible function is the inclusion of fire-resistant coatings or materials, which would improve the panels' safety and compliance with building codes. Additionally, the panels could be designed to incorporate acoustic insulation properties, making them suitable for use in environments where noise reduction is important. These additional functions could be explored in future iterations of the prototype, depending on stakeholder feedback and market demand.
Step 3. **Technology & Materials & other Inputs needed** What technologies, platforms, or tools will be used? If it's a physical prototype: What materials are suitable?
The development of the digital prototype for the modular insulation panel system relied exclusively on free AI-powered platforms and tools to ensure accessibility, cost-efficiency, and innovation. One of the primary tools used was Blender, an open-source 3D modeling software that allowed for the creation of detailed and realistic digital representations of the panels. Blender's AI-powered rendering capabilities enabled the generation of high-quality visualizations, showcasing the panels' design, textures, and modular connection mechanisms. This tool was essential for creating a visually accurate and engaging prototype without the need for expensive software licenses.
Step 4. **Type of Prototype** Low-Fidelity (low detail level): Sketches, wireframes, paper models High-Fidelity (high detail level): Interactive mockups, functional models (Written detailed description ; prevent intellectual property infringement)
The type of prototype developed for the modular insulation panel system is a low-fidelity digital prototype, generated using free AI-powered platforms. This prototype represents the simplest form of visualization, focusing on conveying the core design concepts and functionality without delving into intricate details or advanced interactivity. The goal of this low-fidelity prototype is to provide a clear and accessible representation of the panels' design, modularity, and sustainability features, while avoiding intellectual property infringement by keeping the details at a conceptual level. The prototype consists of basic sketches and wireframes created using AI-driven tools. These sketches outline the overall structure of the panels, including their dimensions, modular design, and connection mechanisms. Despite its simplicity, the prototype includes enough detail to demonstrate the panels' potential for improving energy efficiency, reducing plastic waste, and simplifying the installation process. The use of AI-powered platforms ensures that the prototype is visually engaging and accessible, even without the high level of detail found in more advanced models. This approach also minimizes the risk of intellectual property infringement, as the prototype focuses on general design principles rather than proprietary technical details.
Step 5. **Testing Strategy** How will the prototype be tested? Which metrics or feedback methods will be used?

The testing strategy for the low-fidelity digital prototype of the modular insulation panel system focuses on gathering feedback from stakeholders and validating the design concept through virtual simulations and interactive demonstrations. Since the prototype is digital and low-fidelity, the testing process will rely on visual and conceptual evaluations rather than physical performance tests. The goal is to ensure that the prototype effectively communicates the core features and benefits of the solution while identifying areas for improvement. The feedback collected will be analyzed to identify common themes and areas for improvement. For example, if multiple stakeholders find the connection mechanism unclear, the team will revise the design to make it more intuitive. Similarly, if there are concerns about the panels' durability or energy efficiency, the team will explore ways to address these issues in future iterations of the prototype. The testing process will be iterative, with multiple rounds of feedback and refinement to ensure that the prototype meets the needs and expectations of the target audience.
Step 6. **Iteration and Development Process** What steps follow after the first prototype? How will the feedback be integrated?
After the initial low-fidelity digital prototype is created and tested, the next steps involve an iterative process of refinement and development. The first step after the initial prototype is to analyze the feedback collected from stakeholders. This involves identifying common themes, recurring suggestions, and critical areas for improvement. The feedback will be categorized into technical, aesthetic, and functional improvements to ensure a comprehensive approach to refinement. As the prototype becomes more refined, the team will also explore additional functionalities that could enhance the panels' appeal and performance. For example, the integration of smart technology, such as sensors for monitoring temperature and humidity, could be considered in later iterations. These advanced features will be tested and validated through virtual simulations and stakeholder feedback before being incorporated into the design. Throughout the iteration and development process, communication with stakeholders will remain a priority. Regular updates will be provided to keep stakeholders informed about the progress and to gather ongoing feedback. This collaborative approach ensures that the prototype remains aligned with the needs and expectations of the target audience.
Step 7. **Circularity** How does the prototype impact circularity/sustainability/requirements of circular economy?
The prototype of the modular insulation panel system has a significant impact on circularity and sustainability, aligning closely with the principles of the circular economy. By focusing on the use of recycled materials and promoting resource efficiency, the prototype addresses several key requirements of a circular economy, including waste reduction, material reuse, and environmental sustainability. One of the primary ways the prototype impacts circularity is through the use of recycled plastic as the core material for the panels. This approach directly reduces the amount of plastic waste that would otherwise end up in landfills or the environment. The prototype also promotes resource efficiency by designing the panels to be modular and reusable. In addition to material reuse, the prototype addresses energy efficiency, which is another critical aspect of sustainability. The panels are designed to provide high-performance

thermal insulation, reducing the energy consumption required for heating and cooling buildings.

The prototype of the modular insulation panel system has a profound impact on circularity and sustainability. By using recycled materials, promoting resource efficiency, improving energy efficiency, and minimizing environmental impact, the prototype aligns with the core requirements of a circular economy. This approach not only addresses the environmental challenges associated with plastic waste and energy consumption but also sets a precedent for sustainable innovation in the construction industry. Through continuous refinement and stakeholder engagement, the prototype paves the way for a more sustainable and circular future.

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GUIDELINE – DEMO FACTSHEET

no.8

Pillar III : REUSE

Deliverable D.1.2.5

Proposed solution identification – based on DTWs:
Waste reduction: - Using the available free space within the punching grid for new products (enclosures for different industries) - Recycling the production scraps to manufacture customizable plastic films to cover enclosures for different industries
Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase :

Prototyping and Demonstration step-by-step :

Step 1. **Understand your idea** Goal & Purpose of the Prototype What problem is the prototype meant to solve? Who is the target audience? Which hypotheses are to be tested?
Goal and Purpose of the Prototype The prototype concept revolves around the idea of repurposing the already produced high quality materials and transforming them into new valuable products, rather than discarding them as waste and with that loosing valuable materials. This approach works towards waste reduction, resource conservation, sustainability and recycling. **What problem is the prototype meant to solve?** The prototype addresses the issue of the company discarding a significant amount of valuable material during production. This not only results in the loss of high-quality product that is already being produced but also leads to the waste of virgin material used in the manufacturing process. Therefore, the prototype will repurpose this "waste" into new products, reducing material loss and enhancing sustainability. To tackle this issue, the prototype offers two solutions and approaches. The first solution is using the space within a punching grid more efficiently and taking the unused space that would be discarded as space for new small products. This would significantly decrease the produced waste. The second solution is to recycle the scrap produced to manufacture customizable films for covering enclosures in different industries. This would require the expansion to a new customer base but would ultimately lead to a diversification of the customer clientele in the strategic orientation of the company and thus make the company independent of industry-specific risks. **Who is the target audience?** - Already existing customers – To already providing customers the company can offer a broader range of products.

- Eco-conscious customers – companies that are looking for companies that are working on improving their environmental footprint - Companies that want a recognizable and uniform product line
Step 2. **Functionality & Features** What are the core functions? Which features are necessary to achieve the goal? Which functions could be added later?
What are the core functions? - Waste reduction: minimization of production waste, reducing loss of valuable high-quality material - Improving resource efficiency - New product line: While using the space within the punching grid, the company can provide new and unique high-quality products - Expansion to new business fields - Customization: the customer can have the same design throughout their product line, to increase their brand recognition **Which features are necessary to achieve the goal?** - Quality Assurance: Ensuring that incorporating new products within the spaces of the punching grid does not compromise the quality of the originally produced product; verifying that the recycled material meets required quality standards. - Product Design & Development: Designing and developing new products that fit within the punching grid while effectively integrating recycled materials. - Market Expansion Strategy: Identifying and targeting new business fields where repurposed materials can create added value. - Collaboration with recycling company (already established in this company)
Step 3. **Technology & Materials & other Inputs needed** What technologies, platforms, or tools will be used? If it's a physical prototype: What materials are suitable?
- Already existing space within the punching grid - Already used material will be reused - Cooperation with a separate recycling company to recycle the produced waste to manufacture - Alternatively, the purchase of machines (capacity expansion) to utilize the remaining materials. - In terms of logistics, existing infrastructure should be used wherever possible.
Step 4. **Type of Prototype** Low-Fidelity (low detail level): Sketches, wireframes, paper models High-Fidelity (high detail level): Interactive mockups, functional models (Written detailed description ; prevent intellectual property infringement)

Low-Fidelity

- Sketches & Diagrams: Basic drawings how new products can fit into the available free space within the punching grid
- Process mapping: flowsheets depicting how production scraps will be collected, processed, and repurposed into plastic films.
- Rough physical prototypes of enclosures to test size, shape and fit for the existing space

High-Fidelity:

- 3D CAD Models: Digital models of enclosures to fit into punching grid, with precise dimensions and material usage
- Small-scale production samples: using the punching grid space and customizable plastic films to test durability and quality of new products and already produced products
- Interactive Digital Mockups: Visual presentations of enclosure designs, including customization options for different industries.
- Pilot implementation in production: Testing integration of waste reduction strategies within the existing manufacturing process

Step 5.
Testing Strategy

How will the prototype be tested?

Which metrics or feedback methods will be used?

Material & Quality Testing

- Conduct industry-relevant standard tests
- Quality control of recycled material & comparison to virgin material-based product

Production Process Testing

- Run pilot production to evaluate the efficiency of integrating new products into punching grid
- Identify potential bottlenecks or production adjustments needed

Customization

- Ensure the enclosures properly fit within the punching grid and align with industry requirements.
- Test different customization options
- Sustainability & Waste Reduction Analysis
- Measure the percentage of waste reduction achieved by repurposing materials.
- Evaluate the environmental impact (e.g., reduction in raw material consumption, carbon footprint).

Metrics & Feedback

- Waste Reduction Rate: Percentage decrease in production waste.
- Material Efficiency: Percentage of available punching grid space effectively utilized.
- Production Yield: Number of usable enclosures and plastic films produced from repurposed waste.
- Cost Savings: Reduction in raw material expenses due to recycling.
- Durability & Performance: Results from standardized material testing.

Step 6. **Iteration and Development Process** What steps follow after the first prototype? How will the feedback be integrated?
Analyze Feedback & Test Results - Review collected data from material, production, and performance tests. - Analyze customer and industry feedback to identify strengths and weaknesses. - Compare the prototype's performance against original goals (e.g., waste reduction, cost savings, quality). **Implement Improvements** - Design Adjustments: Modify the enclosure design or plastic film properties based on fit, durability, and customization needs. - Material Optimization: Enhance the recycling process to improve the quality of repurposed plastic films. - Production Efficiency: Adjust manufacturing processes to reduce bottlenecks and improve integration. **Pre-Production & Scaling Strategy** - Finalize design and production processes for large-scale implementation. - Ensure compliance with industry regulations and sustainability certifications. - Develop a business model for pricing, logistics, and customer adoption. **Market introduction** - Launch the product to a select group of businesses (pilot market entry). - Gather real-world data on product adoption and performance. - Continue refining based on ongoing customer feedback and technological advancements.

Step 7. **Circularity** How does the prototype impact circularity/sustainability/requirements of circular economy?
The prototype not only reduces waste and increases resource efficiency but also drives innovation and market expansion within a circular economic framework. It transforms production scraps into valuable products, minimizes the use of virgin materials, and supports compliance with sustainability regulations—all of which contribute to a more circular, sustainable business model. **Waste Reduction & Resource Efficiency** - Optimized Material Usage: By utilizing free space within the punching grid, the prototype reduces material waste during production. - Recycling of Production Scraps: Transforming waste into customizable plastic films ensures that valuable materials are reintegrated into the production cycle instead of being discarded.

- Lower Raw Material Demand: Reducing reliance on virgin materials decreases environmental impact and conserves natural resources.

Reduction of Environmental Footprint

- Lower Carbon Emissions: By reducing waste disposal and virgin material extraction, the prototype helps to reduce environmental impact

Compliance with Circular Economy Requirements

- EU & Global Sustainability Regulations: The prototype supports Extended Producer Responsibility (EPR) and waste reduction policies, helping businesses meet sustainability targets.
- Supports ESG & Corporate Sustainability Goals: Companies integrating this solution can enhance their Environmental, Social, and Governance (ESG) ratings and improve their sustainability reporting.

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GUIDELINE – DEMO FACTSHEET

no.9

Pillar IV : COLLECTION

Deliverable D.1.2.5

Proposed solution identification – based on DTWs :
Based on the DTW workshop held at ICMPP, Iași, on September 19th, 2024, the most promising solutions identified to advance plastic recycling technologies and product development was **Simplified Funding for Circular Economy Projects and Research-Industry Collaboration**.
Possibly any comments and description of the proposal which has currently proven to be significant and important for the prototyping phase :

To develop a prototype concept and demonstration case for the identified solutions, the **"CircularPlastHub: Accelerating Funding & Partnerships"** proposal presents a comprehensive approach to enhancing collaboration between research institutions and industry while improving access to funding for circular economy projects.

Currently, Romania lacks a dedicated platform or cluster focused on fostering collaboration in the circular plastics sector. There is no centralized initiative that connects research institutions, industry players, and funding bodies to support the development of circular economy solutions in plastics. **CircularPlastHub** fills this gap by providing a structured and accessible framework to accelerate funding access, knowledge exchange, and cross-sector partnerships.

At this stage, the proposal demonstrates strong potential in the prototyping phase for several key reasons:

1. **Breaking Down Financial Barriers** – By simplifying access to financial resources for SMEs and other stakeholders, the hub addresses a major challenge: the complexity of identifying and applying for suitable funding opportunities. This is particularly crucial for small and medium enterprises that often struggle with the administrative burdens involved in the funding process.
2. **Promoting Research-Industry Synergy** – The proposal emphasizes the importance of strengthening collaboration between research institutions and the plastics industry. Acting as a bridge, the hub creates a structured environment where innovations in circular plastics can be rapidly transitioned into practical, scalable solutions.
3. **Supporting Circular Economy Implementation** – The hub facilitates the development of circular solutions by offering not only funding opportunities but also networking and partnership-building resources. This is essential for driving the adoption of sustainable and circular practices in the plastics industry.
4. **Enhanced Access to Knowledge and Resources** – Beyond funding and partnerships, the platform provides valuable insights, case studies, and best practices from both research and industry, helping companies overcome barriers to adopting circular technologies and solutions.
5. **Building a Sustainable Ecosystem** – **CircularPlastHub** serves as a catalyst for creating a collaborative environment that unites researchers, SMEs, industry leaders, policymakers, and funding bodies. This synergy accelerates the development and scaling of circular plastic solutions, contributing to a more sustainable and circular economy.

Given that Romania lacks a dedicated initiative or cluster focused on circular plastics, **CircularPlastHub represents a crucial step in bridging this gap and fostering long-term cooperation in the sector.**

In other words, this prototype acts as a **central platform designed to accelerate the development and implementation of circular technologies**, making sustainable practices more **feasible, scalable, and impactful** across industries. By prioritizing **accessibility, innovation, and collaborative networks**, it ensures **industrial relevance** while also supporting successful **dissemination and commercialization** of circular solutions.

Prototyping and Demonstration step-by-step :

Step 1.
Understand your idea
Goal & Purpose of the Prototype
What problem is the prototype meant to solve?
Who is the target audience?
Which hypotheses are to be tested?

The goal of the prototype ("CircularPlastHub: Accelerating Funding & Partnerships") is to facilitate access to funding opportunities and foster research-industry collaboration for circular economy projects. The hub will serve as a centralized resource for funding information, matchmaking, and best practices:

- **Creating a digital hub** that connects researchers and industry stakeholders in the field of plastic circularity.
- **Providing structured access to information** on funding opportunities for circular economy projects.
- **Offering guidance and matchmaking tools** to help SMEs, research institutions, and startups navigate funding options and collaboration opportunities.

By enhancing accessibility, collaboration, and knowledge exchange, **CircularPlastHub purpose is to** support the practical implementation of circular economy solutions in Romania's plastics industry while fostering long-term industrial engagement and innovation.

The prototype aims to solve key challenges that hinder the advancement of circular economy solutions in the plastics industry, including:

- **Limited Research-Industry Collaboration:** A disconnect between research institutions and industry stakeholders slows down the development and implementation of innovative circular solutions.
- **Barriers to Funding Access:** Many SMEs and innovators struggle to identify and secure appropriate funding opportunities due to complex application processes and fragmented information.
- **Administrative and Structural Challenges:** Bureaucratic hurdles, lack of tailored support, and insufficient guidance make it difficult for businesses—especially SMEs—to transition towards circular practices.

The following diagram illustrates the **key target audience** for the "**CircularPlastHub**" prototype, highlighting the diverse groups that will benefit from the platform's resources and collaboration opportunities.

The hypotheses to be tested are:

• A centralized hub for funding information and research-industry collaboration will enhance participation in circular economy projects.
• Improved access to funding opportunities will result in a higher success rate of applications.
• Research-industry partnerships facilitated by the hub will accelerate the development of innovative recycling and circular solutions.

Therefore, the following flowchart illustrates three questions need to be addressed in order to **evaluate the potential impact and effectiveness of the prototype**:

Step 2.

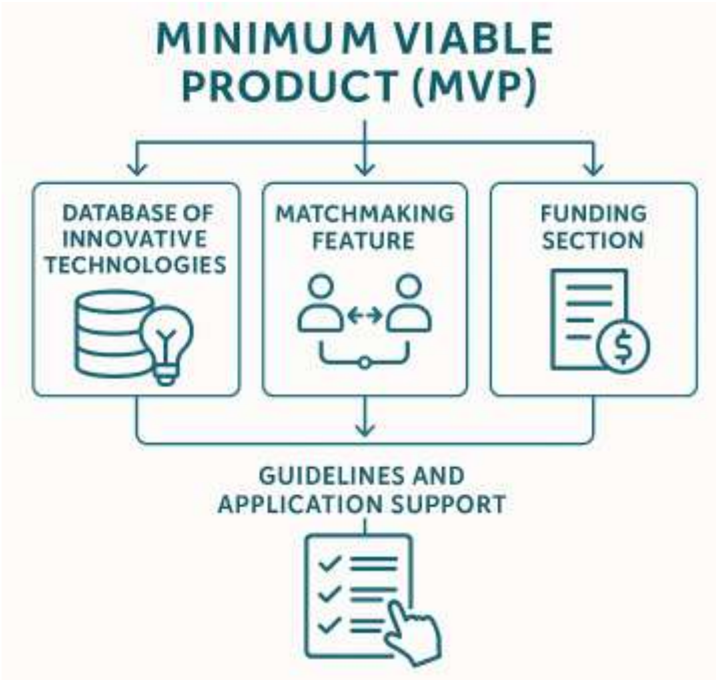
Functionality & Features What are the core functions? Which features are necessary to achieve the goal? Which functions could be added later?

Core Functions:

• **Intuitive Platform for Funding Access**: Easy-to-navigate interface providing a comprehensive list of available funding opportunities.

• **Research-Industry Collaboration Matchmaking**: Facilitating connections between researchers and companies to foster circular economy innovations.

• **Minimum Viable Product (MVP)**: Key features (as in bellow diagram) to ensure the successful implementation of the **CircularPlastHub** and the platform's effectiveness



The **necessary features** to achieve the goal of **CircularPlastHub** include:

- **Simplified funding search tool**: A user-friendly interface for easily navigating and identifying relevant funding opportunities.
- **Clear eligibility guidelines and resources for applicants**: Transparent and accessible information that helps users quickly assess their eligibility and understand the application process.
- **Centralized database with funding opportunities and matchmaking tools**: A comprehensive, organized platform that integrates funding options and provides matchmaking features to connect researchers with industry partners.
- **Collaboration support through networking features**: Tools designed to foster communication and collaboration among researchers, industry players, and stakeholders, promoting partnerships and joint initiatives.

• **Integration of circular economy principles in plastic industry**: The inclusion of content, tools, and case studies that focus on advancing circular economy solutions, fostering innovation and best practices in the plastics sector. In addition to the core functions, the **following features could be added later** to further enhance the platform's impact and support the continuous growth and collaboration in the circular plastics sector: • A **mentorship program** that connects funded SMEs with research institutions for enhanced collaboration. • A **performance-tracking system** to monitor and report the impact of funded projects. • **Impact assessment tools** to evaluate the economic, environmental, and societal outcomes of circular economy innovations. • **Webinars, workshops, and networking events** focused on circular economy funding and collaboration opportunities. • An **online community platform** for sharing best practices, lessons learned, and successful case studies among stakeholders.
Step 3. **Technology & Materials & other Inputs needed** What technologies, platforms, or tools will be used? If it's a physical prototype: What materials are suitable?
To effectively support the platform's functionality and enhance user experience, the following technologies, platforms, and tools will be used: **Technologies & Tools:** • **A digital platform** for funding information, matchmaking, and collaboration tracking (e.g., custom-built platform or existing solutions such as Notion or Airtable). • **Searchable database** for funding opportunities, project tracking, and impact assessment (e.g., using Airtable, Google Sheets, or a custom-built solution). • **AI-based tools** for personalized funding recommendations (optional, using platforms like IBM Watson or custom AI algorithms). • **Collaboration tools** for project management, team communication, and knowledge exchange (e.g., Miro for brainstorming, Microsoft Teams for meetings). • **Networking and community tools** (Slack for discussions, Discord for real-time communication, LinkedIn Groups for professional networking). • **Newsletter and notification systems** for keeping stakeholders informed of new funding calls and opportunities (e.g., Mailchimp for automated emails, Substack for periodic updates). **Other Inputs:** • IT expertise for platform development. • Funding advisors and experts in circular economy. This is a **digital, process-based prototype**, meaning it will primarily require demonstration materials such as screenshots, mockups, and interactive demos, along with

printed materials for industry events and physical demonstrations showcasing the platform's features and success stories.

Step 4.
Type of Prototype
Low-Fidelity (low detail level): Sketches, wireframes, paper models
High-Fidelity (high detail level): Interactive mockups, functional models
(Written detailed description ; prevent intellectual property infringement)

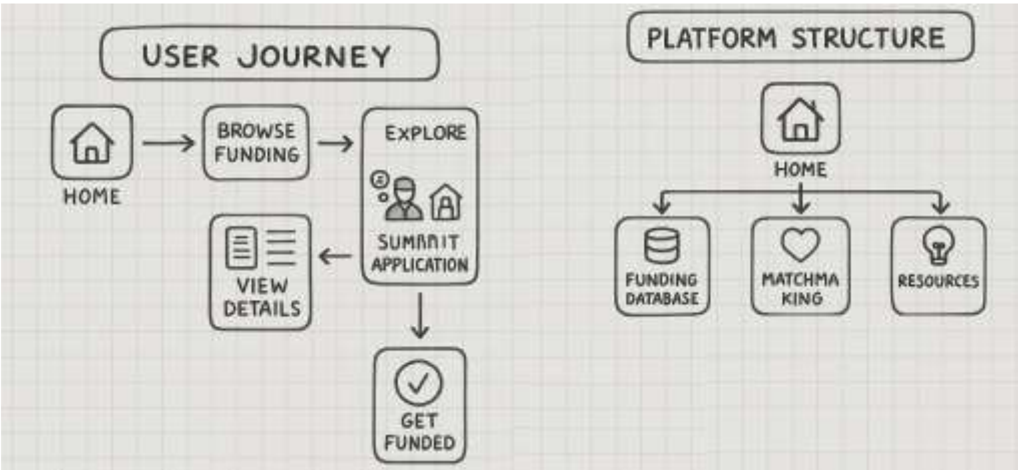
"CircularPlastHub" Prototype Development: The proposed prototype is a digital platform designed to simplify access to funding opportunities, foster research-industry collaboration, and support circular economy projects in Romania's plastics sector. It will serve as a centralized resource, offering intuitive tools for matchmaking, funding search, and knowledge-sharing.

Low-Fidelity Prototype (Conceptual Stage):

The initial phase of the prototype will focus on conceptualizing the platform's layout, user journey, and core functionalities through simple sketches, flowcharts, and wireframes. These representations will help validate the structure, ensure intuitive navigation, and align with user needs before development begins.

Key Elements:

- **Concept Sketches & Process Flowcharts:**
    - **User Journey Diagram:** Illustrates the flow of different users (e.g., researchers, SMEs, policymakers) from landing on the platform to achieving their objectives (e.g., finding funding, forming partnerships).



    - **Platform Structure Flowchart:** Shows the platform's main components—funding database, matchmaking system, and innovative technology section—and how they interconnect.
- **Wireframes of the Digital Platform:**

- Early-stage visual representations of the platform's interface, displaying the layout of search tools, matchmaking functions, and funding opportunities.
- Focus on navigation clarity and usability, ensuring that users can easily access key features.

<u>High-Fidelity Prototype (Interactive & Functional Stage)</u>

As the concept matures, the high-fidelity prototype will provide a more advanced and interactive representation of the platform, integrating essential features and user interactions. This version will support pilot testing and simulate real-world use cases.

Key Elements:

- **Interactive Digital Mockups:**
    - A **clickable prototype** (developed in WIX, or similar tools) to showcase the full user experience, from searching funding opportunities to submitting applications (*as bellow*).

    - Includes intuitive navigation, funding search tools, and matchmaking functionalities tailored to circular economy stakeholders.

- **Functional Models & Pilot Testing:**
    - **Live beta version** with matchmaking features between researchers and companies focused on circular economy solutions.
    - **Test environment** for SMEs and research institutions to explore funding opportunities in bioplastics, advanced recycling, and sustainable materials.
    - **AI-driven funding recommendation system** providing personalized grant suggestions based on user profiles and project themes.
- **Demonstration & Compliance:**
    - **Pilot project showcase:** A real-world example of a successfully funded initiative through the platform.

Step 5.
Testing Strategy
How will the prototype be tested?
Which metrics or feedback methods will be used?

To ensure the platform's effectiveness, a **structured testing strategy** will be implemented, combining pilot campaigns, user feedback, and industry validation, with key metrics assessing usability, engagement, and funding success rates: • A **pilot funding information campaign** targeting a select group of SMEs and research-industry partnerships to evaluate platform usability and impact. • **User feedback collection** from stakeholders in the plastics industry to assess ease of use and effectiveness. • **Performance measurement** focusing on usability, time efficiency, and success in connecting applicants with relevant funding opportunities. • **Industry expert validation** through engagement at events like ***Expo Plast event*** to gather professional insights. • **Workshops** with researchers and companies to refine platform features based on **real-world needs.** **<u>Feedback metrics:</u>** • **Platform engagement**: Number of funding applications submitted after using the platform. • **Efficiency tracking**: Time required for applicants to identify and apply for suitable funding opportunities. • **User experience evaluation**: Satisfaction surveys from researchers, SMEs, and policymakers. • **Impact measurement**: Number of successful industry-research collaborations facilitated. • **Funding success rate**: Percentage of projects that secure funding through the platform. • **Interest in funding opportunities**: Monitoring database views and access frequency. • **Growth in circular economy participation**: Measuring the increase in involvement from SMEs and industry players.
Step 6. **Iteration and Development Process** What steps follow after the first prototype? How will the feedback be integrated?
After the first prototype, the platform will undergo continuous refinement based on user feedback and performance metrics to enhance functionality and user experience. **Next Steps:** • Refining platform functionalities based on user feedback. • Enhancing matchmaking features for industry-research collaboration. • Expanding the funding database and support materials. **Integration of Feedback:** • Iterative updates based on performance indicators and stakeholder input.

- Regularly incorporating new funding opportunities and best practices.
- Improving usability and accessibility through user-driven enhancements.

Step 7.
Circularity
How does the prototype impact circularity/sustainability/requirements of circular economy?

The prototype contributes to circularity and sustainability by facilitating access to funding for innovative projects in the circular economy. It strengthens collaboration between researchers and industry, promoting the development of sustainable materials, recycling technologies, and waste reduction initiatives.

Impact on Circular Economy:

- Encourages the adoption of circular business models by connecting innovators with funding opportunities.
- Supports research-industry partnerships focused on eco-friendly materials, recycling processes, and resource efficiency.
- Increases awareness and accessibility of funding for circular economy initiatives.
- Enhances knowledge-sharing and best practices through matchmaking and networking features.

The prototype supports circularity and sustainability by:

1. **Facilitating Investment in Circular Business Models**
    - The platform connects SMEs and industry players with funding for sustainable plastics solutions, such as biodegradable plastics, plastic recycling technologies, and closed-loop production systems.
2. **Building Circular Economy Infrastructure**
    - By streamlining access to funding, the prototype supports infrastructure development for plastic recycling, including sorting facilities, advanced recycling technologies, and product innovation from recycled materials.
3. **Driving Innovation in Recycling and Waste Reduction**
    - The hub encourages cutting-edge recycling technologies, such as chemical recycling and AI-driven sorting systems, reducing the environmental impact of plastic waste.
4. **Strengthening Industry-Research Collaboration**
    - By linking researchers and companies, the prototype fosters the co-development of sustainable plastic solutions, accelerating the adoption of circular economy principles.

5. **Increasing the Number of Funded Circular Economy Projects**
    - By simplifying the funding application process, more projects focused on bioplastics, advanced recycling, and waste reduction can be financed and implemented.
6. **Promoting Efficient Resource Use and Recycling**
    - The platform prioritizes circular business models that emphasize plastic reuse, upcycling, and sustainable resource management.
7. **Developing a Sustainability-Oriented Business Culture**
    - By offering knowledge-sharing opportunities and funding guidance, the hub encourages SMEs in the plastics sector to embrace circular economy principles.
8. **Providing a Knowledge Hub for Circular Economy Best Practices**
    - The platform serves as a central repository of success stories, innovative solutions, and research insights, helping stakeholders apply circular strategies in their businesses.

***"CircularPlastHub: Accelerating Funding & Partnerships"** is not just a networking platform—it is a catalyst for circular innovation, simplifying access to funding and connecting researchers with industry to drive real impact.*