Product Passport through Twinning of Circular Value Chains

Deliverable 1.1

Plooto Methodological Approach and Business Cases Specifications V1

WP1: Digital Circular Value Chain Framework

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Executive Summary

The implementation of a Digital Product Passport (DPP) is of paramount importance for advancing circular value chains within the manufacturing industry in Europe, aligning with the European Union (EU)'s directives and legislations aimed at fostering sustainability and resource efficiency. According to the EU Circular Economy Action Plan[1], which is closely tied to the European Green Deal[2], transitioning to a circular economy could yield up to €1.8 trillion in benefits by 2030, contributing significantly to Europe's sustainability goals[3].

The DPP, as envisioned in various EU initiatives, acts as a digital record of a product's lifecycle. It contains essential information on its design, materials, manufacturing processes, and potential for repair, refurbishment, or recycling, which aligns with the principles laid out in the EU Waste Framework Directive[4] and the EU Eco-design Directive[5]. These directives set the stage for creating products with longevity and recyclability in mind while promoting sustainable production and consumption.

Moreover, the Digital Product Passport plays a vital role in complying with the EU's Waste Electrical and Electronic Equipment (WEEE) Directive[6], which necessitates the proper management of electronic waste. By enhancing traceability and end-of-life management, the DPP helps meet the WEEE Directive's objectives and contributes to reducing electronic waste. Additionally, the EU's Sustainable Product Policy Initiative, part of the European Green Deal, emphasizes the need for such digital tools to drive the circular economy forward.

Within Plooto's scope, this document provides the initial necessary step to map the circular value chain business processes of the three pilots in the project. The main findings are summarized in the following:

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[1] https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en
[2] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[3] https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Europes%20circular%20economy%20opportunity/Europes%20circulareconomy%20opportunity.ashx
[4] https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en
[5] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02009L0125-20121204&from=EN
[6] https://environment.ec.europa.eu/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en

Pilots' Key Highlights

CRFP Waste for Drones	WEEE for Magnets	Citrus Processing Waste for Juice By-products
Plooto To-be Scenario		
The pilot's goal is to design a process reusing carbon fibre waste generated by HPC's daily operations. This entails optimising requalification for expired prepreg rolls and uncured scraps to ensure efficient material processing. For this, CC seeks insights into the ideal process window encompassing temperature and pressure ranges.	The pilot aims to refine processes with minor adjustments, focusing on Ferimet's operations. Eurecat's support will facilitate automated dismantling of magnets. IMDEA aims to optimize magnet processing and explore requalification, while IMA focuses on proprietary production optimization. Overall, impacts include reduced carbon footprint and cost savings for IMDEA and IMA through process improvements and energy reduction.	The pilot's core goal is to enhance the by-product transformation for the cattle feed. ASPIS seeks to optimize separation and evaporation for increased molasses and CWP production. Additionally, they aim to demonstrate the superior nutritional value of orange by-product-derived CPW and molasses compared to other industry components.
Plooto Intervention Complexity		
High: Waste coming mainly from HPC as "producer" of cut scraps and expired prepreg rolls. Complexities rise as a net new process needs to be developed, especially in light of processing material and waste with a high variability in the properties.	**Medium:** Waste coming from multiple industries (e.g., automotive), treated with processes already in place (magnets extraction, demagnetization and remanufacturing). Complexities are found in the specific properties of magnets that can highly influence the final output and the to-be designed requalification process for contaminated sintered Sr-ferrite magnets.	**Low-Medium:** Waste coming from a single industry (orange juice industry) and produced from the company already active in the pilot. In addition, requalification processes are already in place. The complexity of this pilot raise in the proof of the value of the by-products for the cattle feed industry.
Initial Suggestions to Strengthen the Circular Value Chain		
• Further investigate how to best combine different recycling and remanufacturing techniques to effectively end up waste that could have characteristics similar to the original materials. • Expand the application of remanufacturing outside the production of drones, looking at other personal consumer applications where the light and strength of carbo fibre has a great potential. • Expand companies' engagement outside the pilot to collect external best practices but also to effectively create a consortium dedicated to the reuse of expired or uncured prepreg waste	• Design technologies for dismantling and disassembling devices or appliances to access magnets without damaging them. • Further investigate how to best process ferrite, optimizing the full process to avoid losing grade and reducing the cost of the process, to ensure that the secondary raw material is less expensive than using new raw material. • Produce magnets that are simple to be recycled, that might even simply mean print or impress on the magnet (where possible) the magnet composition and the quality. In case magnets are too small to have such details printed or impressed, a common standard code list can be developed.	• Design better and optimized processes that are also less energy intensive to ensure lower prices and a viable price competition. • Consider out scaling the activities to around oranges by-products outside Plooto's scope and boundaries, looking also at producing fertilizers and compost and potentially provide it back to the companies from where oranges are sourced, so effectively creating a sustainable and circular strategy. • Expand the customer base outside the cattle feed industry, for instance to the pet feed one, to ensure a larger commercialisation opportunities and new revenue streams.

Figure 1. Initial Pilots' Assessment and Considerations

Figure 1 presents an initial overview of the three pilots engaged in the Plooto project. Starting with the assessment of the desired and to-be scenario, the analysis moves to the assessment of the complexity of the tasks that need to be performed to achieve the expectation. Lastly, the suggestions to improve the circularity of each pilot's value chain are restated.

- **CFRP Waste for Drones**
  This is the most complex pilot due to the number of companies involved but also the complexities of the technical and operational work that the companies need to do within the pilot's boundaries. As the pilot aims to develop a new requalification process, especially for expired prepreg rolls, the odds of obtaining non fully satisfactory results might be high. However, the pilot has a great knowledge of the material handled and HPC has already developed in another European project a process to recover uncured scraps of cut prepreg, that can be further refined in this pilot. To improve circularity requirements, it would be highly advisable to connect with other organizations outside of the pilot ecosystem to see if there are already best practices available and also to expand the production objective outside the drone scope, as many other applications (even less complex one) can be exploited.
- **WEEE for Magnets**
  The complexity in this pilot derives from two different challenges; first the need to create a new and automated magnet extraction process (to substitute the current manual one) at the beginning of the value chain, and second to the study of a requalification process for sintered Sr-ferrite magnets that are contaminated by the addition of or coating with polymers or resins. In addition to the aforementioned solutions, to improve circularity strategies, it is advisable to push for standards creation in the labelling of magnets, so to ease the recycling and then the processing.
- **Citrus Processing Waste for Juice by-products**
  This pilot complexity is rated as medium to low because of the simple requirements of process optimization. What might raise the hurdle in completing this pilot is the further study of by-products value for the cattle feed industry. Suggestions to improve the circularity of this pilot can be seen in the expansion to the use of by-products outside the animal feed industry with production of fertilisers and compost, as well as or within the animal feed industry, looking to the pet food industry as an example.

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Acronyms and Abbreviations

Acronym	Description
APQ	Almacenamiento de Productos Químicos (Storage of Chemical Products)
CFRP	Carbon Fiber reinforced polymer
CLP	Classification, Labelling and Packaging
COD	Chemical Oxygen Demand
CPW	Citrus Peel Waste
CPWW	Citrus Peel Wastewater
CRIS	Circular and Resilient Information System
CRM	Critical Raw Material
CRS	Corporate Social Responsibility
DPP	Digital Product Passport
DSC	Differential Scanning Calorimeter
DT	Digital Twin
ICT	Information Communication Technology
EoL	End of Life
ERP	Enterprise Resource Planning
EU	European Union
FCVC	Framework for Circular Value Chain
GHS	Globally Harmonized System
ILSS	Interlaminar Shear Strength
MSDS	Material Data Safety Sheet
Prepreg	A two-part sheet material consisting of fibres (e.g. carbon) and partially cured resin
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHs	Restriction of Hazardous Substances Directive
SRM	Secondary Raw Material
WEEE	Waste from Electrical and Electronic Equipment
WP	Work Package
HPC	HP Composites S.p.A.

Acronym	Description
CETMA	Centro di Ricerche European di Tecnologie Desing e Materiali S.p.A.
CC	Cetma Composites SRL
ACCELI	Acceligence LTD
IMA	Ingeniería Magnética Aplicada SL
IMDEA	Fundacion IMDEA Nanosiencia
EUT	Fundació Eurecat
ASPIS	ELLINIKI VIOMICHANIA CHYMON KON. DEDES ASPIS AE
KPAD	KPAD LTD

1 Introduction

1.1 Purpose and Scope

This document is the first deliverable of T1.1 related to the definition of the Plooto business value chain framework and the development of the specific business circular value chain for each pilot in Plooto project. The main objective of T1.1 is to design the circular value chain by defining the pilot boundaries, identifying the role of stakeholders as well as defining the data flow and material flow across the value chain among the stakeholders. The design process takes place in two stages. The first stage, spanning from M1 to M10 of the project, involves the collection of the required preliminary data from pilot stakeholders through surveys, workshops and interviews. The results of the first phase, summarized in this document, highlights the preliminary design of the three Plooto pilots as well as initial insights on improvements of circularity in each pilot. As pilots' activities will progress in the upcoming months, the second phase aims to do a deep-dive into more details of the three pilot cases in order to update the value chain designs with more precise information. The final updated version of value chains will be delivered in M24.

1.2 Relation with other WPs

T1.1 has been carried out in close collaboration with other tasks of WP1 as well as other WPs of the project. The main interactions happened among the following WPs:

- **WP1**: the interface of the circular value chain with digital traceability strategies and governance model has been a point of interaction between Task 1.1 and other WP1 tasks. The results of preliminary value chains feed other tasks to design the traceability strategies and governance models.
- **WP2**: There has been a very close interaction with WP2 to ensure that the business and technical side of the circular value chain for pilots are aligned. During the phase of primary data collection through surveys and interviews, there has been a continuous collaboration with technical partners of WP2 in order to include the technical layer of information to the requested data. While T1.1 covers the business side, WP2 covers the technical side of the value chain.
- **WP4**: The interaction with WP4 has been the core of the design process of the circular value chain. Considering that the design is customized to each pilot's needs, the engagement of pilot partners has been critical in order to provide the required information. Indeed, they have been the direct targets of the questionnaire, interviews and the workshops that will be explained in detail below.
- **WP5**: the interface of the financial part of the value chain with the business model structure requires an interaction between T1.1. and T5.2 (business model design). In particular, during the data collection process, specific data related to the business model design of the pilots were also collected.

1.3 Structure of the document

The document is structured as follows:

- **Section 2** introduces the methodological approach used to define the Framework for Circular Value Chain (FCVC) and the steps taken to collect feedback from pilots to complete the FCVC. In addition, this section highlights how other projects partners in different work packages have benefitted from this initial information collection.
- **Section 3** describes the FCVC, deep diving in each of the sections of the framework and the relevant topics covered.
- **Section 4** describes the FCVC for each of the project's pilots, highlighting the most relevant outcomes and findings. This section also provides initial suggestion on proactive and repair circular strategies.

2 Methodology

The methodological approach for Task 1.1 has been discussed and agreed very early in the project, since the kick-off meeting in Bologna and has been coordinated by the WP1 stakeholders as a whole to ensure that relevant and overarching information were collected and distributed across the whole WP.

On top of the information already collected in the proposal phase of Plooto project, to perform the initial assessment on manufacturing sector business and technology needs and the development of the framework, existing IDC (data and resources) and external resources have been used. To this overarching and initial background check, further desk research has been performed to deep dive on the specific business and technology needs and requirements within the three pilots, namely: the use of WEEE for the production of magnets, the exploitation of by-products from citrus processing waste and the CFRP waste utilization for the production of components for drones.

2.1 Framework for Circular Value Chains

Assessing the requirements of both the business and technology aspects was a fundamental initial step towards gaining insights into the methodology of constructing a holistic framework. This effort encompassed not just conventional business prerequisites and technological necessities, but also the complex information workflows that interweave them. Nevertheless, the development of this framework demanded an in-depth exploration of the circular dynamics of the various organizations participating in the value chains, a central and pivotal focus of this overarching project.

However, it is important to recognize that this framework's evolution guides us towards simplistic business and technology needs and information flows. The framework deep dives into the circularity aspects within the diverse array of organizations entangled within the value chains under study. This exploration into circular dynamics was not just a "nice-to-have" addition but rather a core component of the entire Task 1.1 efforts. The intricate interplay of resources, feedback loops, and collaborative synergies within these organizational networks formed the very essence upon which this project's success will be based.

The starting point of the analysis was the Osterwalder's business model canvas, a business strategic tool to describe how organizations create, capture, and deliver value. Originally presented in the book "Business model generation: a handbook for visionaries, game changers and challenges" [2].

This model, as shown in

Appendix A: Osterwalder's Business Model Canvas, is built on nine building blocks:

1. **Key partners**
   This section showcases upstream (e.g., raw material, semi-components providers) and downstream (e.g., wholesalers, retailer chains) partners but also strategic alliances and joint venture.
2. **Key activities**
   This part of the canvas describes how the production/creation process is set up across different transformation activities.
3. **Key resources**
   This part presents the information on assets (IP rights, facilities, and machineries), financial capital, human capital, and raw materials owned by the organization.
4. **Value proposition**
   This area describes the intersection between the value proposition of the organization, so why and what the company offers, and why customer should purchase the product/service offered.
5. **Customer relationships**
   This block identifies tactics and solutions on how to structure a long-lasting customer relation with tactics around acquiring customers, building, nurturing, and growing the relationship.
6. **Channels**
   This component identifies how the organization is selling products and services to the customers.
7. **Customer segments**
   This element identifies the most important customer group(s) to which the organization sells products and services.
8. **Cost structure**
   This section identifies the full model costs of the organization, from production to customer acquisition and retention, to financial capital.
9. **Revenue streams**
   This part of the canvas presents how effectively the value is created and captured for the organization, and which is the business model behind.

Despite being a comprehensive view of how to structure an organization's business model, the Osterwalder's approach misses the ecosystem logics and dynamics of the pilots' activities, one above all the circularity element, core pillar of the pilots' operations. For instance, the framework, focusing on one single company, lacks the objective of this project, so understanding the business and technical relationships across the different companies that work in a single circular value chain. From this initial observation, other aspects fail to be integrated, such as how and when materials and information flow across the different companies and clearly the circularity approach, critical requirement at the heart of Plooto project.

For the aforementioned reasons, we adapted the Osterwalder's business model canvas into a new dedicated framework – easily reusable across industries and new projects – Framework for the Circular Value Chain (FCVC) (see Chapter 3 of this document).

Once the structure and the approach to the "Framework for Circular Value Chain" was validated and approved with the partners and pilots, the framework was customized to each pilot's needs, as shown in Chapter 4, through a 3-phased data collection procedure. The first two phases were based on questionnaires shared with the pilots' partners to be completed offline and then studied by the WP1 partners while the last one involved direct 1 on 1 interview, one with each pilot.

2.2 Primary Research – Workshops and in-person interviews

The primary research activity was crucial to effectively map challenges, business and technical requirements, the relationships among pilots' and what was on their agenda as outcome from their participation in Plooto project. This information collection stage was primarily conducted between February and June, with additional information request between July and September, to finalize any missing information. As already mentioned, the process started with the creation of a first workshop questionnaire to touch base with the pilots' participants and to start collecting information on pilots' needs and requirements. This first questionnaire has been followed by a second workshop questionnaire to deep dive into specific areas, not covered with the first one. In the third stage, to finalize and refine the information collected, three one-to-one interviews have been conducted involving all relevant pilot stakeholders.

Workshop 1

The first questionnaire workshop was presented to the full consortium in early February with the objective to test the waters on the pilots' activities. The complete questionnaire can be found in Appendix B: Workshops Questionnaires – Table 1.
In the first workshop, an initial set of questions has been presented and explained in a conference call. In the following weeks, pilots' ecosystems had to work in tandem to provide the initial information requested across multiple topics, spanning from questions on waste origins (e.g., industries producers), what information and data are exchanged across the pilot's participants and with the final buyer of the pilot's output, which are the steps of the full material recovery and reuse process, which certifications are required to process and sell the waste and the pilot's final output. Also, some initial questions on the value creation and business model (e.g., KPIs, benefits of the circularity approach) were asked to complete the FCVC and to support also Plooto's partners in WP5 (for the assessment of the business model and exploitation activities).

After the analysis of this workshop responses, not only WP1 partners but the whole consortium was able to have a better understanding of the interconnections across pilots' participants, the activities involved in each stage of transformation, as well as benefits and challenges within the transformation process – just to name a few.
The information collected also helped the T1.1 leaders and the broader WP1 team to deep dive on some specific areas that needed more attention and detail, exercise carried out with the second workshop.

The broader set of WP1 partners, benefitted of this initial information collection, and were able to start working on:

- Task 1.2, which deals with the understanding of the participating pilot processes and the digital traceability strategies. The 1st round of workshop provided the baseline for an initial assessment of the existing traceability strategy of each business case by offering insights on its value chain. The outcomes of Task 1.2 will be reported in D1.3 and D1.4.
- Task 1.4, which deals with the definition of the Governance Models and the Sustainability Framework. During the 1st workshop, WP1 partners were introduced to the strategic and operational frameworks of the pilots as well as to the policies of the stakeholders in order to kick-start the discussion on how all these can be combined and on how data can be used to achieve these goals. The outcomes of Task 1.4 will be reported in D1.3 and D1.4.

Workshop 2

The second workshop questionnaire was shared with the pilots' partners in mid-March with the objective to expand and deep dive on some questions already asked in the first workshop as well as investigate on new areas only slightly investigated with the first questionnaire. For instance, this second workshop deep dived into how waste that cannot re-enter the production process is handled and disposed, how information and data are exchanged across the organizations transforming the waste, how the new SRM is distributed and the relative challenges in this process. The complete questionnaire can be found in Appendix B: Workshops Questionnaires – Table 2.
After this second analysis, T1.1 and the broader WP1 partners, had almost a full picture of the status of the pilots and related activities, as well as information on the relationships among partners, processes and resources needed to fulfil the different pilots' mission.

The extended group of partners in WP1 reaped the advantages of this additional information gathering, enabling them to initiate their work on:

- Task 1.3, which deals with the Information Modelling Framework and exploits the work of T1.1 and T1.2, initiated in the first workshop. The second workshop enabled WP1 partners to identify the need of a semantic modelling framework, defining the semantics of different aspects of technical information, and to communicate it to the pilot partners. Their feedback will serve as a basis for Knowledge Graph creation and will support the development of associate technical partners' solutions. The outcome of Task 1.3 will be reported in D1.3 and D1.4.

- The collection of initial sets of information concerning the relationships among pilot's participants to draft governance strategies and to identify the relevant KPIs to assess the value chain performance (T1.4).

One-to-one Interviews and additional follow-up

Once the information was filled in the different pilots' specific FCVCs, T1.1 partners moved to finalize the analysis of the information missing, especially in light to the information requested for Taks 1.1 in the Plooto's scope according to the description of actions (e.g., pilot's boundaries, to-be-scenario, potential constraints/risk associated to each pilot). In addition, in coordination with WP5 activities, we started deep diving on business value creation, asking pilots to respond to questions related to commercial channels, current and expected IP rights from the project, and value proposition, which can be found in Appendix B: Workshops Questionnaires – Table 3.

The in-person interviews were carried out in three different moments, for the WEEE for Magnets pilot, T1.1 leader took the opportunity to question IMA, IMDEA and EUT during the Barcelona Consortium Meeting (May 4th – 5th). With the Citrus processing waste for juice by-products, T1.1 leveraged one on-site visit and an ad hoc call with ASPIS and KPAD (on site visit May 26th on and ad hoc call on June 13th). Similar to the WEEE for Magnets, for the CFRP waste for Drones pilot, an onsite visit was organized with participation of CC, HPC, ACCELI, and CETMA (June 29th-30th).

The larger set of partners involved in WP1 derived benefits from this second round of information collection, which empowered them to commence their tasks:

- Task 1.5, which deals with the Circular and Resilient System (CRIS) specification and architecture has benefited greatly from the whole chain of workshops. The individual interviews allowed for the analysis of the specific needs per case. The preliminary definition of the system-level specification and the user/system requirements will also support the development of the technical partners' solutions and their adaptation to pilots' unique characteristics. The outcome of Task 1.5 will be reported in D1.5 and D1.6.
- The workshops initiated under Task 1.1 have been crucial for WP1 as a whole, since they set the baseline and the starting point not only for all WP1 Tasks but also for the whole project.

2.3 Usage of information collected in T1.1 activities from other partners

These rounds of information collection were helpful for T1.1 partners but also to the full set of partners involved in the project. Information and data collected during the first 10 months of the project leading to this deliverable, will be essential for T1.1 to continue the deep dive on the FCVC that will be reported in D1.2 "Plooto Methodological Approach and Business Cases Specification" V2, due in month 24, and to the full set partners in WP1, in order to effectively understand sustainability requirements that must be delivered within the sustainability balanced scorecard, effort of T1.2, T1.3 and T1.4 reported in M12 under deliverable D1.3 "Sustainability balanced scorecard framework V1" and to design the Circular and Resilient Information System (CRIS) – T1.5 effort that will be reported in M12under deliverable D1.5 "CRIS requirements and specification V1".

However, tasks across other WPs have benefitted of this information collection to draft initial and conceptual work, such as:

WP2

- ***T2.1*** to do the first model of the value chain as interconnected DTs that is based upon the data gathered within the pilots, the traceability strategies and the internal processes modelled in Task 1.3 (e.g., identification of main actors involved, their relationships, data exchanged and services to be executed) that will lead to the initial model of the pilots' value chain in terms of Digital Twins).
- ***T2.2*** to identify data that will constitute the Waste supply chain dataspaces.
- ***T2.6*** to implement the Process Modelling and Simulation in order to identify the process model entities, their interconnections and interactions as well as the characteristics that describe their behaviour and the means to quantify how they respond to state and value changes. These will be reported in D2.3 and D2.4.

WP4

- ***T4.5*** provide a first version of "certification KPIs' requirements for circular economy standards and digital passports". This will ensure that certification measurement and parameters – including risk and opportunities for recycling and remanufacturing – identified by WP4 as certification guidelines are related to the recorded inputs-outputs during the production process of each pilot. The first draft is delivered in Appendix C.

WP5

- ***T5.2*** Collaborative Business Models for Circular Value Chains to start examining pilots' business models, value propositions, joint and individual exploitation plans. The data collected will be reported in D5.5, D5.6, and D5.7.

The process of gathering this information marked a crucial and initial phase in the project's progression. It laid the groundwork for various important aspects that were imperative to advance the project in a structured manner. This initial data collection activity was pivotal in several key ways:

- **Foundational Step (information gathering)**
  This information-gathering process served as a foundational step that set the tone and direction for T1.1. It established a solid base upon which the subsequent T1.1 activities and developments could be built.

- **Pilot Insights (Workshop iterations, 1:1 interview, visits)**
  By obtaining insights from pilot activities, the project gained valuable lessons and real-world observations. These insights helped T1.1's trajectory and informed decisions about refining and optimizing various tasks components.
- **Pilot's Process Mapping Drafting (Finalization of missing data, visits)**
  The collected information played an instrumental role in creating an initial outline of the pilot's transformation processes. This preliminary process mapping was vital for understanding the sequence of tasks, workflow, and dependencies involved in the pilot's operations.
- **Technical and Data Requirements Identification (Basis for WP2, WP3)**
  Through this information collection, critical technical specifications and data requirements were identified. These specifications were essential for guiding the technical partners in selecting and designing appropriate technologies, tools, and resources to meet the pilot's objectives.
- **Product Passport Development (Basis for WP3)**
  The information collected will constitute the initial input for constructing a comprehensive product passport. This passport will serve as an agreed set of information shared along the supply chain with regards the of the product's components and basic metrics (sustainability and other KPIs).
- **Digital Twin Design Initiation (Basis for WP2)**
  With the gathered information, work was initiated on designing the digital twin of the waste transformation phase. The digital twin, a virtual replica of the physical processes, enabled simulation, analysis, and experimentation in a controlled environment, contributing to the project's innovation and efficiency.

These interconnected steps collectively formed the backbone of the project's early stages, ensuring a well-informed and structured approach to achieving its goals.

3 Framework for Circular Value Chain

As already mentioned in Chapter 2, the Framework for Circular Value Chain (FCVC) is a customization of the Osterwalder's Business Model Canvas. The customisation was required by the different approach of the analysis, under multiple aspects (e.g., multiple actors involved, sustainability requirements not specified in the Osterwalder' model). The extensiveness of the new framework, primarily driven by the number of partners involved in each pilot and by the circularity requirements, asks for a deeper knowledge of the relationships that are created within each pilot. In recent times, the establishment of circular value chains has garnered significant prominence due to their capacity to effectively tackle the mounting environmental and economic challenges. This stands in contrast to the conventional "linear" value chains, which culminate at the conclusion of the product's lifecycle with a mere disposal of waste. IDC data shows that more than 55% of European companies evaluate supply chain alignment and enforcement of sustainability practices as well as circular product design and lifecycle management are critical ESG aspects (IDC's Future Enterprise Resilience and Spending Survey, Wave 4, May 2023 – European sample); considering only manufacturing companies these activities become crucial for more than two thirds of the companies in this sector. Circular value chains, in creating closed-loops systems, support different critical sustainability and economic requirements:

- ***Natural resources and raw material conservation***
  In prioritizing efficient resource usage in conjunction with SRMs reusage, organizations can have a lower impact on scarce availability of "virgin" resources, supporting the conservation of the planet.
- ***Waste reduction and extended lifecycle***
  In reusing and reprocessing waste materials (in their integrity or for just a portion) it is possible to extend the lifecycle of different components (reducing the pressure on "virgin" material) and reduce the pollution of waste ending up in landfills or incineration facilities.
- ***Resilience to supply chain disruptions with shorter supply chains***
  It is not only about reducing dependencies on sourcing raw materials/components from countries outside the European boundaries, but also matter of improving the resilience of supply chains to geopolitical challenges or supply chain disruptions. In addition, organizations seek to shorten the sourcing of (secondary) raw materials closer to the origin (and the production) so to reduce the carbon footprint impact of transporting these across countries.

The methodological approach for "closing-the-loop" in industrial value chains has been based on a solid sustainability framework that consists of governance models and the Sustainability Balanced Scorecard Framework. The main objectives derived are the establishment of a digital transformation framework for the circular value chain, the development of a Digital Twin platform to support circularity in industrial processes, and the creation of a Circular and Resilient Information System for real-time monitoring and decision-making.

Circularity in value chains is being reinforced by improved traceability and transparency strategies, and the corresponding reference processes. Aiming to elaborate prosperous and valuable circular value chains, the identification of processes, products, new technical capabilities that can generate economic advantage, resilience, sustainability, and business opportunities, are critical. To do so, a systemic digital traceability strategy was defined, including steps and stages of maturity, and a conceptual traceability framework delineating the goals, solutions, and enablers, aiming to provide added value at each step of the strategy's stages (sourcing, processing, packaging, distribution, consumption, disposal, circularity).

Plooto Integrated Sustainability Framework was defined by valorizing essential information from thorough research, and input derived from T1.1 activities and outcomes. This framework is a combination of handpicked elements from already available knowledge. It encloses the principles and overall perspective of the ESG framework, numerous Sustainability Frameworks and Standards that have been successfully tested and delivered, incorporating modules from the Sustainability Balanced Scorecard. To this end, a pool of KPIs was derived (and currently being updated within Tasks 1.2 and 1.4) from the integrated framework; a generic set of KPIs, adopted in circularity of all Plooto supply chains, and three tailored ones, each for one pilot case, adjusted to the specialised processes.

This work will be reported in D1.3 and D1.4 "Sustainability Balanced Scorecard framework", in D1.5 and D1.6 "CRIS requirements and specification" and in D2.3 and D2.4 "Plooto complete suite of services".

Before deep diving into the Framework for Circular Value Chain, it is important to remind the reader of the 6Rs [1], the different circular strategies that manufacturers can pursue and which of these play a relevant role for this project purposes.

- **Reduce**
  Mainly focuses on the first three stages of the product life-cycle, and refers to the reduced use of resources in pre-manufacturing, reduced use of energy, materials and other resources during manufacturing, and the reduction of emissions and waste during the use stage.
- **Reuse**
  Refers to the reuse of the product as a whole, or its components, after its first life-cycle, for subsequent life-cycles, to reduce the usage of virgin materials to produce newer products and components.
- **Recycle**
  Involves the process of converting material that would otherwise be considered waste, into new materials or products.
- **Recover**
  The process of collecting products at the end of the use stage, disassembling, sorting and cleaning for utilization in subsequent life-cycles of the product.

- **Redesign**
  Involves the act of redesigning of next generation products, which would use components, materials and resources recovered from the previous life-cycle, or previous generation of products,
- **Remanufacture**
  Involves the re-processing of already used products for restoration to their original state or a like-new form through the reuse of as many parts as possible without loss of functionality. Of these circular processes for the manufacturing industry, the recycle/redesign and remanufacture will be used by organizations participating to the three pilots involved in this project.

3.1 Structure and Components

The FCVC is composed by four main parts, as presented in Figure 2.

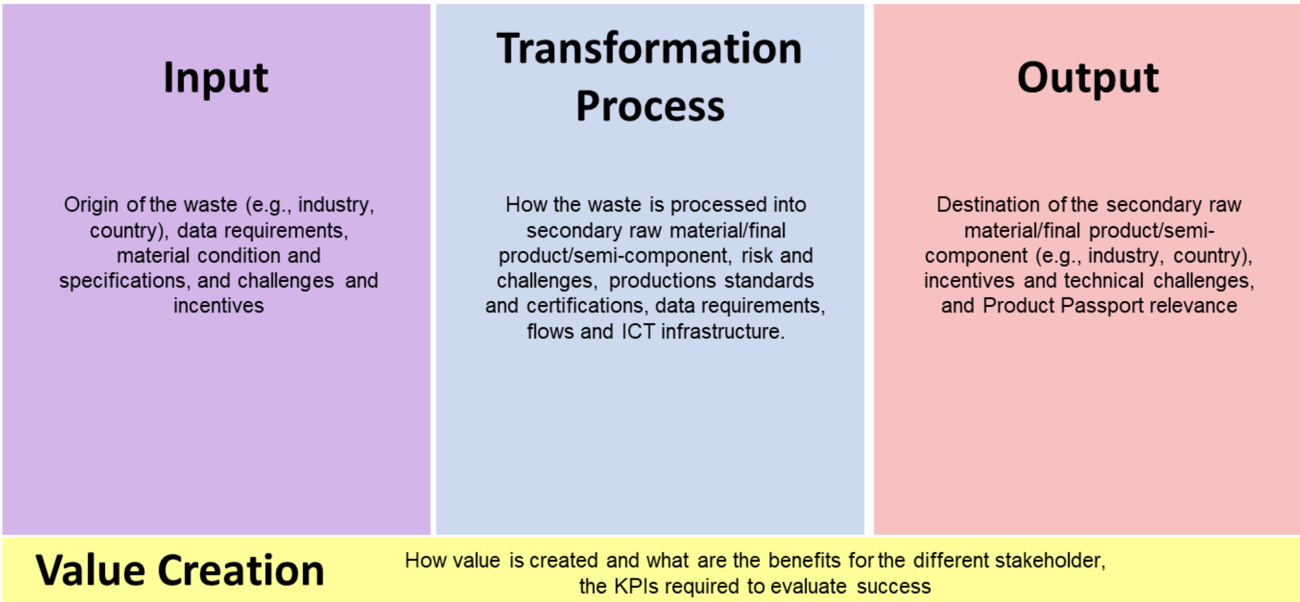

Figure 2. Plooto Framework for Circular Value Chain

1. ***Input***
   This section of the framework aims at identifying and mapping how and where the waste to be transformed in SRM, semi-components or finished goods is produced, what are the critical data and information that partners involved in this first stage needs to track, how they currently collect this data, and what are the main challenges and benefits of this stage.
2. ***Transformation Process***
   This second section highlights the core transformation process (that can be recycling or remanufacturing) and the different actors involved (if more than one actor is involved in this stage). The idea of the transformation process stage is to provide a high-level overview of the processes composing the transformation activities, highlighting

challenges and (if already available) best practices, in order to support other work packages in their tasks (e.g., creation of digital twins, delivery of CRIS).

3. ***Output***

   This section of the framework highlights the output of the full transformation process, providing insights also on what are the key information that need to be included in the product passport that will accompany the final product, what are the current challenges in placing the output on the market and how the pilots plan to exploit the output of the transformation process.

4. ***Value Creation***

   This last section, especially for this deliverable, will present a draft idea of how the organizations are planning to create value and understand what the benefits for the different stakeholders involved in the pilots are. This will be inspirational also in the definition of the business model creation, part of WP5.

This framework not only serves as a valid starting point upon which fellow partners within the Plooto project can build their work, but it also holds value due to its inherent adaptability for use beyond the confines of the project. Remarkably versatile, this framework remains impartial to specific manufacturing processes, rendering it applicable across diverse manufacturing sectors — ranging from discrete to process manufacturing and regardless to the different output production.

Its comprehensive nature lies in its capacity to scrutinize and delve into the multifaceted components of the overarching value chain. What's more, its modular structure enables seamless adjustments, allowing sections to be tailored or removed in accordance with the type or intricacy of the production process, as well as the number of organizations engaged within the value chain.

3.3.1 Input

The "Input" section of the framework tracks and assesses where and how the waste to be transformed in the SRM is sourced. It goes beyond this, also highlighting responsibilities in this phase, critical data and material specifications required in the sourcing stage. Other information such as challenges, incentives and how data and information are exchanged between the producer / collector of the waste and the pilot's partner dedicated to this sourcing phase are provided. Important to mention is that not all the pilots collect waste from outside the pilot's boundaries, so eventually not every field of this section will be populated.

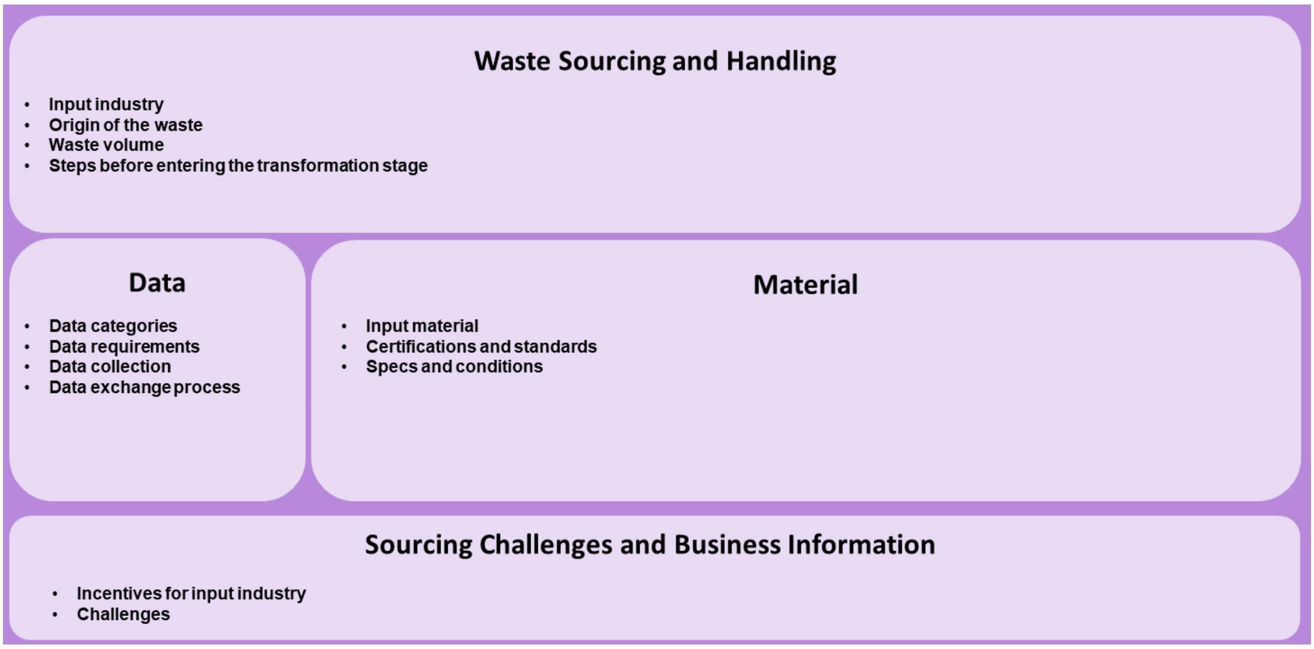

Figure 3. Input section of the Plooto Framework for Circular Value Chain

Each of the illustrated boxes in Figure 3 represent a domain that adds depth and understanding to the input phase.

- Waste Sourcing and Waste Handling
  This first box collects information around the industries producing the waste, the localization of such "producer", the quantity of waste received and whether there are pre-processing operations to carry out.
  - Input industry – information on the industries from which the waste is sourced.
  - Origin of the waste – country of origin of the waste.
  - Waste volume– specification around how much waste is expected to be introduced in the recycling/remanufacturing process.
  - Steps before entering the transformation stage – critical steps that need to be carried out before entering the waste into processing.
- Data
  This box provides information on data that the pilot needs to be provided to start the circular transformation process and how this information are exchanged.
  - Data categories – high level information on the categories of data that need to be exchanged along with the waste.
  - Data requirements – details around specific data points that need to be provide with the waste.
  - Data collection – how this information and data are collected (available if the waste producer is inside the Plooto/pilot value chain).
  - Data exchange process – what are the channels and tools to exchange data from the waste producer to the organization(s) processing the waste.
- Material

It identifies the main characteristics of the material before entering the transformation process as well as if there is any certification needed before starting to treat the waste.

- Input material – description of the waste.
- Certification and standards – required certifications or standards that need to be provided alongside the waste.
- Specs and conditions – what are the visual/quality characteristics of the waste prior to entering the transformation process.

- Sourcing Challenges and Business Information

  This box collects the challenges in sourcing the material but also provides further colour to business and technical activities not covered elsewhere in the "Input" section of the framework.

  - Incentive for input industry – description of incentives for the waste producer in entering the value chain.
  - Challenges – description of the challenges that the first pilot's company that connects with the waste producer or collector needs to address when sourcing the waste.

3.3.2 Transformation

The "Transformation" section covers the most critical activities and related challenges of the transformation stage to process the waste in the secondary raw material, semi-component or finished products. In addition, the information required to be exchanged across the different partners within the pilot are highlighted and how these exchanges are carried out. Equally important to mention is that not all the pilots have multiple organizations working in the transformation stage, so eventually not every field of this section will be filled in.

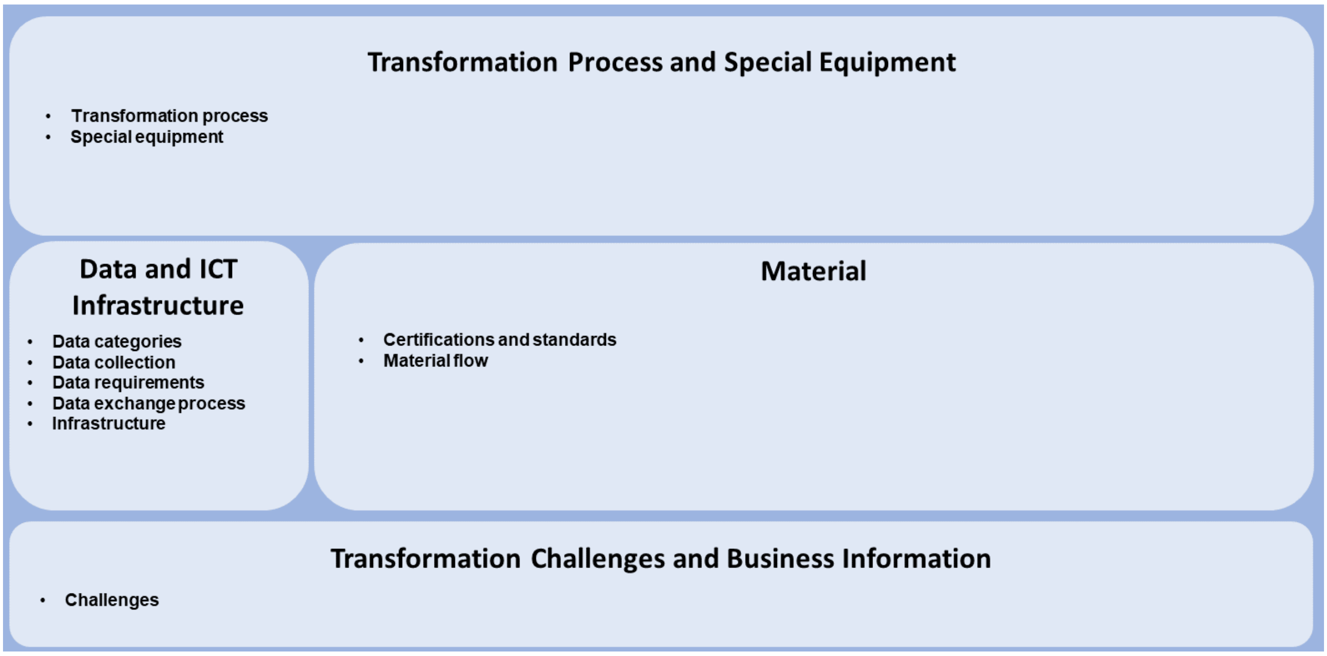

Figure 4. Transformation section of the Plooto Framework for Circular Value Chain

Each of the illustrated boxes in Figure 4 represent a domain that adds depth and understanding to the transformation phase.

- Transformation Process and Special Equipment
  In the first box the critical steps to transform the sourced waste into a semi-component or an effective secondary raw material are presented. With this, also the roles and specific initiatives of each partner are highlighted.
    - Transformation process – high level description of the transformation process to transform the waste into a secondary raw material, semi-component or a final product.
    - Special equipment – transformation, laboratory and quality control machineries needed to process the waste or control the process.
- Data and ICT Infrastructure
  This box provides information on the type of data that the pilot partners require to exchange between one another (if available) to effectively optimize and improve the transformation process. The more detailed and precise the information exchanged is, the better and the more optimized the process can be. At this stage, it is also critical to understand how this information are exchanged between the different partners.
    - Data categories - high level information on the types or categories of information that need to be exchanged along the transformation process (if more than one company is involved).
    - Data collection – how data and information are collected across the transformation process.
    - Data requirements - provide details around specific datasets that need to be provided across the transformation process (if more than one company is involved).
    - Data exchange process - what are the channels and tools to exchange data across the transformation process (if more than one company is involved).
    - Infrastructure – high level information of the ICT infrastructure the companies involved in the transformation process use to store and analyse the data (e.g., ERP, sensors).
- Material
  This section presents the critical certifications and standards (if required) to transform the waste into SRM along with details of at what stage the waste is moved across the different companies (if available) during the transformation process.
    - Certification - required certifications or standards that need to be in place to treat the waste.
    - Material flow – how and when the treated material moves from one company to another in the transformation process (if available).
- Challenges and Business Information

This box collects the most relevant challenges faced in the transformation process (e.g., material condition and process requirements: temperature, pressure, % of water, toxicity) and provide further information around business and technical activities not covered elsewhere in the "transformation" section of the framework.

- Challenges - description of the challenges that the company(ies) transforming the waste need(s) to address.

3.3.3 Output

The output section provides information on the last phase of Pilot's boundaries, so it details how the final SRMs, semi-components or final products are delivered to the final users and who those users are. As for the previous two sections, we highlight also what data is critical to be shared, this time within the product passport of the component/SRM. Important to mention is that not all the pilots have identified the specific customer target but might use their usual channels and customer base, so eventually not every field of this section will be filled in.

Figure 5. Output section of the Plooto Framework for Circular Value Chain

Each of the illustrated boxes in Figure 5 represent a domain that adds depth and understanding to the output phase.

- Final Production and Distribution
  This box provides a description of the final output of the transformation process, providing also insights around how it is distributed, and who are the users.
  - Output – description of the final output of the transformation process.
  - Sales channels – description of the path that a business takes to reach its end customers to sell them the SRM or the semi-component.

    - Target markets (industry) – industries that buy the output of the transformation stage (if available).
    - Target markets (geography) – where are based the industries buying the output.
    - Target markets (company size/user) – what is the company size of the targeted customer. In case the product goes directly to private consumers, a description of the average user is provided.
- Data
  This section highlights the relevant information that the producer must exchange with the supply chain nodes and the buyer, via the digital product passport (DPP). Each node in the production value chain until the final product is ready will hold a variety of information. The DPP will hold information – agreed by the supply chain stakeholders - regarding the manufacturing process of the product, product quality characteristics as well as the specifications of the product in order to match them at later stage with the requirements of the next value chain node. At each value chain node, the DPP stores the information from the current manufacturing process, but also is updated with some of the information from the previous steps, according to the data sharing agreement between the two value chain nodes. The data exchange process for the DPP can vary according to the needs and the type of the product, blockchain technology can be used as part of the data exchange process, and QR code on the product, can be used to access information.
- Material
  This box highlights the certifications (if available) that are requested by law to commercialize the output of the production process.
    - Certifications and standards - required certifications or standards that are required to commercialize the final product.
- Challenges and Business Information
  This box collects the most significant challenges and benefits of selling SRM or components generated from waste, as well as provides information on how relevant the product passport for the company at the end of the production chain is when proposing its product to the market.
    - Incentives for the buyer - description of incentives for the buyer or end user archiving the final product made with recycled/remanufactured materials.
    - Challenges - description of the challenges that arise in the selling process.,
    - Relevance of Product Passport – how relevant is the product passport for the company providing the transformed output created by recycled/remanufactured materials to certify the product.

3.3.4 Value Creation

The Value Creation section of the framework starts the analysis that will be deep dived in WP5 (Task *T5.2* Collaborative Business Models for Circular Value Chains reported in D5.5, D5.6, D5.7), highlighting how the different pilots aim to create value for each of the partner involved but also at broader pilot level. The value creation shouldn't be considered only in monetary terms, but also the overall value delivered to the society and the broader set of stakeholders at European level. In this section the expected business models are analysed; how potential IP rights will be handled and what is the expected project outcome and how this is evaluated through specific KPIs. Important to mention is that not all the pilots have already identified the exact output of the production, so eventually not every field of this section will be filled in.

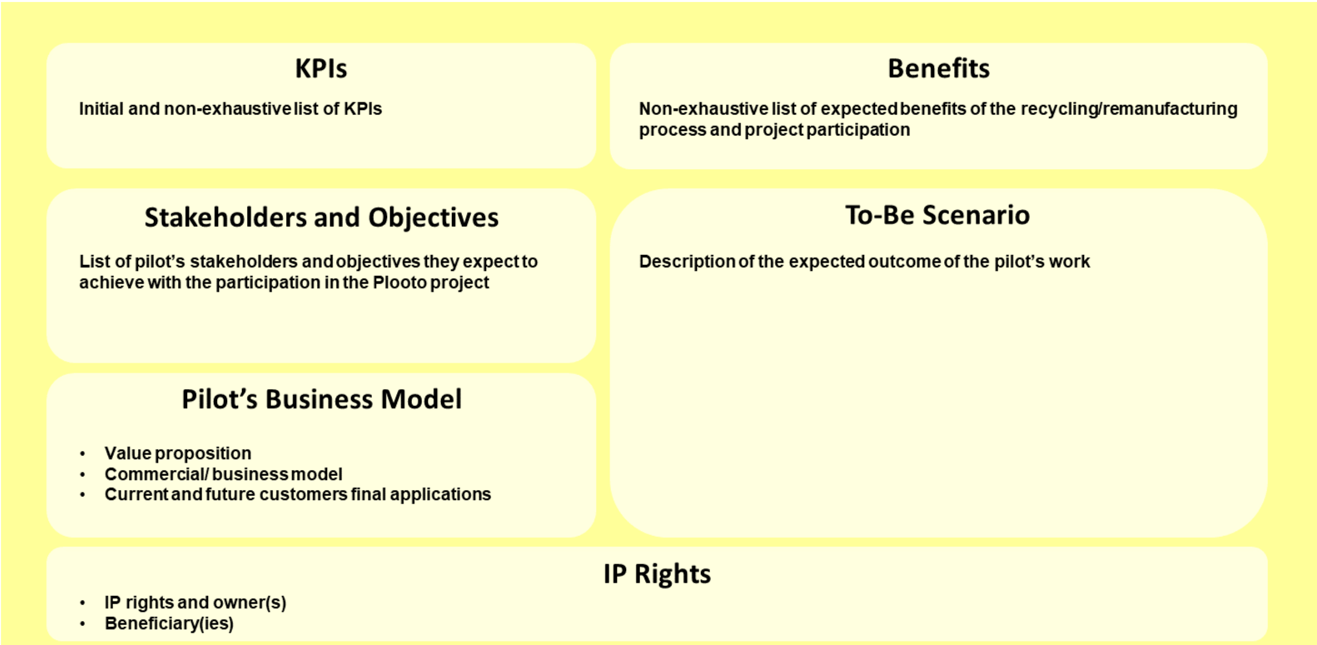

Figure 6. Value Creation section of the Plooto Framework for Circular Value Chain

Each of the illustrated boxes in Figure 6 represent a domain that adds depth and understanding to the approach to value creation.

- KPIs
  This box provides a non-exhaustive list of the most important KPIs that will be used to evaluate the successful implementation of the circularity approach. In this deliverable, we will provide the list of KPIs that partners within the pilots are expected to measure. With the follow up deliverable (D1.2 – Plooto methodological approach and business case specification v2) we expect to provide also targets and measure to evaluate success of the mentioned KPIs.
- Benefits
  In the benefits box the most important benefits of the full process are highlighted but also for the purchaser of the SRM, semi-component or final product depending on the pilot story.
- Stakeholders and objectives
  This section highlights the full pilot's stakeholders and the objectives that have in this project.
- Pilot's Business Model

This box provides an overview on how the pilot is expecting to deliver financial value with the provisioning of the SRM, the semi-component, or final product sold. In addition, this first deliverable aims at providing a draft of the pilot's value proposition.

- Value proposition – statement of the benefits and objectives that the pilot has in delivering to customers what has been produced.
- Commercial/business model – how the pilot/organization selling the product is expected to deliver monetary value.
- Current and future customers final applications – current objective for final application and potential extension to the business models in terms of new applications (e.g., where the output can be used or further industries that could be interested buying the transformed SRM or semi-component).

- To-Be Scenario

  This box, at this stage highlights the expected outcome of the pilot's work. In future deliverables, it will highlight how to further improve the work and processes done (even outside the current work).
- IP Rights

  This box highlights if there are already in place IP rights that will be helpful for the processing of waste and in future deliverables if there are new process IP rights that the Pilot's will benefit.
  - IP rights & owners – details if the pilot is expected to patent any new process or product and who is the company within the pilot retaining ownership.
  - Beneficiaries – who within the pilot is expected to benefit from the IP rights.

4 Pilots and Findings

The previous two chapters extensively delved into the examination of the employed methodology for acquiring information concerning the pilots, as well as the step-by-step process involved in crafting the Framework for Circular Value Chains. Transitioning to this chapter, the focus will shift towards scrutinizing the most important results stemming from the information collection in connection with each pilot. This significant analysis culminated in the establishment of a dedicated Framework for Circular Value Chains pertaining to each of the three pilots: CRFP Waste for Drones, WEEE for Magnets, and Citrus Processing Waste for Juice By-Products.

4.3 CFRP Waste for Drones

Carbon fibre composite production is an intricate process that involves transforming carbon-rich precursor materials into lightweight, strong, and durable objects. Carbon fibre is widely used in various industries, including aerospace, automotive, sports equipment and more. The production of objects using carbon fibre is a multi-step, precision-oriented process that requires expertise and specialized equipment. The resulting carbon fibre composites offer exceptional strength, stiffness, and lightweight properties, making them a material useful for a wide range of applications.

The most relevant challenges in this industry are:

- the cost of the workforce engaged in the production of carbon fibre objects,
- the energy consumption required by the curing stage (e.g., curing in autoclave),
- the high variability of the material depending on the structure of carbon fibre (e.g., different polymers, different threads, different fabric)
- the variability related to storing and handling condition,
- the cost and challenges in disposing of uncured or expired carbon fibre rolls.

Hence the need for Plooto is to provide a solution in the reusage of expired or uncured carbon fibres prepregs for lower-value added and non-high-end industries.

4.3.1 Pilot Description

In the CFRP Waste for Drone Pilot four stakeholders are involved:

- HPC, which specializes in working with carbon fibre materials to meet customer orders, generates a significant amount of waste primarily during the cutting phase. Moreover, HPC in some cases encounters situations where surplus materials remain in the form of expired prepreg rolls that need to be recycled.
- CETMA is in charge to study a re-qualification process of both expired prepreg rolls and waste from cutting activities performed by HPC. In detail, CETMA is in charge of assessing if the waste material can be re-used and in which ways.

- CETMA COMPOSITES will receive waste from HPC and technical information on the new processes by CETMA and will produce the drone parts as per request of ACCELI.
- ACCELI is the final producer and assembler of drones.

The objective of the pilot is to design a requalification process, identifying the optimal process parameters to secure material processability to obtain high quality components.

4.3.2 FCVC and Preliminary Findings

In Appendix D: CFRP Waste for Drones Framework for Circular Value Chain" the full Framework for Circular Value Chain for the CFRP waste for drones' pilot is provided.

The framework, built in sections and boxes, helps to simplify the understanding of the process and companies involved in this pilot. In a more succinct view, the pilot can be summarized as follows:

- **To-be scenario**
  The objective of this pilot is to design a new process to effectively reuse the carbon fibre waste that HPC is producing within its day-to-day business activities. Therefore, the to-be scenario is the design of an optimized requalification procedure for both the expired prepreg rolls and for uncured scraps, that ensures the ability to process the material in an optimal way. CC, to put into practice this process, needs insights around the exact process window (namely, the right time, temperature and pressure range) to which the expired rolls or the uncured scraps can be processed in an optimal way once they are re-qualified.
- **Boundaries, processes, and stakeholders**
  Everything starts with HPC cutting prepreg rolls for their ordinary production. With this process HPC creates roughly 50-60 tons (about 30% of the total prepregs used) of waste per year that needs to be recycled. In addition, some of these prepreg roll might have not been used before reaching their expiration date. Therefore, they have the responsibility to dispose those waste. As part of this project, HPC will provide samples of those waste to CETMA that is in charge to study the material and technical properties of the scraps and expired rolls and to identify a new process to re-qualify those waste so they could enter a new production process. With this requalification process, CETMA is also expected to provide a new process window, detailing the range of the optimal temperature and pressure to process the waste. Once this information will be identified, CC will be in charge of sourcing the waste produced by HPC and apply the new process studied (by CETMA) to produce drones' parts, as per ACCELI request. ACCELI is the organization in charge of producing and assembling the drone to be sold to end users.
  In this context, the most relevant operations identified for this pilot are:
    - Production, storing, packing, and transporting of waste (HPC in the input stage).
    - Analysis of the waste properties. Technical and mechanical properties of the full uncured material (scraps and expired prepreg rolls) need to be analysed to identify an adequate requalification process (CETMA).

- Re-qualification process identification. Development of a suitable process and related process windows (it will be necessary to understand if the processing parameters, in particular temperature, time, and pressure of polymerization, need to be changed and how) (CETMA).
- Remanufacturing of the waste into drone parts (CC). In this stage, a few further steps can be identified:
    - Cut and Peeling
      Expired prepreg rolls are cut and then together with uncured scraps are removed from the protecting film.
    - Lamination & vacuum bag
      Lamination involves layering plies of carbon fibre reinforced prepregs to optimize material properties. Vacuum bagging, used in curing, removes air between layers via a sealed bag under vacuum, enhancing resin impregnation and resulting in stronger, defect-free composite part.
    - Selection of the right production process
      Identification of the right production process according to the production needs among the three main options: autoclave, bladder moulding and press moulding.
    - Curing
      Application of heat and pressure to promote the matrix polymerization of carbon fibre reinforced prepregs.
    - Object extraction and refinement.
      The final object is extracted from the bag and the mould is cleaned and polished.
    - Quality control
      The object is examined to control after curing properties, void content, and other aesthetics characteristics.
- Assembly of drones. Once the drones' parts are created are then shipped to ACCELI to assemble and produce the drones.

- **Data types, flows, and ICT infrastructure**
  Each of the stakeholders involved in the pilot's process have different requirements and clearly information requested varies depending on the tasks and operations carried out. Overall, the most important information and data that need to flow across actors of the full pilot are around technical and mechanical properties of the waste, such as thermal properties, rheological properties (e.g., viscosity in function of the temperature), mechanical properties (e.g., ILSS), and deviation of waste properties from the original material (just to name a few). However, looking more closely at these requests of information, we can identify some specific data categories that each stakeholder requires or needs to provide.

  - HPC needs to provide data on history, material data, scraps geometry, properties of non-polymerized/uncured prepreg and properties of polymerized/cured prepreg (for expired prepreg rolls and cut waste) to CETMA and CC. In addition, HPC should provide information on uncured (e.g., viscosity, cross-linkage degree) and on cured (e.g., glass transition temperature, mechanical properties, void content) carbon fibre properties.
  - CETMA COMPOSITES to effectively enter the waste into a production process requires information from all the pilot's stakeholders (the first set of information from HPC has already been discussed in the bullet point above).
    - From CETMA are needed the new rheological and physical properties of material and new process window.
    - From ACCELI are needed information on the geometry of the product that needs to be produced (e.g., parts' diameter, weight), mechanical properties, machinability, and other physical requirements.

  At this stage, information is exchanged across pilot's partners via email in datasheets. Looking at the ICT infrastructure used by the partners, we see that at this stage there is no cloud option available to exchange information and that the information resides in different proprietary datacentres. The process is supported by ERP systems (AMS for production line plant) for both HPC and CC, supported by solutions for lot and serial number tracking. Information (e.g., temperature, pressure) is stored in a specific database that creates reports in .txt files. CETMA relies on a proprietary database to store data and information obtained with the analysis of the mechanical and technical properties of the waste.

- **Business and technical challenges**

  As mentioned in the opening paragraph of this section, the industry producing carbon fibre objects has different challenges, from production costs to recycling alternatives and high material variability. However, in each of the framework stages we find challenges and risks associated, that are relevant to one or more stakeholders.
  - In the input stage, the main challenges are:
    - The scarce/unclear waste specific recycling regulation - lacking incentives or guidance especially in terms of circular approaches.
    - The storage and collection of waste - carbon fibres reinforced prepregs require a rigid storing process to avoid a too fast ageing, contamination and properties reduction, something that needs to be considered also in the collection and transportation process.
    - The lack of traceability – there are difficulties tracking or tracing the origins of material, history, and usage.
    - The unclear material performance when it comes to the use of expired prepreg rolls.
  - In the Transformation stage, the main challenges are:

        - The high variability of the prepreg scraps (differences across batch because of polymers, threads, structure) and therefore a different transformation process need to be applied.
        - Technical problems arising when the material is too deteriorated and cannot be used in any shape or form for other purposes (if not with little value added when trimmed and used as filler in the construction industry).
        - The smaller window process that expired prepreg is subjected to when entering a new production process. With process window is intended the combination of temperature, pressure and time that need to be applied to prepregs to be cured. As the company deals with expired prepregs, the process window is reduced because of the lower condition of the material.
        - The difficulties in processing too small shapes of uncured scraps (especially for the lamination stage, where the scraps need to be displayed on the desired shape).
    - Output stage main challenge is the competition from non-EU countries (e.g., China) producing carbon fibre objects at lower price because of the lower quality of the raw material and the non-usage of secondary raw carbon fibre materials. Clearly this price competition has an impact also on the buyer behaviour. If the buyer doesn't see or understand the benefit of buying a sustainable product created with requalified carbon fibre is not willing to pay a higher price.
- **Key Performance Indicators (KPIs)**
  The pilot program seeks to attain diverse key performance indicators (KPIs), all falling within the scope of enhancing and optimizing the utilization of scraps and waste materials. At this stage, the list of KPI is as follows:
    - Increase prepreg shelf life.
    - Increase the value of uncured prepreg scrap.
    - Reduce prepreg disposal (reduction of the quantity of prepreg disposal in HPC).
    - Create new jobs in partner facilities related to exploiting uncured prepreg scraps.
    - Reduce of the existing unused CFRP waste.
    - Reduce the amount of unused CFRP waste in the production of composite materials (%).
    - Reuse material to produce components for drones (% of material reused).
- **Benefits gained by Pilot's Participants**
  Manufacturing cost reduction and waste reduction will be the most critical benefits gained by this pilot. In addition, tons of prepreg that would otherwise end up in landfills can now be repurposed as secondary raw material, generating revenue from product sales and reducing turnover. Expired prepreg will no longer need costly disposal but can instead be utilized to create structural components at a lower cost than using fresh material. Additionally, the opportunity to potentially dispose of unused prepreg is enabled.

Looking ahead and considering the pilot's activities, processes, and interrelations, the ability to close the value chain with the valorisation of even a small sample of the full carbon fibre portfolio used by HPC could allow a great return in term of cost saving in the disposal process and in terms of new value creation from the commercialization of products produced with secondary raw materials. This is because despite the pilot focuses on the production of drones, the applicability of this material can be further extended to other private consumer products and applications but also to non-high-end industries where non-critical but lighter components are required – with non-critical we intend the creation of parts that are not essential to the right and efficient use of the final product as the quality of the requalified carbon fibre might be lower compared to the more traditional usage in automotive and aerospace.

This project could also benefit of outcomes from another European project "LIFE CIRCE". In this project, HPC and CETMA developed, together with other partners, an innovative recovering system for industrial scraps deriving from carbon fibre prepregs cutting phase. Moreover, the most suitable manufacturing technologies to produce new components with the reprocessed prepreg scraps have been developed. The processes of the pilots are reported in Figure 7.

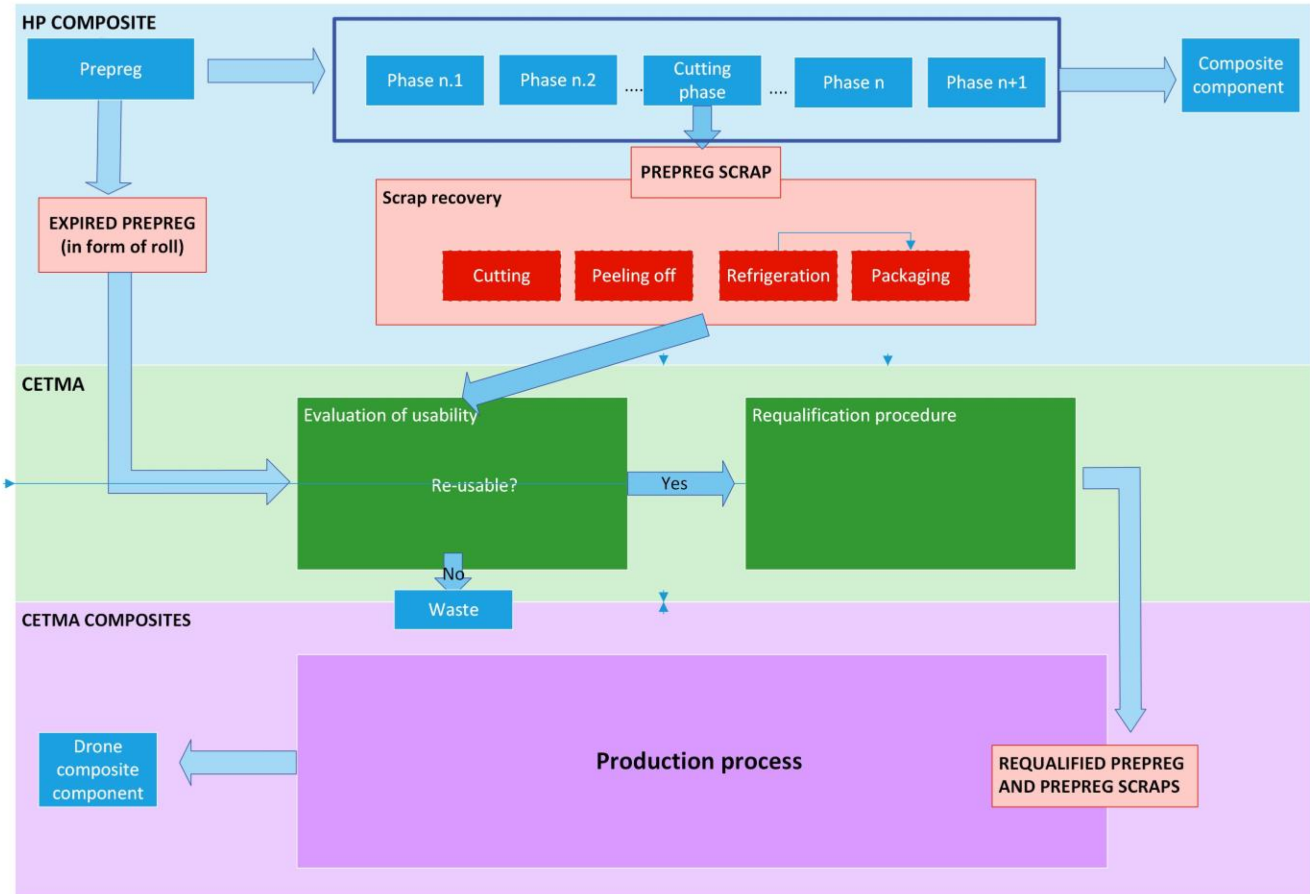

Figure 7. CFRP Processes Flowchart

4.3.3 Preliminary Suggestions on How to Strengthen the Circular Value Chain

Considering the pilot's description stated above, it is possible to draw a first set of suggestions on how to further strengthen the circularity strategy already identified by the organizations taking part to this pilot. This pilot can:

- Further investigate how to best combine different recycling and remanufacturing techniques to effectively end up waste that could have characteristics similar to the original materials.
- Expand the application of remanufacturing outside the production of drones, looking at other personal consumer applications where the lightness and strength of carbon fibre has a great potential.
- Expand companies' engagement outside the pilot to collect external best practices but also to effectively create a consortium dedicated to the reuse of expired or uncured prepreg waste.

4.4 WEEE for Magnets

Nowadays, magnets play a significant role across many industries, with a special role in the electronics, transportation, healthcare, energy production, and manufacturing sectors. Clearly, we can see the relevance of these simple objects as pivotal components in modern technologies such as the magnets used in Magnetic Resonance Imaging (MRI) machines in the healthcare sector or in the electronic industry with magnets used across many different products, such as transformers, motors, generators, loudspeakers, sensor, data storage devices and printed circuit boards. Two are the main categories, permanent magnets and electro-magnets, but for this pilot only the permanent magnets will be analysed, in the form of bonded NdFeB, Sr-ferrite and sintered Sr-ferrite magnets.

The industry faces significant challenges, with price volatility being foremost due to magnets comprising rare earth or other components already entered in critical raw materials list proposed by the European Commission. Rare earth or critical raw materials extraction companies, frequently located beyond the European Union, pose the risk of hindering self-reliance and independence from non-EU nations. This highlights the additional hurdle of extended and heavily dependent supply chains, strongly reliant on sources outside the EU. In addition, Sr-ferrite magnets comes with two specific challenges. First, are less expensive to be produced with fresh raw material than with recycled ferrite, so there is a clear obstacle in the capability to close the value chain, and second, sintered Sr-ferrite magnets are coated or mixed with polymers and resins, that cannot be treated alike any other magnets, so these need a dedicated transformation process.

Hence the need for Plooto to provide a solution supporting the pilot participants in the optimization of magnets extraction, qualification, and processing with a quality sufficiently high to avoid the addition of fresh raw material in the transformation stage – or at least to reduce at the minimum the requirements of these fresh raw materials.

4.4.1 Pilot Description

In the WEEE for Magnets Pilot four stakeholders are involved.

- Ferimet that is in charge to retrieve magnets from engines and motors. This process is highly manual (currently, the employees manually disassemble the engines/motors from machines or devices and then magnets from engines/motors).
- EUT is in charge of supporting industrial pilot partners in the required digitalization for the project scope. This includes the assessment of the digital tools for the use case and designing a robotic-assisted process to help in the magnets' extraction.
- IMDEA is in charge to sort the different magnets that are provided by Ferimet and to crush them in pellets. In an ideal scenario, IMDEA aims to have magnets at least already sorted by types or machines producers (e.g., LG, Bosch, Beko).
- IMA is the organization in charge to produce magnets. In this pilot there is not a defined final usage or customers target, so magnets produced with magnets waste will be sold to IMA's traditional customers that will choose to purchase high-quality and certified (via the product passport) magnets produced within Plooto's transformation stage.

So, the objectives of the pilot are, first to design a fully or semi-automated robotic process to extract magnets from disposed devices and machines, second, to optimize the processes to prepare crushed magnets prior to re-enter the production process, and third, to design a better process to remove the coating or the impurities created by polymers and resins in sintered Sr-ferrite magnets.

4.4.2 FCVC and Preliminary Findings

In Appendix E: WEEE for Magnets Framework for Circular Value Chain the full Framework for Circular Value Chain for the WEEE for Magnets pilot is provided.

The framework, built in sections and boxes, helps to simplify the understanding of the process and companies involved in this pilot. In a more succinct view, the pilot can be summarized as follows:

- **To-be scenario**

  The objective of this pilot is to refine the overall process with minor adjustments. The biggest changes that this pilot seeks are related to Ferimet's operations. With the support of EUT, the company expects to design an automated and robotic process to dismantle magnets from motors and engines. The second most impacted company is IMDEA, that within Plooto expects to understand how to better process the limited number of magnets (1 kg of magnets per week) and eventually scale this up, and to study a requalification process for the coating removal and requalification from impurities for sintered Sr-ferrite magnets. In addition, IMDEA expects to be using self-developed methods for processing the materials, such as flash milling to process sintered Sr-ferrite magnets - process useful to improve the coercivity (Hc) of strontium ferrite magnets due to the addition of alph-Fe2O3 hematite to the mix and casting-based polymerization of the materials to prepare the bonded magnets. IMA is the company that expects the simplest intervention, with the optimization proprietary production processes. Looking at the broader impact scenario, IMA and IMDEA expects to improve their carbon footprint and saving costs (across multiple dimensions, e.g., optimization, energy reduction).

- **Boundaries, processes, and stakeholders**

  This pilot begins with Ferimet that receives/collects appliances and devices to be dismantled from green/recycling points. Ferimet is in charge not only to dismantle and recycle the metallic parts of appliances and devices (outside the Plooto's scope), but also to recover the magnets present in the motors or engines of these appliances. This process is done mostly manually, with employees detaching magnets from the designated location. After this, IMDEA starts to process the magnets extracted and received by Ferimet. The constraint of IMDEA is that as a research institute their ability to process magnets is constrained to 1kg per week. IMDEA is entitled to sort end-of-life magnets according to different grades of strontium ferrite and NdFeB (magnetic properties are recorded). After this initial stage, IMDEA is in charge to clean, polish and create pellets, with two different processes for sintered strontium magnets and bonded NdFeB magnets, that will effectively renter the magnets production with IMA in the following steps. After the creation of pellets, IMA is in charge to process the pellets into magnets, following clients' instructions on properties, geometry, and magnet quality/grade.

  In this context, the most relevant operations identified for this pilot are:

  - Disassembly and extraction.
    Machines, appliances, and devices are first disassembled to remove the engine and motor and then magnets are extracted from the latter (Ferimet in the input stage).
  - Sorting.
    Magnets are sorted according to chemical composition, origin, and grade (IMDEA).
  - Demagnetization.
    Magnets are demagnetized before being crushed (IMDEA).
  - Uncoating
    This process applies only to sintered Sr-ferrite magnets that require the removal of the coating (IMDEA).
  - Crushing.
    Magnets are crushed to create pellets (IMDEA).
  - Mixing
    Crushed magnets are mixed with polymers (IMDEA for bonded magnets if needed / IMA ferrite and NdFeB- and sintered ferrite magnets).
  - Injection.

Crushed magnets and added polymers are injected to produce new magnets (IMA).
  - Magnetization.
    The basis created in the injection stage are now magnetized (IMA).
  - Quality control, packing and storing.
    Magnets' quality is controlled via machines and human supervision and then prepared for the shipment (IMA).
- **Data types, flows, and ICT infrastructure**
  Each of the stakeholders involved in the pilot's process have different requirements and clearly information requested vary depending on the tasks and operations carried out. However, looking more closely at these requests of information, we can identify some specific data types that each stakeholder requires or needs to provide.
  - The data categories that are relevant to Ferimet are the type of material, the quantity and the origin of the magnets. More in detail, Ferimet currently provides information on the origin of the magnet (from which appliance/device this has been removed). In an ideal scenario, for magnets' quality/grade mapping purposes, it would be relevant to IMDEA if Ferimet could also provide information on the producer and the specific model from which the magnets are detached.
  - The data categories that are relevant to IMDEA and should be provided by Ferimet are: Type of material, quantity of the material received, physical, magnetic and chemical properties of the magnets. After IMDEA processing stage, the same data categories that IMA requires should be provided to IMDEA too. More in detail, these data categories will include information on the chemical substances composing the magnets, with information around MSDS and GHS. In addition, following the current legislation, other type of information should be exchanged, such as REACH, RoHs, CLP, APQ. The same data categories exchanged among IMDEA and IMA will be critical input for the digital product passport.

  At this stage, data is exchanged across pilot's partners via email or communication/sharing platforms in the format of datasheets. Looking at the ICT infrastructure used by the partners, we see that at this stage there is no cloud option available to exchange information and that the information resides in different proprietary datacentres. The process is supported by ERP systems to collect and store information collected form machines (production, quality control) or from manual and visual inspections carried out by operators.
- **Business and technical challenges**
  As mentioned in the opening paragraph, the industry producing magnets has different challenges, but the most relevant one is that the production is based on rare earth materials, which price is highly sensitive to the demand-offer law (and clearly the scarce availability of the material itself). However, in each of the framework stage we find challenges and risks associated, and relevant to one or more stakeholders.

- In the input stage, the main challenges are:
  - The burdensome manual work that Ferimet workforce need to carry out to dismantle magnets from metal scraps of engines and motors.
  - The transportation requirements to move magnets from Ferimet premises to IMDEA ones, as the magnets moved are not demagnetised, and to avoid that magnets stick together due to the magnetic properties, each magnet need be packed in a box large enough to extinguish the magnetic force before finding other metal to stick to.
  - The frequency of the shipping because of the large volume of packages but the low quantity of magnets transported (one box per one magnet).
- In the transformation stage, the main challenges can be split between the two companies working on the requalification and processing of magnets.

  Looking at ***IMDEA***, the challenges they face are:
  - The sorting of the different magnet types that need to be entered in the transformation stage, as they enter different processes, according to the material used.
  - The sorting of the grade of the same magnet types, so effectively the quality of the magnets (e.g., magnets coming from Eastern countries usually have lower grade and therefore a lower quality of the material used in magnets produced in Western countries).
  - The requalification of sintered Sr-ferrite magnets, that in being coated by or mixed with polymers or resins they need to be processed before being crushed. This process consists in the coating removal or in removing impurities that lower the magnetic property of the material.

  Looking at ***IMA***, the challenges the company face in the latter stage of the requalification/remanufacturing process are:
  - The high cost of using requalified material to produce the same quantity that is produced with fresh raw material.
  - The lack of pure circularity loops as some fresh and new material often needs to be introduced in the transformation process to increase quality and magnetic properties that are not up to the common production and delivery standards for IMA.
  - The cheaper production of Sr-ferrite magnets from raw material because the requalification of these types of magnets is too expensive compared with the usage of new material (this means that the cost of using freshly sourced Sr-ferrite is way less expensive than the cost of Sr-ferrite pellets that need to be dismantled, demagnetized, crushed, and transported).

  In addition, IMA still faces minor but daily challenges related to the effective production of magnets such as the creation of magnets that fits customers exact requirements and applications purposes (shape, size, weight).

- In the output stage, the main challenges are:
  - Lack of understanding and awareness in the buyer audience of the relevance of using recycled magnets to fulfil circularity and sustainability requirements.
  - The competition from non-EU countries (e.g., China) producing low quality but low-price magnets (somehow also related to the closeness to extraction points – therefore reducing transportation costs and importing duties and fees).
  - The need to reduce the energy consumption of the overall process, that drives up prices for magnets produced with waste, while increasing the efficiencies.

- **Key Performance Indicators (KPIs)**

  The KPIs that this pilot is aiming to achieve are varied but still within the perimeter on better and optimized magnets reprocessing. At this stage, the list of KPI is as follows:
  - Reduction of WEEE landfilled.
  - Increase the usage of Sr-ferrite crushed pellets in magnets production.
  - Improve the quantity of leftovers and disregarded magnets entered into the transformation process.
  - Increase the usage of SRM (bonded NdFeb and Sr-ferrite) in PM magnets pellets' production.
  - Increase the number of types of validated materials.
- **Benefits gained by Pilot's Participants**

  The production of magnets from waste offers a range of compelling benefits. It reduces the environmental impact through the conservation of resources and lowered energy consumption. Moreover, it diminishes the dependency on non-EU countries for critical raw materials, potentially leading to import tariff reductions. The added benefits of shortening the supply chain and reducing delivery times further enhance the appeal of opting for these types of magnets, that are sourced and produced locally – especially when the customer is based in Europe.

Looking ahead and considering the pilot's activities, processes, and interrelations, the ability to close the value chain of magnets is relevant to the reduction of costs related to the sourcing of the raw materials – that in most of the cases come from non-EU countries – and to sustain high quality production of magnets within the European territory. This is even more relevant, especially since the European Union already lists as critical raw material, or CRM, (e.g., strontium) materials that are not rare earth ones and that these materials are critical in the production of magnets[7].

In addition, this is a market that is expected to have a continued growth, due to the wide applicability and usage of magnets across many industries, especially in relation to the ICT

[7] https://single-market-economy.ec.europa.eu/publications/study-critical-raw-materials-eu-2023-final-report_en

market. The capability to deliver consistent and high-quality production can ensure wide market opportunities in Europe but also for exporting to countries that see a dominant ICT market (e.g., USA). But as mentioned at the beginning of this section, not only the ICT industry is depending on magnets, but also the medical and the automotive sectors, with specialised magnets requirements.

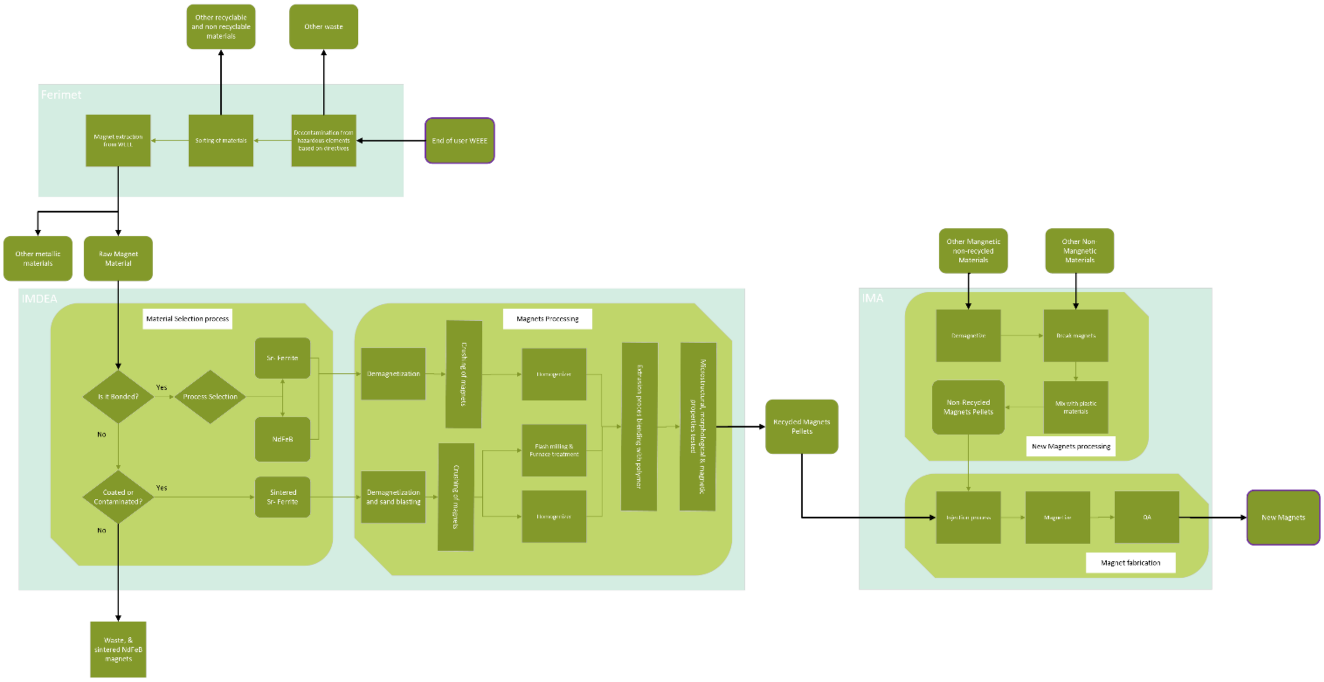

Figure 8. WEEE Processes Flowchart

4.4.3 Preliminary Suggestions on How to Strengthen the Circular Value Chain

Analysing the current pilot's objectives and challenges, it is possible to identify a first set of suggestions on how to further strengthen the circularity strategy already in place among the organizations taking part to this pilot. This pilot can:

- Design technologies for dismantling and disassembling devices or appliances to access magnets without damaging them.
- Further investigate how to best process ferrite, optimizing the full process to avoid losing grade and reducing the cost of the process, as well as trying to obtain a SRM more competitive than using new raw material, given the shorter and local supply chains and a strategy for more European autonomy.
- Produce magnets that are simple to be recycled, that might even simply mean print or impress on the magnet (where possible) the magnet composition and the quality. In case magnets are too small to have such details printed or impressed, a common standard code list can be developed.

4.5 Citrus Processing Waste for Juice By-products

Several by-products created during the production of juice contain useful compounds that can be used as potential resources in many applications. The main by-products generated during the washing and citrus processing are: peels, pulp and residue, seeds, and wastewater. From different waste, it is possible to produce different secondary products, for instance essential oils (e.g., D-Limonene) from the oils contained in the peels, can be used in cosmetics and flavouring, in biofuels, or even in the production of animal feed.

The most relevant challenges in this industry are:

- the seasonality of the product, where depending on the geography analysed the harvesting of oranges is done in a specific season,
- the weather condition of the season that can highly influence the abundance or scarcity of oranges and therefore the production of juice first and subsequently of by-products.
- The third critical challenge is related to the high variability of the quality and composition of the by-products, that strictly depend on the quality of the oranges themselves (e.g., Brix (sugar) concentration or quality of essential oils).

Across the different applications mentioned in the opening of the section, the production of animal feed – more precisely for cattle feed – is analysed according to this project's scope. Hence Plooto needs to provide an optimized and sustainable solution for the processing of the by-products, aiming for the production of input components for the cattle feed industry, alongside the certification of these by-products as of higher nutritional value, compared to chemically produced additives for cattle feed.

4.5.1 Pilot Description

In the Citrus processing waste for juice by-products Pilot works two stakeholders.

- ASPIS that is the producer of orange juice and related by-products,
- KPAD that is in charge to support ASPIS in the life cycle assessment of the waste valorisation line to effectively optimize the production of cattle feed industry components.

The objectives of the pilot are, first to assess the life cycle of the waste valorisation line, second to optimize the process and reduce the energy consumption and third to provide further evidence, via the product passport, on the higher quality and higher nutritional value of the oranges' by-products in the production of cattle feed, compared with the chemical ones.

4.5.2 FCVC Preliminary Findings

In Appendix F: Citrus Processing Waste for Juice By-products Framework for Circular Value Chain the full Framework for Circular Value Chain for the Citrus Processing Waste for Juice By-products pilot is provided.

The framework, built in sections and boxes, helps to simplify the understanding of the process and companies involved in this pilot. In a more succinct view, the pilot can be summarized as follows:

- **To-be scenario**
  The primary objective of this pilot is to refine the transformation process of by-products to produce cattle feed. More in details, ASPIS aims to optimize the separation and evaporation stages of the production to allow a larger production of molasses and CWP. The optimization, despite being the primary objective is not the only one. ASPIS desire to further study and provide evidence of the higher quality and better nutritional value of CPW and molasses from oranges' by-products compared to other SRMs or chemical components entering the cattle feed industry. Moreover, Plooto Project will assist ASPIS in constructing a DPP for the molasses product, which will boost the company's ties with the animal feed production industrial sector.
- **Boundaries, processes, and stakeholders**
  The entire pilot initiate and ends with ASPIS operating end-to-end transformations. APSIS first activity starts with the production of orange juice (not in Plooto's scope) and therefore the creation of by-products (within the Plooto's scope). There are multiple by-products that can be created, CWP for the cattle feed industry, CPWW, Water, D-Limonene, sludge and molasses. These by-products need several processing steps before the final output can be obtained. These steps will require optimization from an energy consumption standpoint. As mentioned previously, the role of KPAD in this pilot is to assist ASPIS in the assessment of the life cycle management of the valorisation line and analysis if the environmental footprint of the processes (CPW-to-cattle-feed production procedure).
  - **CPW for the cattle feed industry**
    The most relevant operations, identified for this pilot are:
    - Milling
      Pulp and peel from oranges are trimmed into a fluid.
    - Neutralization
      Lime is added to the milled fluid to adjust the pH.
    - Dewatering
      Via mechanical press the fluid is separated from the water.

    After these steps, two parallel processes can occur, depending on the type of final SRM that is desired.

    - Packaging
      The dewatered (but still humid) CPW are packaged and then shipped.
    - Dehydration
      The dewatered CPW are subjected to an effective dehydration process and then these are packaged and shipped.
  - **CPWW – Citrus Peel Wastewater**

Production of wastewater form the production of orange juice. The operations relevant for this output are:

- Extraction
  Orange juice is extracted from oranges.
- Centrifuge
  The emulsion of water and oil is centrifuged to separate the water from the oil.

- **Orange oil**: After the centrifuge, the remaining orange oil is cold pressed and sent to other companies for further processing depending on the needs of the companies, exiting the Plooto value chain.
- **Sludge**
  After the production of CPW for the cattle feed industry (milling, neutralization and press dewatering) the CPW can enter a different production process to produce the sludge (that before the last step is also called liquor). Subsequent processes are:
  - Refining
    The liquor is analyzed looking for particle size of the insoluble solid.
  - pH adjustment
    pH is adjusted with the addition of fresh sludge and citric acid.
  - Desludging
    Liquor is separated into watery and solid particles. Solid particles will be the final output as sludge.
- **Water, D-limonene and molasses**
  After the desludging, the residual watery waste can enter two different processes depending on which is the desired output. The first step, condensation/heat evaporation, is shared for all the three outputs. After that to produce:
  D-limonene and Water
  - Condenser
    The water vapor obtained in the first condensation process is further condensed.
  - Decanter
    In this phase, the different density of water and d-limonene allow to separate them.

  Molasses
  - Cooling.
    The outcome from the former condensation/heat evaporation process is cooled.
  - Mixing
    The output of this cooling phase is mixed with other batches of molasses products from previous work plans. This is to achieve the desired

characteristics of the final product (i.e., Brix, viscosity). No extra chemical reagent is added.

- Storing
  After the mixing phase, the output is stored, and the molasses are produced.

- **Data types, flows, and ICT infrastructure**
  In this pilot, composed of only two partners and only one is involved in the transformation process, there is not a massive need of information exchange. The information exchange will result in sharing sensors data required by KPAD for the life cycle assessment for the waste valorisation line. This data is expected also to support KPAD in the evaluation of the environmental footprint for the waste valorisation streams performed by ASPIS. Looking closely at these requests of information, we can identify some specific data types that APSIS will need to provide, such as temperature and time of the separation and evaporation processes and other sensor captured data. ASPIS stores those data and information in ERP and datacentres for mass balance (as well as waste entered in the production line, concentration level of each batch and final output quantity and quality).
- **Business and technical challenges**
  As mentioned in the opening of the paragraph, the industry dealing with oranges by-products has different challenges, from weather conditions to the variability of the chemical composition of the output. This pilot composed by one single company performing the full process, from waste production to valorisation, will focus only on APSIS challenges in the different stages.
  - The input stage doesn't have strictly sourcing-related challenge, as the waste is already produced by ASPIS. The only partially related challenge that the company might experience is related to previous steps (outside Plooto's boundaries), so in sourcing of oranges when the weather conditions negatively impact the production of oranges. Clearly, adverse weather conditions impacting the production of oranges (too small quantities) have also negative impact on the quantity of waste available to be treated.
  - In the transformation stage the main challenges are:
    - The rising cost of energy related to the energy intensive processes. Clearly the transformation process requiring high temperature to dewater or dehydrate materials can be defined as energy intensive process, and with the current geopolitical scenario, the rising price of energy are worrisome.
    - The compliance with rigid requirements around material condition and concentration. In fact, ASPIS needs to guarantee specific requirements levels, such as:
      - For molasses, the initial solids should be around 7-9%, while the final one should be around 60-65%.
      - For silene, the initial humidity should be around 90%, while the final one should be up to 60%.

        - For dried silene, the initial humidity should be around 90%, while for the final one should be less than 15%.

      Another important measure is BRIX, or sugar concentration, that cannot be higher than 65 brix.

    - In the output stage the main challenge is the competition on product, either regional or international. As already mentioned, the use of citrus by-products for the cattle feed industry is quite a niche market, not fully developed or embraced by cattle feed producers. Cattle feed producers produces still relies on their usual suppliers of chemical components or components coming from other types of industries. So, there is the need to prove that oranges by-products have higher nutritional value compared to traditional products used and therefore, substitute current products usage with oranges by-products SRM.

- **Key Performance Indicators (KPIs)**

  The KPIs that this pilot is aiming to achieve are varied but are tightly related to the processing of the generated wastes for the production of molasses. At this stage, the list of KPI is as follows:
    - Increase production of animal feed components.
    - Higher molasses quality.
    - Reduce COD of CPWW.
    - Lower volume of CPWW that goes to biological treatment.
    - Increase revenue from animal feed production.
    - Improve energy savings.
    - Improve cost savings.
- **Benefits gained by Pilot's Participants**

  The benefits driving this pilot's activities are the waste valorisation and energy savings during production, alongside ensuring the high nutritional value of the end product. Through meticulous process optimization and vigilant monitoring to prevent any potential alterations to the final product.

This pilot, composed of only one manufacturing company that takes care of the full value chain, see less criticalities driven by the coordination of multiple actors. In addition, the availability of data that is collected across the full process mostly by sensors will enable KPAD in assessing the life cycle of the valorisation line as well as its carbon footprint. What might come with a higher complexity, is the "advertising" of the higher quality of the SRM produces from oranges by-products for the cattle feed industry. This is not only a matter of customers understanding the benefits, but also price competition will pay a great deal within this market.

The company already closes the value chain, as the production of molasses and CPW for the animal food industry is already in place. Looking ahead and considering the pilot's activities, processes, and interrelations, the only further steps that could be taken are to improved customer base to finally balance supply and demand and to find new applications.

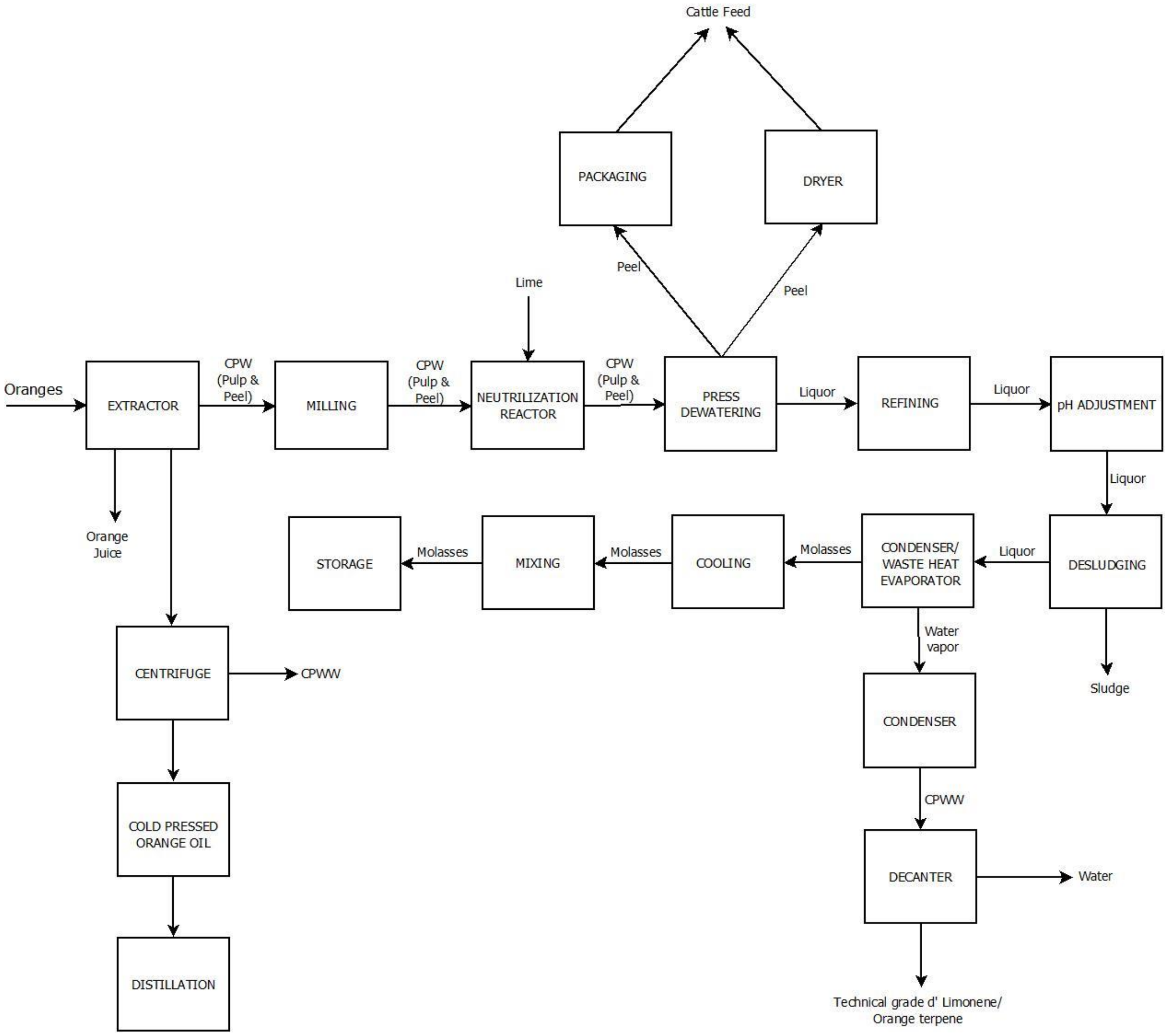

Figure 9. Citrus Processing Waste for Juice By-products Processes Flowchart

4.5.3 Preliminary Suggestions on How to Strengthen the Circular Value Chain

Examining the current goals and difficulties faced by the pilot, it is possible to pinpoint an initial set of recommendations for enhancing the existing circularity strategy set by the organizations participating to the pilot. This pilot can:

- Design better and optimized processes that are also less energy intensive to ensure lower prices and a viable price competition.
- Consider out scaling the activities around oranges by-products outside Plooto's scope and boundaries, looking also at producing fertilizers and compost and potentially provide

it back to the companies from where oranges are sourced, so effectively creating a sustainable and circular strategy.

- Expand the customer base outside the cattle feed industry, for instance to the pet feed one, to ensure a larger commercialisation opportunities and new revenue streams.

Conclusions and Next Steps

The activities carried out in the context of T1.1 led to the definition of the Plooto business value chain framework and the development of the specific business circular value chain for each pilot in Plooto project. The information collected helped to define the pilot boundaries, identify the role of stakeholders as well as define the data flow and material flow across the value chain among the stakeholders. The results of the first phase, summarized in this document, highlights the preliminary design of the three Plooto pilots as well as initial insights on improvements of circularity in each pilot. The activities of T1.1 will continue in the upcoming period of Plooto project to improve and enrich the initial findings and results regarding the circular value chain mapping of the three pilots. In particular, due to progress of pilot activities in the upcoming months, some specific aspects of mapping are expected to be improved with more detailed information such as KPIs. Future interactions will take place through potential interviews with the pilots to collect the updated information and finalize the mappings. The results of the updated mapping will be included in the D1.2 (next deliverable of T1.1) which is due in December 2024.

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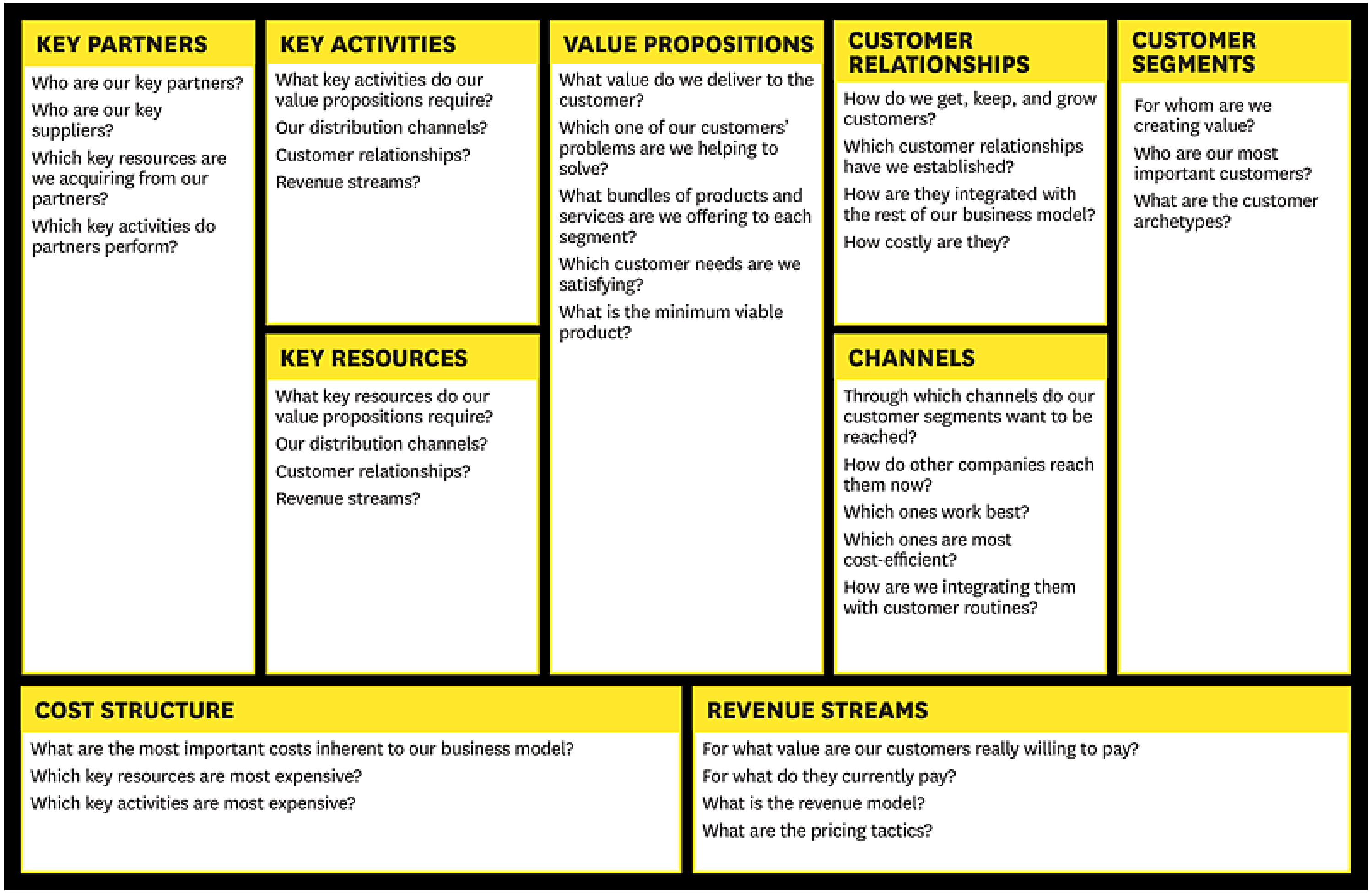
Appendix A: Osterwalder's Business Model Canvas



Source : https://hbr.org/2013/05/a-better-way-to-think-about-yo

Appendix B: Workshops Questionnaires

Table 1. First workshop questionnaire

Framework Macro Area	Framework Topic	Question
INPUT	Waste Sourcing and Handling	What are the industries from which you receive the waste? (if different from production)
	Data	What type of data is exchanged with the producer(s)/upstream industry(ies) of the waste/"raw" material(s)? (e.g., provenance, usage, expiry date)
	Material	What type of waste/"raw" material(s) you receive to be processed/transformed?
		Is it required to you to get any certification of the waste/"raw" material(s) you transform? Are there any regulatory standards?
	Sourcing Challenges and Business Information	NA
TRANSFROMATION	Transformation Process and Critical Requirements	How is the waste/"raw" material(s) transformed/processed to be converted into a secondary raw material(s)?
		Do you rely on partners to treat/process the waste/"raw" material(s)?
		In which stage they are involved and for what part of the process they are responsible for?
		What are the technology requirements (e.g., AI, sensors, IoT) to transform/process the waste/"raw" material?
		What are the key resources you need in place to process/transform the waste/"raw" materials(s)? Can you estimate them? (e.g., assets, FTEs, public funding)
	Data	NA
	Material	NA
	Transformation Challenges and Business Information	Is there any risk or constraint involved in this process? (e.g., waste/"raw" material too damaged to be transformed and

Framework Macro Area	Framework Topic	Question
		therefore costs associated with disposal)
OUTPUT	Final Production and Distribution	What are the industries that will use secondary raw material(s) produced/transformed?
		What type of secondary raw material(s) you produce/transform within the "transformation process"?
	Data	What type of data is exchanged with the downstream industries? (e.g., usage, expiry date, transformation type, new specs)
	Material	Is it required to you to get any certification of the secondary raw material(s) you transform? Are there any regulatory standards?
	Go-to-Market Challenges and Business Information	NA
VALUE CREATION	KPIs	What are the KPIs (Key Performance Indicators) to evaluate the process? What improvements are expected?
	Benefits	What are the benefits that the overall process creates?
	Beneficiaries and Stakeholder	Who are the beneficiaries/Stakeholders and what are the effects for them?
	Pilot's Business Model	What are the use cases or applications of the secondary raw material in the downstream industry?
	IP Rights	NA
	To-be-scenario	NA

Table 2. Second workshop questionnaire

Framework Macro Area	Framework Topic	Question
INPUT	Waste Sourcing and Handling	Is there any chance that the waste/material you receive cannot be recycled/remanufactured? What percentage of the waste/material you receive is used vs disposed? (Response by each pilot participant)
		(Question to be asked if previous question answer is "Yes"), if you cannot recycle/remanufacture the waste/material, is it input for some other process (internal or external)?
		(Question to be asked if previous question answer is "No"), if the waste/material is not used by you or does not enter any other third-party transformation process, how it is disposed?
	Data	How do you exchange data and information with organizations providing material? (e.g., protocols, platforms, Excel, email)
	Material	What are the conditions/specific requirements of the waste/materials you receive from upstream industries?
	Sourcing Challenges and Business Information	What are the incentives for upstream industries to participate in the process? (e.g., monetary, others, etc.…)
		What are the challenges in sourcing waste to be processed? (e.g., collection, scarce/unclear waste-specific recycling regulation, scarce interest in recycling from originating industries, etc…)
TRANSFROMATION	Transformation Process and Critical Requirements	Describe the current operational processes relevant to Plooto – Please, provide flow diagrams / graphs / any other means to make it easier to understand and upload them in the folder dedicated to your pilot
		Describe the new operational process (if any) within Plooto. What areas of improvement do you see in your as-is transformation process? How do you

Framework Macro Area	Framework Topic	Question
		expect Plooto to play a role in improving them?
	Data	How do you exchange data and information across pilot's partners? (e.g., protocols, platforms, Excel, email)
		How do you collect data from the process? (e.g., sensors, RFID)
		What is the data exchanged/required in each step of the transformation process?
	Material	Please describe the specs and conditions of the material across the process (e.g., humidity, temperature)
		Are there any EU/national laws around your specific transformation process you have to comply with? If yes, which?
		If previous question "yes", What is the impact on your process?
		What are the environmental requirements and/or standards the process is subject to?
		Are there specific standards and protocols that you need to apply in your transformation process? (e.g., chemical standards and protocols)
	Transformation Challenges and Business Information	NA
OUTPUT	Final Production and Distribution	What are the channels you use to distribute the SRM to downstream industries/customers?
	Data	How do you exchange data and information with organizations buying the outcome of your transformation process? (e.g., protocols, platforms, Excel, email)
	Material	NA
	Go-to-Market Challenges and Business Information	What are the challenges in distributing/providing SRM? (e.g., distribution, reselling)
		What are the incentives for downstream industries to buy/use SRM? (e.g., monetary, etc.)

Framework Macro Area	Framework Topic	Question
VALUE CREATION	KPIs	NA
	Benefits	NA
	Beneficiaries and Stakeholder	NA
	Pilot's Business Model	NA
		NA
		NA
		NA
	IP Rights	NA
	To-be-scenario	NA

Table 3. One-to-one workshop questionnaire

Framework Macro Area	Framework Topic	Question
INPUT	Waste Sourcing and Handling	From which country(ies) do you receive the waste to be treated?
	Data	NA
	Material	NA
	Sourcing Challenges and Business Information	NA
TRANSFROMATION	Transformation Process and Critical Requirements	NA
	Data	Which ICT infrastructure technologies is the pilot using? (e.g., cloud, datalake, AI, ML CRM, ERP)
	Material	NA
	Transformation Process and Critical Requirements	NA
OUTPUT	Final Production and Distribution	Who are your target customers? (Industry, company size, geography or customer profile when selling articles for the personal consumer industry)
	Data	NA
	Material	NA
	Go-to-Market Challenges and Business Information	From a scale from 1 to 5, how do you think Is relevant having a product passport to allow product information transparency for your pilot?
VALUE CREATION	KPIs	NA
	Benefits	NA
	Beneficiaries and Stakeholder	NA
	Pilot's Business Model	What's the pilot value proposition?
		Do you have already in mind a commercial/business model for the Pilot?
	IP Rights	What are the IP rights within the pilots that will be useful for the pilot development? Who will be responsible for those? (e.g., commercial exploitation)
	To-be-scenario	Can you describe the pilot ideal scenario within Plooto?

Appendix C: Proposed Requirements for Certification KPI's (Circular Standards and Digital Passport)

Table 4. Proposed Requirements for Certification (Circular Standards and Digital Passport)

	Process	KPIs	Corresponding Documentation
1. INPUT PROCESS	**1.1 Supplying Industries**	1. Percentage of materials sourced from sustainable suppliers.	Supplier sustainability reports, procurement records.
		2. Number of audits or assessments conducted on suppliers.	Audit reports, sustainability assessment documentation.
		3. Compliance rate with supplier selection criteria.	Supplier selection criteria, compliance records.
		4. Rate of material quality issues or recalls from suppliers.	Quality issue reports, recall records.
	1.2 Inbound Waste/"Raw" Material	1. Composition analysis of inbound materials.	Material analysis reports, tracking records.
		2. Percentage of recycled or reused inbound materials.	Tracking and origin documentation, recycling records.
		3. Waste management efficiency (e.g., landfill diversion).	Waste management reports, landfill diversion data.
		4. Rate of successful recycling or reuse of inbound materials.	Recycling/reuse process documentation, success rate records.
	1.3 Certification(s)/Regulatory Standards/Certification Body(ies) - Business Regulations	1. Compliance rate with relevant certifications/standards.	Certification compliance reports, audit findings.
		2. Number of regulatory violations or non-compliance incidents.	Non-compliance incident reports, corrective actions.
		3. Frequency and outcomes of external audits or assessments.	External audit reports, assessment outcomes.
		4. Documentation of regulatory updates and communication.	Regulatory update notifications, internal communication records.
	1.4 Data/Information Exchanged	1. Data security incidents or breaches.	Data security incident reports, breach notifications.
		2. Data access controls and authorization levels.	Data access policies, authorization records.

	Process	KPIs	Corresponding Documentation
		3. Adherence to data exchange protocols.	Data exchange protocol documentation, compliance records.
		4. Case studies or reports on data-driven improvements.	Data-driven improvement reports, case studies.
2. TRANSFORMATION PROCESS	**2.1 Process Type**	1. Percentage of materials processed using each process type.	Process type distribution records, material processing data.
		2. Process efficiency (e.g., material yield, energy consumption).	Efficiency reports, yield calculations.
		3. Achievement of environmental and efficiency targets.	Goal-setting documentation, performance assessments.
		4. Customer satisfaction and feedback related to processes.	Customer feedback surveys, satisfaction reports.
	2.2 Functions, Roles, and Skills	1. Skills and training completion rates among employees.	Training records, skills assessment results.
		2. Cross-functional collaboration effectiveness.	Cross-functional team collaboration reports, feedback.
		3. Time and resource allocation for cross-functional efforts.	Resource allocation records, project timelines.
		4. Documentation of skill gap assessments and actions taken.	Skill gap assessments, corrective actions records.
	2.3 Partners	1. Partner performance and reliability assessments.	Partner performance reports, reliability evaluations.
		2. Partner selection criteria and decision documentation.	Partner selection criteria, decision records.
		3. Communication frequency and effectiveness with partners.	Communication records, feedback from partners.
		4. Incident response plans and partner risk assessments.	Contingency plans, risk assessments.
	2.4 Risk/Constraints	1. Risk assessment reports and mitigation actions.	Risk assessment documents, mitigation plans.
		2. Number of risk incidents and their impact.	Incident reports, risk incident assessments.
		3. Compliance status with environmental and regulatory constraints.	Compliance reports, regulatory audits.

	Process	KPIs	Corresponding Documentation
		4. Incident response and adaptation records.	Incident response documentation, adaptation reports.
	2.5 Tech Requirements	1. Technology utilization and uptime rates.	Technology utilization logs, uptime records.
		2. Technology upgrade plans and implementation progress.	Technology upgrade plans, implementation reports.
		3. Technology investment proposals and justifications.	Investment proposals, justifications.
		4. Sustainability impact assessments of technology choices.	Sustainability impact assessments, technology alignment reports.
3. OUTPUT PROCESS	**3.1 Customer Industries / Partners**	1. Customer satisfaction and feedback from customers and partners.	Customer and partner feedback surveys, satisfaction reports.
		2. Quality control and product compatibility assessments.	Quality control reports, compatibility assessments.
		3. Criteria and selection documentation for partnerships.	Selection criteria, partnership documentation.
		4. Environmental impact assessments in output processes.	Environmental impact assessments, tracking reports.
	3.2 Outbound Secondary Raw Material(s)	1. Volume and composition of secondary raw materials produced.	Production volume records, composition analysis.
		2. Secondary raw material marketing and sales performance.	Marketing and sales reports, revenue records.
		3. Quality standards compliance for secondary raw materials.	Quality standards documentation, compliance records.
		4. Circular economy impact assessments and reports.	Circular economy impact assessments, reports on contributions.
	3.3 Certification(s)/Regulatory Standards/Certification Body(ies) - Business Regulations	1. Compliance rate with customers / partners industry certifications/standards.	Certification compliance reports, audit findings.
		2. Documentation of compliance efforts and corrective actions.	Compliance documentation, corrective action records.
		3. Records of product disposal and reuse compliance.	Disposal and reuse compliance records, regulatory audits.
		4. Collaboration and communication with customer / partner certification bodies.	Collaboration records, communication documentation.

	Process	KPIs	Corresponding Documentation
	3.4 Data/Information Exchanged	1. Data security incidents or breaches in data exchange.	Data security incident reports, breach notifications.
		2. Data access controls and authorization levels in data exchange.	Data access policies, authorization records.
		3. Adherence to data exchange protocols and standards.	Data exchange protocol documentation, compliance records.
		4. Case studies or reports on data-driven improvements.	Data-driven improvement reports, case studies.
	3.5 User Cases or Applications:	1. User cases and applications	User case documentation
		2. Product customization methods	Customization documentation
		3. Emerging use cases	Exploration and innovation plans
		4. Sustainability contributions	Sustainability impact reports
4. VALUE CREATION	**4.1 Key Resources**	1. Resource utilization efficiency and optimization.	Resource utilization reports, optimization assessments.
		2. Resource diversification plans and progress.	Diversification plans, progress reports.
		3. Alignment of resources with sustainability goals.	Sustainability goal alignment documentation, resource assessments.
		4. Sustainability impact assessments of key resources.	Sustainability impact assessments, alignment reports.
	4.2 Benefits	1. Quantification of financial benefits (e.g., cost savings, revenue).	Financial benefit reports, cost-saving calculations.
		2. Environmental and social impact assessments.	Impact assessments, environmental and social reports.
		3. Documentation of social/community engagement efforts.	Engagement documentation, community feedback.
		4. Case studies and success stories showcasing benefits.	Case studies, success story documentation.
	4.3 KPIs (Key Performance Indicators)	1. Monitoring frequency and reporting of KPIs.	KPI monitoring reports, reporting frequency records.
		2. Achievement of KPI targets and benchmarks.	Target achievement reports, benchmark comparisons.
		3. Documentation of KPI setting and tracking processes.	KPI setting documentation, tracking procedures.

	Process	KPIs	Corresponding Documentation
		4. Alignment of KPIs with sustainability and circular economy goals.	KPI alignment documentation, goal assessments.

Appendix D: CFRP Waste for Drones Framework for Circular Value Chain

Waste Sourcing and Handling

- **Input industry**: HP Composites, when producing carbon fibre products for aviation, high-end maritime/marine, automotive
- **Origin of the waste**: Italy
- **Waste volume:** 50-60 tons per year (roughly 30% of the original material entered in the production)
- **Non treatable waste disposal (not within Plooto's scope): disposal process:** (1) Mechanical processes: material is ground and used in low-value applications as a filler; (2) Thermal processes (Pyrolysis): the resin matrix is broken down into smaller volatile molecules and the carbon fibres remain intact; (3) Solvolysis: the resin is degraded by various solvents and converted into a soluble form, so the carbon fibres can be recovered; (4) Landfill
- **Steps before entering the transformation stage**: HPC oversees (1) Storing, (2) Packaging, (3) Transportation

Data

- **Data categories:** history of the material and handling processes, material data, and scraps geometry
- **Data requirements**: 1) Certification of conformity (see "Material" box; 2) Technical datasheet (TDS) of the source material (TDS of the supplier); 3) History of the source material (for prepreg roll, storage time and temperature; for scraps cut, number of times that was used – i.e., how many times it was thawed)
- **Data collection:** Special sensors to be used to get more information during the process
- **Data exchange process**: mainly via email

Material

- **Input material:** uncured prepreg derived from cutting (different shapes and combination of matrix/fibres and resins/polymers) and expired prepregs rolls
- **Certifications and standards**: HPC is not required to provide any documentation around standards when providing the waste but is required to provide a "Certification of Conformity" (COC) of the expired prepreg roll, containing information on production date, expiry date, technical characteristic of the roll, storage information. Same level of information to be provided for the uncured cut prepreg waste.
- **Specs and conditions**: HPC is required to provide both expired prepregs rolls or cut uncured prepreg frozen at -18-degree Celsius to preserve from deterioration.

Sourcing Challenges and Business Information

- **Incentives for input industry**: reduction of waste landfill and reduction of waste entering thermal and solvolysis processes (cost incentive),
- **Challenges:** (1) scarce/unclear waste specific recycling regulation; (2) storage and collection of waste; (3) lack of traceability; (4) unclear material performance (esp. for expired prepreg rolls)

Figure 10. Input Stage of the CRFP for Drones Framework for Circular Value Chain

Transformation Process and Special Equipment

- **Transformation process**
  - ***Analysis of the waste properties***. (1) Analyses the technical and mechanical properties of uncured prepreg (2) Analysis of the expired rolls of prepreg for requalification purposes; (3) Measurement of physical, thermal, rheological and mechanical properties of the material; (4) Evaluation of deviations from initial properties (CETMA)
  - ***Requalification process identification:*** Development of a suitable process and related process windows (it will be necessary to understand if the processing parameters, in particular temperature, time, and pressure of polymerisation, need to be changed and how) allowing CETMA Composites to requalify the material (CETMA)
  - ***Remanufacturing***. (1) Cut and peel prepreg rolls requalified or peel the uncured cut prepreg; (2) Lamination and vacuum bag; (3) Selection of the right production process; (4) Curing; (5) Object extraction and refinement; (6) Quality control (CC)
- **Special equipment**

For the analysis process: (1) Laboratory equipment (DSC, Rheometer, Tack-Dynamometer) for qualification test; (2) Equipment for prepreg polymerization (muffle, press)

For the re-manufacturing process: (1) Cutting and peeling machine; (2) Humidity controlled cold rooms; (3) Tools for packaging for transformation process. Special sensors could be used to get more information during the process. Scraps re-processing machines and manufacturing equipment

Data and ICT Infrastructure

- **Data categories**

***CETMA*:** properties of non-polymerized/uncured prepreg and properties of polymerized/cured prepreg (for expired prepreg rolls and cut waste). Uncured: viscosity & cross-linkage degree /cured: glass transition temperature, mechanical properties, and void content

CC: void content, other non-distracted analysis (e.g., ultrasound) and process parameter

ACCELI: geometry of the product (e.g., diameter, weight), mechanical properties, machinability, physical requirements

- **Data collection: CETMA and CC**: Laboratory equipment, such as DSC, rheometer, dynamometer, and other.
- **Data requirements:**

1) Thermal properties (Tg), rheological properties (Viscosity in function of temperature), mechanical properties (for example ILSS); 2) Percentage of deviation from initial properties; 3) New processing window; 4) Material characteristics. The definitive information will be established during the re-qualification procedure development

- **Data exchange process:** mainly via email with technical datasheets
- **Infrastructure:** ERP (AMS for production line plant), lot and serial number tracking solutions (lot lineage), temperature database (reporting in .txt files)

Material

- **Certifications and standards:** none other than common standard requirements (e.g., ISO) and in accordance with current legislation
- **Material flow**:
  - ***CETMA***: Provide information on the experimental tests carried out in laboratories and define a new process window (based on material provided by HPC)
  - ***CC***: Receive the scraps and the prepreg rolls from HPC, test the new process window identified by CETMA, and produce the drones' parts

Transformation Challenges and Business Information

- **Challenges**

1) Raw material (prepreg scraps) could have variable characteristics from batch to batch and, hence, the transformation process has to be modified.
2) Damaged waste cannot be transformed in secondary raw material and, hence, should be disposed (i.e., too old resin).
3) The expired prepreg will be characterized by a smaller process window in comparison with fresh material. A too small process window will imply the possibility to use the material for a small number of components
4) Difficulties in processing too small cut scraps

Figure 11. Transformation Stage of the CRFP for Drones Framework for Circular Value Chain

Final Productions and Distribution

- **Output:** ACCELI to produce drones (equipped with parts produced by CC) – model: to be determined, parts produced: to be determined
- **Sales channels**: to be determined
- **Target markets (industry):** Personal consumer
- **Target markets (geographies)**: to be determined
- **Target markets (company size/users)**: users to be determined

Data

- **Data categories:** ACCELI need to provide a product passport of the drone with specification of the parts produced with secondary raw carbon fibre
- **Data exchange process**: User manual and technical sheet with the end user and linked product passport

Material

- **Certifications and standards:** none other than common standard requirements (e.g., ISO) and in accordance with current legislation

Go-to-Market Challenges and Business Information

- **Incentives for the buyer**: purchasing drones that are sustainable because manufactured with secondary raw material
- **Challenges**: (1) Foreign country competition on lower prices and lower quality; (2) Lack of understanding of relevance of circular value chains and willingness to pay a higher price for a sustainable product
- **Relevance of Product Passport**: 3-4 on a scale of 5

Figure 12. Output Stage of the CRFP for Drones Framework for Circular Value Chain

KPIs

- Increase prepreg shelf life
- Increase the value of uncured prepreg scrap
- Reduce of prepreg disposal (reduction of the quantity of prepreg disposal in HPC)
- Create new jobs in partner facilities related to exploiting uncured prepreg scraps
- Reduce of the existing unused CFRP waste
- Reduce of the amount of unused CFRP waste in the production of composite materials (%)
- Reuse material to produce components for drones (% of material reused)

Benefits

- Manufacturing cost reduction and waste reduction
- Reduction of tons of prepreg that go to landfills every year and turnover deriving from new products made with this secondary raw material and from the sale of the secondary raw material itself
- The expired prepreg will be not disposed with the related costs, but it can be used to produce structural components instead of fresh material at a lower cost
- Enable of potential disposal of unused prepreg

Stakeholders and Objectives

- HPC will be able to effectively valorise scraps and expired prepreg rolls
- CETMA will study a process to valorise HPC's waste
- CC will produce and sell drones parts with a new and optima valorisation process for carbon fibre waste
- ACCELI will sell drones with components made of secondary raw carbon fibre with at a better price/quality relationship
- Consumers buying drones produced with secondary raw carbon fibre

To-Be Scenario

The objective of this pilot is to design a new process to effectively reuse the carbon fibre waste that HPC is producing within its day-to-day business activities. Therefore, the to-be scenario is the design of an optimised requalification procedure for both expired prepreg rolls and uncured scraps, that ensures the ability to process the material in an optimal way. CC, to put in practice this process, needs insights around the exact process window (namely, the right time, temperature and pressure range) to which the expired rolls or the uncured scraps can be processed in an optimal way.

Pilot's Business Model

- **Value proposition**: providing drones purchasers with financially and environmentally sustainable products, derived from the use of waste composite material
- **Commercial/ business model**: To be determined
- **Current and future customers final applications:**

  Current: creation of drones for drone's enthusiasts

  Future: broader UAVs manufacturing industry, other types of industries that could replace current material with secondary raw carbon fibre (with characteristics compatible with the performance of the secondary raw material), any consumer design products producers.

IP Rights

- IP Rights and owner(s): to be determined. Potential usage of new process developed by HPC in another project (LIFE CIRCE) and potentially to patent the new process waste from production of carbon fibre products and prepreg rolls (to be determined)
- Beneficiary(ies): HPC for the proceed developed in "LIFE CIRCE".

Figure 13. Value Creation Approach of Framework for Circular Value Chain for CRFP for Drones Pilot

Appendix E: WEEE for Magnets Framework for Circular Value Chain

Waste Sourcing and Handling

- **Input industry**: Primarily household appliances but also automotive, electronic devices, telecommunication, and medical devices
- **Origin of the waste**: Spain (mostly Barcelona region) – Green points in Cataluña
- **Waste volume:** 1 kg of magnets per week (current maximum quantity processable by IMDEA in the next stage)
- **Non treatable waste disposal (not within Plooto's scope):** landfill
- **Steps before entering the transformation stage**: *Ferimet* is in charge of (1) machines/appliances/devices disassemble, (2) engine/motor disassemble, (3) manual magnets extraction

Data

- **Data categories:** Type of material, quantity and origin of the magent
- **Data requirements**: origin of the magnet (machine/appliance/device) and magnet type/composition
- **Data collection:** manual process to identify the magnet type and shape/geometry
- **Data exchange process**: mainly via email and via sharing/Communication platforms

Material

- **Input material:** magnets extracted primarily from washing machines
- **Certifications and standards**: none other than common standard requirements (e.g., ISO) and in accordance with current legislation
- **Specs and conditions**: Ferimet is required to provide magnets already by origin (each magnet is packed in a single box to avoid sticking)

Sourcing Challenges and Business Information

- **Incentives for input industry**: (1) profit from selling the EoL magnets (obsolete magnets), (2) Less environmental impact, (3) Reduced cost of disposal
- **Challenges:** (1) manual process of magnets extraction form engines, (2) large packaging volume to avoid connection of magnetic fields, (3) frequent shipment because of the low volume of material shipped

Figure 14. Input Stage of the WEEE for Magnets Framework for Circular Value Chain

Transformation Process and Special Equipment

- **Transformation process**
  - ***Sorting***. Magnets need to be sorted according to chemical composition, origin and grade (IMDEA)
  - ***Demagnetisation***. Magnets are demagnetised before being crushed (IMDEA)
  - (***Uncoating***). This process applies only to sintered Sr-ferrite magnets that require the removal of the coating (IMDEA)
  - ***Crushing***. Magnets are crushed to create pellets (IMDEA) – max weight of magnets per weeks 2kg
  - ***Mixing***. Crushed magnets are mixed with polymers (IMDEA for bonded magnets if needed / IMA ferrite and NdFeB- and sintered ferrite magnets)
  - ***Injection***. Crushed magnets and added polymers are injected to produce new magnets (IMA)
  - ***Magnetisation***. The basis created in the injection stage are now magnetized (IMA)
  - ***Quality control, packing and storing***. Magnets' quality is controlled via machines and human supervision and then prepared for the shipment (IMA)
- **Special equipment:** (1) machineries to transform waste powder NdFeB magnets, (2) injection equipment with molds, (3) equipment to demagnetize and magnetize, (4) quality control equipment (magnetization, visual inspection).

Data and ICT Infrastructure

- **Data Categories**

IMA/IMDEA: Both companies require the same data categories to be exchanged as well as within the product passport. These categories are: type of material, quantity, physical, magnetic and chemical properties.

- **Data collection:**

IMDEA: Visual inspection and instrumental measurements (e.g., magnetic characterization) and calculations

IMA: Visual information about the parameters used in equipment of the production processes, data from measurements and tests of magnetic properties carried out in laboratory through control equipment.

- **Data requirements:** name, reference, batch number, label according to the current legislation (such as REACH, RoHs, CLP, APQ). In addition, IMDEA needs to provide information on the chemical substance, so the exchange should include MSDS and labels with the GHS
- **Data exchange process:** mainly via email and via sharing/communication platforms
- **Infrastructure:** EPR system collecting information from machines (production, quality control – when not done manually) and database to store information.

Material

- **Certifications and standards:** not required to provide any documentation around standards to carry out the process, except for common requirements (e.g., ISO)
- **Material flow**:
  - ***IMDEA***: To provide magnets in pallets with specification around chemical composition of the pallet and weight of the pallet.
  - ***IMA***: Produce new magnets with the pallets provided by IMDEA and according to their current business activities and customers' requests.

Transformation Challenges and Business Information

- **Challenges**

  IMDEA: (1) Sort of the different types of magnets (NdFeB or Sr-ferrite); (2) Sort of different grades for the same magnet type; (3) Remove coating from the magnet surface before processing (for sintered Sr-ferrite magnets the coating can heavily contemn the magnet with impurities decreasing magnetic properties)

  IMA: (1) Lower the cost of material to carry out the same orders ; (2) Introduce new powder to solve quality problems of the crushed magnets, (3) Sr-Ferrite magnets are less expensive to be produced directly with new raw material. "Usual" operational challenges: adapt production processes to manufacture magnets according to the client's application

Figure 15. Transformation Stage of the WEEE for Magnets Framework for Circular Value Chain

Final Productions and Distribution

- **Output:** IMA to produce new magnets
- **Sales channels**: Direct to business (B2B – business to businesses)/current trade routes
- **Target markets (industry):** Any electronic application (e.g., automotive, household appliance, CPG, electronics, communication, medical sectors, defense)
- **Target markets (geographies)**: Worldwide except those prohibited by the European Commission
- **Target markets (company size/users)**: medium and large companies

Data

- **Data categories:** IMA need to provide to the buyer information around magnets types, grades and purity of the constituent materials. Other relevant information that need to be provided are batch and lot information of the magnet(s), including information on chemical composition, percentage of secondary raw material vs. new material used, and shape/geometry
- **How data is exchanged**: technical sheet of the product and product passport

Material

- **Certifications and standards:** not required to provide any documentation around standards to carry out the process, except for common requirements (e.g., ISO)

Go-to-Market Challenges and Business Information

- **Incentives for the buyer**: (1) positive Corporate Social Responsibility (CRS); (2) improvement of sustainability posture
- **Challenges**: (1) Circularity and sustainability awareness of the market; (2) Competition from non-EU countries, (3) Cost of the overall process driving increase in the price of magnets
- **Relevance of Product Passport**: 5 on a scale of 5

Figure 16. Output Stage of the WEEE for Magnets Framework for Circular Value Chain

KPIs

- Reduction of WEEE landfilled
- Increase the usage of Sr-ferrite crushed pellets in magnets production
- Improve the quantity of leftovers and disregarded magnets entered into the transformation process
- Increase the usage of SRM (bonded NdFeb, Sr-Ferrite) in PM magnet pellets' production
- Increase the number of types of validated materials

Benefits

- Reduce environmental impact
- Reduce dependency of non-EU countries for critical raw materials
- Import tariff reduction
- Shortening of the supply chain and reduction of delivery time

Stakeholders and Objectives

- Ferimet will be able to change the current manual process and increase the number of magnets extracted per day
- IMDEA will be able to study better and more standardized requalification processes improving the throughput
- IMA will be able to increase the production of magnets produced with secondary raw materials thanks to more precise information
- Eurecat will support Ferimet in improving magnets extractions processes.
- Final customers sourcing regionally magnets produced with secondary raw materials

Pilot's Business Model

- **Value proposition**: developing a process that allow the provisioning of magnets from secondary raw material with the same quality of magnets produces with net new raw material
- **Commercial/ business model**: Creating an optimized manufacturing process that can be licensed via fees. IMA to keep producing and selling magnets but potentially at a higher markup as using secondary raw materials.
- **Current and future customers final applications:**
  - Current: Electronic application (e.g., electric motors and generators, MRI machines, magnetic sensors)
  - Future: As IMA already targets multiple customers across multiple countires and industries, there is no need for further expansions

To-Be Scenario

The objective of this pilot is to refine the overall process with minor adjustments. The biggest changes that this pilot seeks are related to Ferimet's operations. With the support of Eurecat, the company expects to deploy an automated and robotic process to dismantle magnets from motors and engines. The second most impacted company is IMDEA, that within Plooto expects to understand how to better process the limited number of magnets (1 kg of magnets per week) and eventually scale this up, and to study a requalification process for the coating removal and requalification form impurities for sintered Sr-ferrite magnets. In addition, the company is expecting to be using self-develop methods for processing the materials, such as flash milling to process sintered Sr-ferrite magnets and casting-based polymerization of the materials to prepare the bonded magnets. IMA is the company that expects the simplest intervention, with the optimization proprietary production processes. Looking at the broader impact scenario, IMA and IMDEA expects to improve their carbon footprint and saving costs (across multiple dimensions, e.g., optimization, energy reduction).

IP Rights

- **IP rights and owner(s)**: Potentially the development of robotic extraction process of magnets from engines (to be confirmed)
- **Beneficiary(ies)**: Ferimet and Eurecat (to be confirmed)

Figure 17. Value Creation Approach of Framework for Circular Value Chain for WEEE for Magnets Pilot

Appendix F: Citrus Processing Waste for Juice By-products Framework for Circular Value Chain

Waste Sourcing and Handling

- **Input industry**: ASPIS juice production function
- **Origin of the waste**: Greece – Peloponnese area
- **Waste volume:** 7-12% of the weight of oranges that are sourced (either bad fruits – unless too deteriorated e.g., rotten – and waste from juice production)
- **Non treatable waste disposal (not within Plooto's scope):** Landfill or biogas production
- **Steps before entering the transformation stage**: As there is only one company involved in the full production process, ASPIS first produce the waste from juice extraction

Data

- **Data categories:** See transformation stage
- **Data requirements**: See transformation stage
- **Data collection:** See transformation stage
- **Data exchange process**: NA

Material

- **Input material:** oranges pulp and peel
- **Certifications and standards**: not required to provide any documentation around standards to carry out the process, except for common requirements (e.g., ISO) and HCCP standards for animal production feed
- **Specs and conditions**: NA (processing own waste) – specs will be adjusted during the transformation process

Sourcing Challenges and Business Information

- **Incentives for input industry**: ASPIS will create cost efficiencies derived from the waste valorisation into new products
- **Challenges:** NA (excluding the previous step challenge in sourcing oranges during bad agricultural year, impacting also the availability of waste)

Figure 18. Input Stage of the Citrus Processing Waste for Juice By-products Framework for Circular Value Chain

Transformation Process and Special Equipment

- **Transformation process:**

For *CPW* for cattle feed industry:

Milling. Pulp and peel from oranges are trimmed into a fluid
Neutralization: lime is added to the milled fluid to adjust the pH
Dewatering: via mechanical press the fluid is separated from water
After this, two different processes may occur: the dewatered material can be directly packaged or can be first further dehydrated and the packaged

For *CPWW – Citrus Peel Wastewater*:

Extraction: The emulsion of water and oil is centrifuged to separate the water from the oil
Centrifuge: water is partially removed from orange juice

For "*Orange oil*": After the centrifuge, the remaining orange oil is cold pressed and sent to other companies for further processing depending on the needs of the companies, exiting the Plooto value chain

For *Sludge*: (after the production of CPW for the cattle feed industry the CPW can enter a different production process)

Refining. The liquor is analysed looking for particle size of the insoluble solid.
pH adjustment. pH is adjusted with the addition of fresh sludge and citric acid
Desludging. Liquor is separated in watery and solid particles. Solid particles will be the final output as sludge. (*continue*)

(*continue*)

For *Water, D-limonene and molasses*: (after the desludging, the /residual watery waste can enter two different processes depending on which is the desired output)

D-limonene and Water.

Condensation. The water vapor obtained in the first condensation process is further condensed.
Decanter. In this phase, water and d-limonene are split with this process.

Molasses.

Cooling. The outcome from the former condensation/heat evaporation process is cooled.
Mixing. The output of this cooling phase is mixed with other batcheS of molasses to obtain the desired characteristic in the final product
Storing. After the mixing phase, the output is stored, and the molasses are produced.

- **Special equipment:** The entire production process requires machineries, decanters, evaporators, colling systems and mixing machines.

Data and ICT Infrastructure

- **Data categories:** quality and characteristics
- **Data collection:** Sensors for temperature, flow-meters and analytical process for pH measurement
- **Data requirements:** pH, calcium addition, temperature, level of condensation, moisture of peels when doing pellets, desired BRIX for the final product)
- **Data exchange process:** Internal emails and spreadsheets
- **Infrastructure:** ERP and datacenter to collect information on mass balances (waste entered in the production, concentration level, final output quantity and quality)

Material

- **Certifications and standards:** not required to provide any documentation around standards to carry out the process, except for common requirements (e.g., ISO) and HCCP standards for animal production feed
- **Material flow** :

Waste and semi components simply move across ASPIS departments according to the production/ requalification stage

Transformation Challenges and Business Information

- **Challenges**

1) Maintain the adequate requirements on material condition (e.g., *molasses: initial solids 7-9%, final solids 60-65%, silane: initial humidity: 90%, final humidity: up to 60%, dried silane: initial humidity: 90%, final humidity: < 15%*) and Brix (sugar) concentration, 2) rising energy cost due to energy intensive process

Figure 19. Transformation Stage of the Citrus Processing Waste for Juice By-products Framework for Circular Value Chain

Final Productions and Distribution

- **Output:** citrus molasses and dried citrus pellets
- **Sales channels**: Direct to business (B2B – business to businesses)
- **Target markets (industry):** companies producing cattle feed industry)
- **Target markets (geographies)**: Greece, Turkey and Albania (potentially medium size companies)

Data

- **Data categories:** nutritional value (e.g., protein, fibres, calcium) and concentration level of pellets and molasses, production and expiry date, batch and serial number
- **Data exchange process**: technical sheet of the product and product passport

Material

- **Certifications and standards:** not required to provide any documentation around standards to carry out the process, except for common requirements (e.g., ISO)

Go-to-Market Challenges and Business Information

- **Incentives for the buyer**: (1) Quality of product; (2) Higher nutritional value; (3) Lower chemical additions
- **Challenges**: (1) Foreign and regional country competition on lower prices from chemical production and lower quality; (2) Difficulties in proving the higher quality and benefits of the product coming from vegetable waste
- **Relevance of Product Passport**: 4 on a scale of 5

Figure 20. Output Stage of the Citrus Processing Waste for Juice By-products Framework for Circular Value Chain

KPIs

- Increase production of animal feed components
- Higher molasses quality
- Reduce COD of CPWW
- Lower volume of CPWW that goes to biological treatment
- Increase revenue from animal feed production
- Improve energy savings
- Improve cost savings

Benefits

- Wastes valorisation
- Energy saving in the production process
- High nutritional value of the final product
- Process optimisation and monitor to prevent alteration in the final product

Stakeholders and Objectives

- ASPIS in optimizing the process, will be able to gain energy savings, and a certification, via the product passport, of the quality and relevance of the production.
- KPAD will perform the life cycle assessment for the waste valorisation line and will support in the evaluation of the carbon footprint of the line
- Organizations in the cattle feed industry to buy locally sourced and produced, natural and higher nutritional value materials.

To-Be Scenario

The primary objective of this pilot is to refine the transformation process of by-products to produce cattle feed. More in details, ASPIS aims at optimizing the separation and evaporation stages of the production to allow a larger production of molasses and CWP. The optimization, despite being the primary objective is not the only one. ASPIS desire to further study and provide evidence of the higher quality and better nutritional value of CPW and molasses from oranges' by-products compared to other SRMs or components entering the cattle feed industry.

Pilot's Business Model

- **Value proposition**: providing fully natural component to cattle feed industries with higher nutritional value and overall product quality
- **Commercial/ business model**: selling to current customers and extending to new customers new geographies.
- **Current and future customers final applications:**
  - *Current*: Cattle feed production
  - *Future*: Potentially to expand to pet feed industry

IP Rights

- **IP rights and owner(s)**: to be determined
- **Beneficiary(ies)**: NA

Figure 21: Value Creation Approach of Framework for Circular Value Chain for Citrus Processing Waste for Juice By-products Pilot