Product Passport through Twinning of Circular Value Chains

Deliverable 1.2

Plooto Methodological Approach and Business Case Specifications v2

WP1: Digital Circular Value Chain Framework

Editor:	Erica Spinoni
Lead beneficiary:	IDC
Version:	1.0
Status:	Final
Delivery date:	20/12/2024
Dissemination level:	PU (Public)

Document Factsheet

Grant Agreement No.	101092008
Project Acronym	Plooto
Project Title	Product Passport through Twinning of Circular Value Chains
Start date	01/01/2023
Duration	36 months

Deliverable Name	D1.2 Plooto Methodological Approach and Business Case Specifications V2
Related WP	WP1 Digital Circular Value Chain Framework
Due Date	31/12/2024

Author	Erica Spinoni (IDC)
Contributor(s)	Golboo Pourabdollahian, Giulia Carosella (IDC), Nikolaos Sifakis (TUC), Margherita Forcolin (MAG), Linda Leonardi (CETMA), Andreas Katsigiannis, Olga Serifi (KPAD), Tryfonas Kekes (ASPIS), Aris Zompras (ACCELI), Itzok Rancelj (JSI), Jose Gonzalez (EUT)
Reviewer(s)	Kostas Christidis (FRONT), Maria Zoidi (AEGIS)
Approved by	All partners

Document History

Version	Date	Author(s)	Organisation	Description
0.1	04/09/2024	Erica Spinoni	IDC	Table of Contents ToC
0.2	28/11/2024	Erica Spinoni	IDC	First draft excluding content to be provided by partner
0.3	01/12/2024	Margherita Forcolin, Erica Spinoni	MAG IDC	Content provided
0.4	03/12/2024	Nikolaos Sifakis. Erica Spinoni	TUC IDC	Content provided
0.5	04/12/2024	Golboo Pourabdollahian, Giulia Carosella	IDC	Internal review
0.6	06/12/2024	Erica Spinoni	IDC	First complete draft
0.7	09/12/2024	Linda Leonardi Margherita Forcolin	CETMA MAG	Partner additional contribution and Q&A response
0.8	11/12/2024	Nikolaos Sifakis Andreas Katsigiannis Olga Serifi	TUC KPAD KPAD	Partner additional contribution
0.9	13/12/2024	Tryfonas Kekes Aris Zompras Jose Gonzalez Linda Leonardi	ASPIS ACCELI EUT CETMA	Partner Q&A response
0.10	16/12/2024	Itzok Rancelj	JSI	Partner additional contribution
0.11	17/12/2024	Kostas Christidis Maria Zoidi	AEGIS FRONT	Peer review
0.12	18/12/2024	Erica Spinoni	IDC	Integration of comments from internal review
0.13	19/12/2024	Armend Duzha	MAG	Quality check
1.0	20/12/2024	Erica Spinoni	IDC	Final version ready for submission

Executive Summary

This document provides an updated analysis of the first release of D1.1. The Framework for Circular Value Chains (FCVC) remains consistent with its initial edition – originally presented in D1.1 "Plooto Methodological Approach and Business case Specifications V1". Evolving details around specific components of the framework have been refined and finalized. In addition, a deep dive on some core parts of the projects such as the digital product passport (DPP), data availability, and KPI understanding will be presented in the text below. Data is essential for mapping processes, supporting analytics, and optimizing services to meet sustainability goals as well as for the creation of the different intermediate and final DPPs.

The three pilots are at two thirds of their journey into the project, but it is already possible to finalize their framework, as the preliminary discussions are over, and they are effectively into the actuation phase.

In the following paragraphs the main points and findings covered by this deliverable are highlighted.

CFRP Waste for Drones

The CFRP for drones pilot has evolved to improve efficiency and sustainability. Initially, the plan was for HPC to send expired or scrap materials to CETMA for requalification, which were then sent to CC for drone parts manufacturing. This process was revised to have HPC send material samples to CETMA for study. CETMA updates a catalogue with requalified materials, allowing CC to select the most suitable materials for drone parts commissioned by ACCELI, process optimized from an economic and sustainable aspect.

CETMA has defined requalification processes for two types of carbon fibre materials. Expired prepreg rolls undergo usability evaluation and process window definition, while prepreg scraps only go through the process window definition. Challenges include time constraints for monitoring long-term performance, variability in the requalification process due to changing conditions, availability and suitability of materials for final production, and rapid advancements in carbon fibre technology.

Due to the complexity and long-term impact of the requalification process, effective KPI assessment is still in progress. Key KPIs like "new jobs in partner facilities" and "reuse of material to produce components for drones" will be assessed after the project completion.

ACCELI has identified a prototype drone with parts made from requalified carbon fibre, targeting B2B companies in agriculture and forestry sectors and possible usage also for security reasons.

Continued collaboration and market exploration for requalified materials are essential for further value chain enhancement. Future steps include studying requalification for different carbon fibre compositions, exploring new market opportunities beyond drones, continuing collaboration to move prototypes to production, sharing best practices with industry stakeholders, and addressing the recycling of cured carbon fibre for further value chain improvement.

WEEE for Magnets

The magnets pilot has taken several actions based on the capabilities of the involved companies and market availability. The types of magnets treated include bonded neodymium, bonded ferrite, and sintered ferrite magnets, sourced from various electronic devices. Initially, magnets were expected from washing machines, but the first batch came from microwaves, demonstrating the circular nature of the process.

IMDEA, with limited processing capacity, can handle 100g per day of sintered magnets and 500g-1kg of bonded magnets. This impacts the feasibility of achieving certain KPIs, such as reducing WEEE landfilled, which now seems too ambitious without outsourcing to a manufacturing company. The KPI for increasing the usage of Sr-ferrite crushed pellets aims to reduce scrap during the injection process by optimizing moulds and re-entering scraps into production.

Challenges include creating new moulds to reduce injection process scraps and developing a process to recycle these scraps efficiently. These challenges aim to enhance the sustainability of the value chain.

Currently, there are no plans to request IP rights for the processes developed, but IMA and IMDEA may consider a joint IP right for the new scrap re-entry process.

The Plooto intervention is a small-scale but significant step towards remanufacturing EoL magnets, a neglected area so far. Post-project, the organizations composing the pilot could boost the value chain by continuing the study around automating magnet extraction, increasing processing capacity, and exploring new polymers for extrusion. Sharing knowledge and best practices with other European producers could reduce dependency on external sources for rare earth and critical materials.

Citrus Processing Waste for Juice By-products

The Greek pilot has begun assessing some KPIs, with further development expected once further iterations of analytics models are ready, particularly for energy and cost-saving KPIs. As of M22-M24, the pilot has identified key KPIs and their impact assessments.

Two new challenges emerged during the transformation phase: producing cleaner recovery water for reuse in the plant and reducing energy consumption during the transformation process. Additionally, there is a minor update on the difficulty of effectively communicating the higher nutritional value of the molasses for animal feed production, highlighting the need for a robust marketing strategy.

Other minor changes include working with Plooto's analytics team to collect historical and real-time data, improving quality control and adding precise information to the digital product passport.

Post-project, the company creating the pilot could further boost the value chain by studying similar processes for other fruit and vegetable waste, optimizing processes to increase efficiency, exploring waste benefits in other industries, and creating energy via waste-to-energy processes. ASPIS is already considering investments in a biogas facility to reduce waste and produce green energy, aiming to cover one-third of its energy needs.

Table of Contents

EXECUTIVE SUMMARY......4

1 INTRODUCTION......10

1.1 Purpose and Scope......10

1.2 Relation with other deliverables......10

1.3 Structure of the document......11

1.4 Summary of changes from version 1......11

2 METHODOLOGY......13

2.1 Framework for Circular Value Chains Reminder......13

3 CFRP FOR DRONES – DEEP DIVE, FINAL FINDINGS AND EXPECTED SCENARIO 15

3.1 New information and changes between M10 and M24......15

3.2 FCVC Final Version......17

3.3 Final Expected Scenario and Recommendations for the CFRP Waste for Drones Pilot......23

4 WEEE FOR MAGNETS – DEEP DIVE, FINAL FINDINGS AND EXPECTED SCENARIO......25

4.1 New information and changes between M10 and M24......25

4.2 FCVC Final Version......27

4.3 Final Expected Scenario and Recommendations for the WEEE for Magnets Pilot 32

5 CITRUS PROCESSING WASTE FOR JUICE BY-PRODUCTS – DEEP DIVE, FINAL FINDINGS AND EXPECTED SCENARIO......34

5.1 New information and changes between M10 and M24......34

5.2 FCVC Final Version......36

5.3 Final Expected Scenario and Recommendations......41

6 DEEP DIVE ON DIGITAL PRODUCT PASSPORT, DATA AND KPIS......42

CONCLUSIONS......50

List of Figures

Figure 1. Plooto Framework for Circular Value Chain 14
Figure 2. CFRP Waste for Drones Processes Flowchart – Updated 16
Figure 3. Final Input Stage of the CFRP Waste for Drones FCVC 19
Figure 4. Final Transformation Stage of the CFRP Waste for Drones FCVC 20
Figure 5. Final Output Stage of the CFRP waste for Drones FCVC 21
Figure 6. Final Value Creation Approach of the Citrus Processing Waste for Juice By-products FCVC 22
Figure 7. WEEE for Magnets Processes Flowchart - Updated 26
Figure 8. Final Input Stage of the WEEE for Magnets FCVC 28
Figure 9. Final Transformation Stage of the WEEE for Magnets FCVC 29
Figure 10. Final Output Stage of the WEEE for Magnets FCVC 30
Figure 11. Final Value Creation Approach of the WEEE for Magnets FCVC 31
Figure 12. Citrus Processing Waste for Juice By-products Processes Flowchart – Updated 34
Figure 13. Final Input Stage of the Citrus Processing Waste for Juice By-products FCVC 37
Figure 14. Final Transformation Stage of the Citrus Processing Waste for Juice By-products FCVC 38
Figure 15. Final Output Stage of the Citrus Processing Waste for Juice By-products FCVC 39
Figure 16. Final Value Creation Approach of the Citrus Processing Waste for Juice By-products FCVC 40
Figure 17. Example of Digital Product Passport aggregation for the WEEE for Magnets pilot 44

List of Tables

Table 1. Information displayed in the DPP by company - Italian Pilot 45
Table 2. Information displayed in the DPP by company - Spanish Pilot 45
Table 3. Information displayed in the DPP by company - Greek Pilot 46
Table 4. Production-related KPI list with expected and current parameters measured - Italian Pilot 47
Table 5. Production-related KPI list with expected and current parameters measured - Spanish Pilot 48
Table 6. Production-related KPI list with expected and current parameters measured - Greek Pilot 49

Acronyms and Abbreviations

Acronym	Description
B2B	Business to business
CFRP	Carbon Fiber reinforced polymer
COD	Chemical Oxygen Demand
CPW	Citrus Peel Waste
CPWW	Citrus Peel Wastewater
CRIS	Circular and Resilient Information System
DPP	Digital Product Passport
DT	Digital Twin
EEE	Electrical and Electronic Equipment
EoL	End of Life
EU	European Union
FCVC	Framework for Circular Value Chain
ILSS	Interlaminar Shear Strength
MSDS	Material Data Safety Sheet
Prepreg	Pre-impregnated
RFP	Request for Proposal
SRM	Secondary Raw Material
WEEE	Waste from Electrical and Electronic Equipment
WP	Work Package
HPC	HP Composites S.p.A.
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
TUC	Technical University of Crete

1 Introduction

1.1 Purpose and Scope

This document is the second deliverable of T1.1, related to finalizing the Plooto framework for the circular value chain and developing specific business circular value chains for each pilot in the project. The primary goal of T1.1 is to create the circular value chain by establishing pilot boundaries, determining stakeholder roles, and outlining data and material flows among stakeholders. This deliverable focuses on providing the final view of these multiple insights through the final version of the Framework for Circular Value Chains. The first 10 months (M1-M10) of the project culminated in the redaction of D1.1 "Plooto Methodological Approach and Business Case Specifications V1," involving the collection of relevant pilot information and data through workshops and interviews. In this second and final stage for T1.1, from month M10-M24, the work refined and finalized the information collected in the first part of the project and defined possible extensions to further strengthen the circularity approach of these productions and the companies involved.

1.2 Relation with other deliverables

Task 1.1 closely collaborated with all other WP1 tasks and other WPs of the Plooto project. The main interactions with the different WPs are as follows:

WP1 – Digital circular value chain framework

For WP1 tasks, Task 1.1 provided a comprehensive view of the pilots' activities and relationships across the companies composing the three pilots. This was a critical step in highlighting traceability strategies, pilot objectives, and initial insights into the pilots' connections and implications for possible governance models. Clear definitions of the boundaries of the activities carried out were established. All this was made possible thanks to the creation of the framework for circular value chains. In particular, a close link was established with Task 1.4, where the results of Task 1.1 served as input to define the scorecard.

WP2 – Supply chain DT modelling and operation

The work carried out in Task 1.1 was critical to design the right interaction process among the different companies composing the pilots, identifying relationships and connections across the organisations. Similarly, the overall process, material, and data flows mapping was decisive to understand how to initiate the waste data space. The understanding of the processes and reflection brought upon the pilot's partners further helped to identify the processes and actions that needed optimization and analytics, activities carried out by this WP.

WP3 – CRIS integration and deployment

Task 1.1 is linked to WP3, and more specifically to Task 3.3, in the initial assessment and identification of the information for the lifecycle assessment, the balanced scorecard, around scraps status, usage patterns, etc.

WP4 – Circular process industry demonstration

The interaction with WP4 has been central to designing the circular value chain. Given that the design is tailored to each pilot's specific needs, the involvement of pilot partners has been crucial for providing the necessary information. Across M1-M24, pilot partners have been the primary participants in the questionnaires, interviews, and workshops, which all resulted in the creation of the final version of framework for circular value chain by pilots, available below.

WP5 – Impact creation, solutions scale-up and exploitation

The work carried out in Task 1.1, was closely related to the activities of T5.2 of this WP. The last part of the framework for circular value chains, the "value creation approach" sheet provided initial material to study the pilot's business model. Conversely, during the M10-M24 the information further elaborated by Task 5.2 became essential in the finalization of Task 1.1's framework.

1.3 Structure of the document

The document is structured as follows:

- **Section 2** introduces the methodological approach followed for this second deliverable for the collection and finalization of the Framework for Circular Value Chains (FCVC) for the three pilots.
- **Section 3, 4 and 5** describes the reviewed and final FCVC the three pilots introducing new mechanism and action items to further strengthen the current set up of the overall value chain. Section 3 will cover CFRP Waste for Drones (Italian pilot), Section 4 will cover WEEE for Magnets (Spanish pilot), and Section 5 will cover Citrus Processing Waste for Juice By-products (Greek pilot).
- **Section 6** describes in detail some critical aspects of Plooto that required a further deep dive to better understand the overall project (KPIs and data) or that have an impact on other parts of the project (DPP component and delivery). These insights are a preview of the work from other WPs.

1.4 Summary of changes from version 1

This second version of the "Plooto Methodological Approach and Business Case Specification" is structured in a different way compared to the previous one so there is not a one-to-one match of the sections. However, the changes that have been implemented content-wise compared to the first deliverable are the following:

- In section 3, 4 and 5, modifications and updates of the content of CFRP for Drones, WEEE for Magnets, Citrus Processing Waste for Juice By-products respectively for the Framework for Circular Value Chains are presented. At the beginning of each section a bullet list summarizes the most relevant updates and changes.

- In section 6 deep dives into relevant areas not meticulously studies in the previous deliverable are presented, such as data, the DPP in the light of the pilot business and value mapping, and the KPIs requirements.

2 Methodology

The preparatory work for this deliverable included several activities aimed at creating the final version of the full Framework for Circular Value Chains (FCVC). The primary activities involved a thorough analysis of the M10 FCVC to identify and address missing elements or areas requiring further exploration, the collection of additional information related to the FCVC of the different pilots from other deliverables, and the initial gathering of information directly from the pilots based on the analysis of the gaps. From the initial assessment conduced well before the submission of the first version of the "Plooto Methodological Approach and Business Case Specification", the pilots have matured in terms of understanding and defining their objectives, activities, processes, people and technical requirements as well as from the business model perspective. This led to the review – via this deliverable - of what was also originally missing due to the early stage of the project. For instance, the effective evaluation of the KPIs improvements, the final identification of the boundaries of the activities to be carried out and the identification of the full spectrum of waste materials to be covered.

To solve the identified gaps two main actions have been taken:

- *Analysis of the content of other deliverables as starting point for information confirmation and collection*. For instance, from D4.1 "Impact Assessment Methodology" the full list of KPIs and details around them have been taken to conclude the KPIs assessment of the "value creation" sheet of the FCVC. Similarly, D1.3 "Sustainability Balance Scorecard Framework V1" has been used to further refine information and understanding on the flow for the DPP and D1.5 "CRIS Requirements and Specifications" has been leveraged to better inform the section around data requirements and technology at play. These are just a few indicative examples.
- *Questionnaire responses and online 1:1 meetings*. From the analysis of the gaps and the new required information, three different questionnaires have been created, one for each pilot, to be completed considering the most relevant and recent updates of the pilots' activities. To further refine and deep dive these written responses, 3 separate virtual meetings were organized to discuss first hand with the pilots' participants the responses provided in the questionnaires.

The overall process described above led to the preparation of this deliverable.

2.1 Framework for Circular Value Chains Reminder

Before going into the update details of the three pilots and update on the activities, a quick reminder of the overall structure of the Framework for Circular Value Chains is presented below (Figure 1).

The framework serves as a robust foundation for partners in the Plooto project and is adaptable for use beyond the project. Its versatility makes it applicable across various manufacturing sectors, from discrete to process manufacturing, regardless of output type. The framework's comprehensive nature allows for in-depth analysis of the value chain's components. Additionally, its modular structure permits easy adjustments, enabling customization or removal of sections based on the production process's type or complexity and the number of organizations involved in the value chain.

The framework is built on four main sections:

- **Input**. This section identifies and maps where waste is generated before being transformed into SRM, semi-components, or finished goods. It tracks critical data and information needed by partners, the way this data is currently collected, and the main challenges and benefits of this stage.
- **Transformation Process**. This section highlights the core transformation process, and the actors involved. It provides an overview of the transformation activities, challenges, and best practices to support other work packages (e.g., creation of digital twins, delivery of CRIS).
- **Output**. This section highlights the output of the transformation process, detailing key information for the product passport, current market challenges, and how pilots plan to exploit the output.
- **Value Creation**. This section presents an initial assessment of how organizations plan to create value and the benefits for stakeholders involved in the pilots.

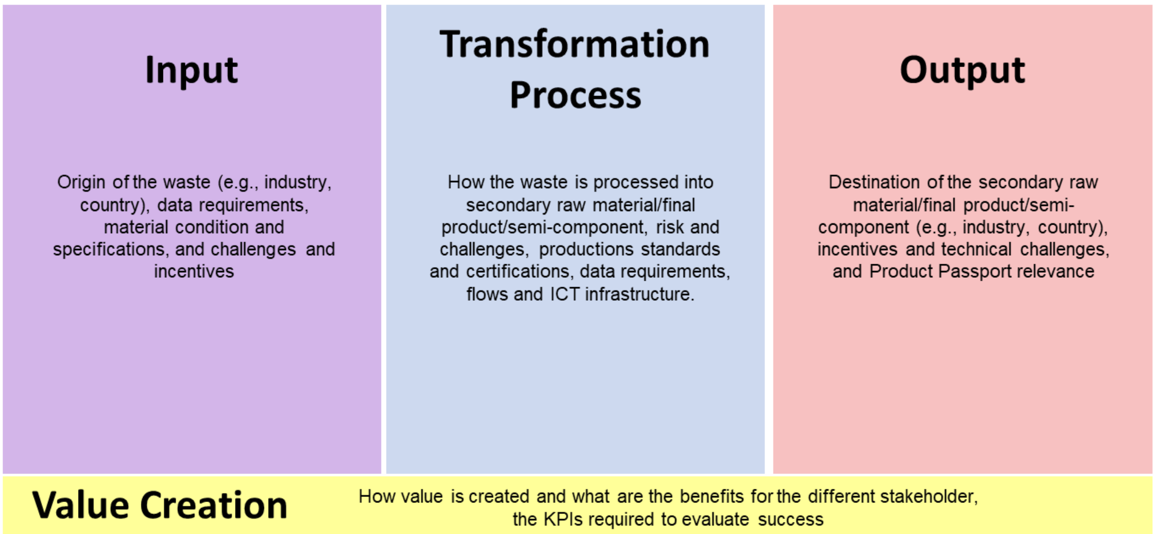

Figure 1. Plooto Framework for Circular Value Chain

For more details on the FCVC, the reader is invited to read the background and structure in the first deliverable D1.1 "Plooto Methodological Approach and Business Case Specifications V1".

3 CFRP for Drones – Deep Dive, Final Findings and Expected Scenario

In this section the final outcomes of the Framework for Circular Value Chains for the CFRP Waste for Drones and final information about the overall pilot activity are presented. The most significant updates compared to the first deliverable about this pilot are:

- the update of the pilot's flowchart impacting the "Transformation process" description in the "Transportation Stage" of the FCVC
- the new requalification process
- the definition of the expected contribution to the output (parts of drones created with requalified prepreg)
- the new challenges that emerged in between M10 and M24
- other minor updates.

3.1 New information and changes between M10 and M24

Flowchart Changes Impacting the Transformation Process

The primary and major change that the updated version of the flowchart highlights is the modification of the material flow from HPC, to CETMA and CC (compared to the original version). The reasons behind this change in the flow are twofold:

- CETMA requires only a sample of material for their analysis, thus sending all the expired material to CETMA is unnecessary. If the material cannot be re-qualified, it must be returned to HPC for disposal, leading to logistical challenges and higher transport costs.
- The process should logically begin when CC receives an order from ACCELI for drone parts production. Based on the order, CC will determine the required material type and request it to HPC, then the HPC provides the material to CETMA for usability evaluation and process window redefinition before sending the material back to HPC (for later use to CC) or to dump them as waste.

Originally, the agreement among the companies was that HPC would send expired or scrap materials to CETMA for requalification, which would then be sent to CC for manufacturing drone parts. Despite the relatively short distance between the three locations, this material flow was neither effective nor efficient, nor highly sustainable. Therefore, the pilot decided that HPC would first send only samples of the material needing requalification to CETMA for study (usability evaluation and process window redefinition). After CETMA's analysis and requalification process, the information about the scraps or requalified prepreg will be updated in a catalogue (upcycled material and prepreg) from which CC can choose the material that best fits the needs for the drone parts commissioned by ACCELI. This selection will be facilitated by the optimization model created in WP2, which highlights the most convenient choice from economic and sustainable perspectives, based on multiple criteria and parameters.

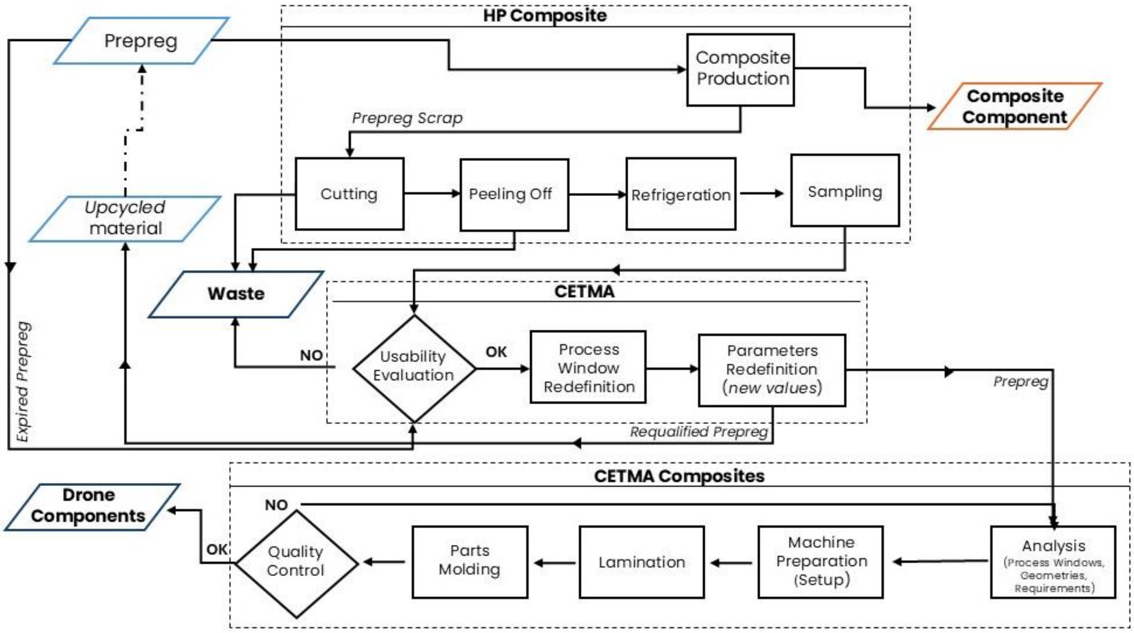

Figure 2. CFRP Waste for Drones Processes Flowchart – Updated

Overall, the new flowchart (Figure 2) details the entire extraction-transformation-remanufacturing process step by step.

Updated in the requalification process

So far, CETMA has studied and defined the requalification process for two specific types of carbon fibre materials to develop a procedure that can be applied in all prepreg types– more details are provided in deliverable D4.2 "Report on Piloting Activities V1" and will be finalized in D4.3 "Report on Piloting Activities V2". In a nutshell, the requalification process for expired prepreg rolls and for scraps is shared only partially. Expired prepreg rolls will go through a first phase of “usability evaluation” and a second one of “process window definition”, while prepreg scraps will go through only the “process window definition” phase.

Details about the two steps are shown below:

- Usability evaluation: to assess the expired prepreg rolls, it is important to understand the thermal, mechanical, and physical properties of the roll before the expiry date (via non expired rolls or from the original technical datasheet). After that, the thermal, mechanical, and physical properties of the expired prepreg rolls are measured. The last part of this first activity is the correlation of these properties to verify the usability of the expired prepreg.
- Process window definition: the identification of the new processing parameters (temperature, pressure and time), is followed by the production of the composite to be added using the new process window. After these two initial actions, the requalified prepreg sees mechanical and physical properties measured and compared with data of non-expired prepreg.

An important note on the usability evaluation: since the procedure is valid for each batch with a specific history, any changes in the batch history (e.g., storage conditions) will require the process to be reassessed. Moreover, the definition of the prepreg new expiry date is a long and timeconsuming procedure due to the fact that the prepreg has to be analysed at increasing time intervals until it is no longer usable.

Defined output expectations

Compared to the first deliverable, ACCELI has identified the prototype drone that will be built with parts in requalified carbon fibre materials. At this stage, there are two parts that will be effectively produced with secondary raw carbon fibre, the tubes and the plates, while other parts can be done on a custom base (e.g., body cover). This prototype drone is studied for the B2B (business to business) commerce, and the deployment is envisioned in the agricultural or forestry sector for overseeing activities and assessment of the ground as well as for airborne security. At this stage there are no fixed target markets, but expectations are around the possibility of commercialization as wide scale, also outside the European boundaries. ACCELI will use its traditional sales channels, once the prototype will be created and first samples delivered.

Challenges emerged between M10-M24

In terms of the challenges emerged since the submission of the first deliverable, there have been minor updates. What previously stated has been confirmed and four new challenges have emerged and identified.

For the transformation process, the project's 3-year timeframe may be too short to effectively monitor the behaviour and aging of the requalified materials, particularly regarding their long-term performance and, hence, the definition of the new expiry date. Similarly, the study and development of a requalification process is subjected to too many changing variables and conditions, from the carbon fibre composition to storing and stocking history. Therefore, multiple studies need to be carried as conditions and variables changes. This is also the reason why, so far, it has been possible to study the requalification process of only two types of carbon fibre materials.

For the output phase, two new challenges emerged. First, the availability of material that matches the types, quantity, and quality provided by HPC for requalification and its suitability for the final production of drone parts. Second, concerns the aging of the technology. Carbon fibre technology is continually evolving with the discovery of new molecules and polymers—especially with faster testing enabled by AI innovations. Consequently, materials on the market that have already reached their expiry date might be too outdated for some applications.

Other minor changes

To what previously stated about IP rights, the technique developed by HPC in the context of "LIFE CIRCE" project to treat and display carbon fibre scraps in a mould won't enter the IP rights assets of Plooto (outside of the project's monetization and value creation objective) but will be used to support the requalification of prepreg scraps.

3.2 FCVC Final Version

As of the moment of the submission of the deliverable, M24 of the project, there are no signs of significant future variation on the new version of the Framework for Circular Value Chain for the CFRP waste for Drones pilot. Below the full and final FCVC for this pilot is presented. The FCVC has also been refined to correct typos, erroneous punctuation, and other types of errors.

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 via (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 fibre material remain intact; (3) Solvolysis: the resin is degraded by various solvents and converted into a soluble form, so the carbon fibre material 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 data sheet (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 3. Final Input Stage of the CFRP Waste for Drones FCVC

Transformation Process and Special Equipment

- **Transformation process**
  - ***Analysis of the waste properties:*** (1) Analyses of 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:*** a) for EXPIRED prepreg: (1) Usability evaluation (determination and measurement of the different properties and correlation of the properties to verify the usability of the material); (2) Process window definition (in case the material is still usable (definition of new processing parameters, production of the composite using new process window, measurement of mechanical and physical properties, comparison of data with no-expired prepreg.
    b) for prepreg SCRAPS: Definition of the process window (see point #2 for "EXPIRED prepreg").
  - ***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 (e.g., DSC, rheometer, tack-dynamometer) for requalification test; (2) Equipment for prepreg polymerization (e.g., 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-polymerised/uncured prepreg and properties of polymerised/cured prepreg (for expired prepreg rolls and cut waste). Uncured: viscosity and 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, etc.
- **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**:
  HPC: Sends some sample of the material that needs to be disposed to CETMA.
  CETMA: Provides information on the experimental tests carried out in laboratories and define a new process window (based on material provided by HPC).
  CC: Selects and receives the scraps and the prepreg rolls from HPC, tests the new process window identified by CETMA, and produces 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 characterised 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; (5) Due to the time constraints of the project, it will be possible to study the requalification process only for a small portion of materials; (6) Long procedure in monitoring the behavior and aging of requalified process.

Figure 4. Final Transformation Stage of the CFRP Waste for Drones FCVC

Final Productions and Distribution

- **Output:** ACCELI to produce customised drones according to customers and clients' specifications. These drones that are still a prototype will be equipped with two standard parts produced with requalified carbon fibre, tubes and plates, and one that can be custom, according to ACCELI and customers' needs (e.g., body cover).
- **Sales channels**: Traditional ACCELI sales channels.
- **Target markets (industry):** B2B (agricultural, airborne security, forestry).
- **Target markets (geographies)**: There is no current market, but the expectation is selling to companies worldwide.
- **Target markets (company size/users)**: No specific company size target identified so far.

Data

- **Data categories:** ACCELI needs 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; (3) Availability of the material; (4) Aging of the technology.
- **Relevance of Product Passport**: 3-4 on a scale of 5.

Figure 5. Final Output Stage of the CFRP waste for Drones FCVC

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 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) at 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**: Provisioning of standard or custom drones, based on customer requirements.
- **Current and future customers final applications:**
  - _Current_: Creation of drones for specific business case and industries.
  - _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 – to enable the preparation of the prepreg scraps) 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” – but outside the Plooto’s monetization/value creation.

Figure 6. Final Value Creation Approach of the Citrus Processing Waste for Juice By-products FCVC

3.3 Final Expected Scenario and Recommendations for the CFRP Waste for Drones Pilot

For this pilot, no changes have been made to the definition of the expected scenario, so it reads as follows:

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) at which the expired rolls or the uncured scraps can be processed in an optimal way.

With Plooto's intervention the companies within the pilot will gain relevant circular benefits, reducing the amount of waste from carbon fibre production thanks to a requalification process that renter scraps or overall waste into a sustainable value chain. The requalification process is the pivotal process for this pilot, showcasing the strengths and potential of this study.

After the project completion, the pilot could do to the following further boost the value chain:

- Continuing studying requalification process for different types of carbon fibre composition (resin/fabric/fabric matrix), to track and collect information about commonalities among families of the material (CETMA specifically).
- In addition to the waste and scraps produced by HPC, also scraps and waste produced by CC in the production sport equipment in carbon fibre could be treated.
- Find new market opportunities for the reuse of requalified scraps and waste producing new parts not only for the drone industry. Other types of applications could be studied for instance in non-high-performance industries, such as games or hobbyist, for the provision of products in carbon fibre that could replace metal or other types of materials that show similar characteristics but doesn't require high standards (CC and ACCELI).
- Continuing the collaboration among the four companies, especially with ACCELI to move the current prototype into a permanent production line. This will support also the achievement of one of the KPIs provided in the initial project agreement, namely "new jobs in partner facilities related to exploiting uncured prepreg scraps". As of today, and most likely until the end of the project, the drone will remain in a prototype phase, implying that no modification to the current employee base will be made. However, in the short to medium term after the project completion a continued collaboration will bring opportunity to have this KPI as reality.
- Share best practices and the requalification process of carbon fibre with other industry stakeholders who could benefit from this knowledge and capability to close their own value chains. This shared knowledge will contribute to a more sustainable sector, enabling the commoditization of not only traditional commodities but also waste, scraps, and currently unusable materials.

Additionally, to further improve the value chain for this material there is a large market that can be addressed, tackling the recycling of cured carbon fibre. While some carbon fibre artifacts, such as aircraft and boats, have a long lifespan, others, like racing cars, have shorter life cycles. As a result, many carbon fibre parts ultimately end up in landfill at the end of their life. Finding new ways for repurposing or transforming these EoL parts would further improve the value chain of carbon fibre materials. Incentives could be provided in such a way that organizations could prioritize such activities in other projects like Plooto.

4 WEEE for Magnets – Deep Dive, Final Findings and Expected Scenario

In this section the final outcomes of the Framework for Circular Value Chains for the WEEE for Magnets are presented, as well as information about the overall pilot activity. The most relevant changes to what was presented in the first deliverable about this pilot are:

- a brief update of magnet' types included in the project and what discovered so far by the pilot
- an update of the pilot's flowchart impacting the "Transformation process" description in the "Transportation Stage" of the FCVC
- new challenges that emerged in between M10 and M24
- other minor updates.

4.1 New information and changes between M10 and M24

Magnets specifications

After a careful analysis of the capabilities and transformation capacity of the companies involved in the pilot and what's available on the market in terms of magnets from scraps, the following actions have been taken:

- The types of magnets that will be treated are identified as bonded neodymium magnets, bonded ferrite magnets or sintered ferrite magnets, all based on the types of devices or appliances that Ferimet will have at its premises.
- In the previous deliverable it was mentioned that magnets were primarily coming from washing machines, however the first effective batch of magnets originated from microwaves, supporting the principle that this is a circular process envisioning the recycling of magnets from any type of EEE device.
- As a research laboratory, IMDEA has a reduced processing capacity, therefore what will be feasible to treat is 100g per day for sintered magnets and 500g-1kg for bonded magnets. This has a strong impact on one of the KPIs proposed and on already practical suggestions to further improve the value chain after the project completion.
- At the current stage the pilot has dealt only with sintered ferrite magnets, as they are the most common available on the market. However, in case IMDEA starts receiving also bonded magnets, these will be treated as well.
- Additionally, the pilot has not yet encountered coated magnets. Therefore, at this stage, the processes related to coating removal from the magnets are theoretical and will only be applied if the pilot receives such types of magnets.

Flowchart Changes Impacting the Transformation Process

The new version of the flowchart (Figure 7) is more clearly showcasing the relationship between the different steps that the magnet needs to undergo to be reduced into effectively reusable powder as first requirements. This has also changed the role of the flash milling activity to further reduce the particle size of the powder before the extrusion. Clearly, this process also takes into account the eventual "sand blasting" step needed in case IMDEA sources coated magnets from Ferimet.

In addition, the magnet fabrication block of processes has undergone significant updates, focusing on improving efficiency and clarity. The steps now highlight the integration of plastic material mixing, magnet breaking, and the injection process as critical components of the workflow. The magnetization phase has been revised to ensure consistency in quality before proceeding to quality assurance, where defective outputs are redirected back for refinement. These enhancements emphasize a structured and iterative process to achieve high standards in the final magnet products.

Overall, the new flowchart details step by step the full extraction-transformation-remanufacturing process (during the whole value network), while also reflecting these important refinements in the magnet fabrication phase.

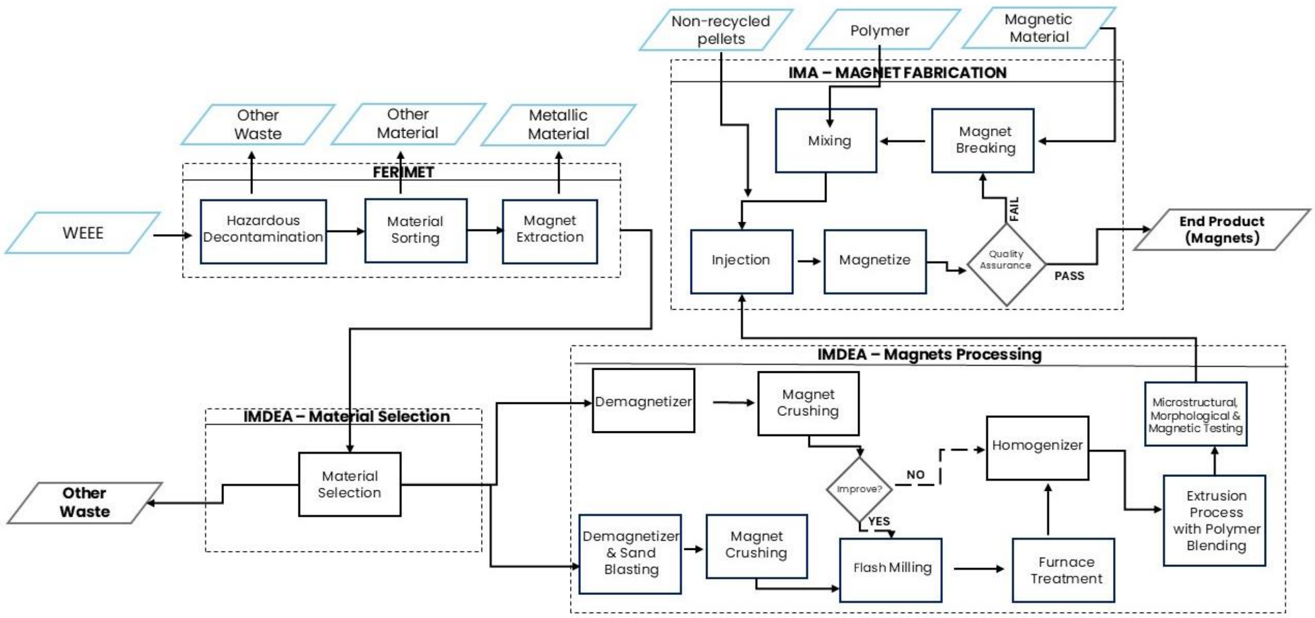

Figure 7. WEEE for Magnets Processes Flowchart - Updated

Challenges emerged between M10-M24

Two new challenges have emerged in the transformation process stage and are already being under consideration. The first challenge is creating new moulds that reduce scraps generated by the injection process (scraps being the surplus material connecting different magnets created in one mould via a single injection). The second challenge is developing a new process to effectively and efficiently reintroduce these — hopefully reduced — scraps back into the production and injection process, creating a virtuous cycle of recycling scraps multiple times. These challenges aim to further improve pre-Plooto processes and create a more sustainable value chain for the scraps.

Other minor changes

At this stage, the pilot's participants have no plans in asking for an IP right on what has been delivered so far. However, IMA and IMDEA that are already closely collaborating on multiple projects might decide to ask for a joint IP right – with IMA as primary exploiter due to their production capacity – on the new process developed to re-enter scraps from the injection process into the production line. In addition, an updated version of the to-be scenario has been provided with modifications pointing primarily at the form and not at the content.

4.2 FCVC Final Version

As of the moment of the submission of the deliverable, M24 of the project, there are no signs of strong and visible variation on the new version of the Framework for Circular Value Chain for the WEEE for Magnets pilot. Below the full and final FCVC for this pilot is presented. The FCVC has also been refined to correct typos, erroneous punctuation, and other types of errors.

Waste Sourcing and Handling

- **Input industry**: Primarily household appliances but also automotive, electronic devices, telecommunication, and medical devices (based on the WEEE waste available at Ferimet's premises). Magnets treated: Bonded Neodymium or Ferrite or Sintered Ferrite magnets.
- **Origin of the waste**: Spain (mostly Barcelona region) – Green points in Cataluña.
- **Waste volume:** Depending on Ferimet's availability of WEEE to be dismantled and the overall capacity of IMDEA to treat different types of magnets (for Sintered magnets currently capability is 100g per day, for Bonded magnets is 500g-1kg per day).
- **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 magnet.
- **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:** First batch of magnets from microwaves but extraction of magnets for the project purpose can be done from any type of electric and electronic waste.
- **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 8. Final Input Stage of the WEEE for Magnets FCVC

Transformation Process and Special Equipment

- **Transformation process**
  - ***Sorting***. Magnets need to be sorted according composition and isotropic or anisotropic characteristics (IMDEA).
  - ***Demagnetisation***. Magnets are demagnetised (thermal demagnetization) before being crushed (IMDEA).
  - (***Uncoating***). This process applies only to sintered Sr-ferrite magnets that require the removal of the coating via sandblasting (IMDEA).
  - ***Crushing***. Magnets are crushed to create powders (IMDEA) – max weight of magnets per weeks 2kg (based on specific magnet types).
  - ***Milling*** (sintered magnets only). Sintered magnets are further processes to decrease the particle size (average size 1mm).
  - ***Annealing***. The milled powders are annealed to get the right phase of the magnet.
  - ***Extrusion***. The powders are mixed with polymers to obtain pellets and the pellets (IMDEA) are passed to IMA for the following steps.
  - ***Injection***. Crushed bonded magnets and added polymers are injected to produce new magnets (IMA).
  - ***Scraps reuse.*** With the creation of the new mould and the new process, IMA expects to be re-entering into the production cycles scraps form the injection process.
  - ***Magnetisation***. The magnets injected are now magnetised (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 moulds; (3) Equipment to demagnetise and magnetise; (4) Quality control equipment (e.g., magnetisation, 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 characterisation) 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***: Provides magnets in pallets with specification around chemical composition of the pallet and weight of the pallet.
  - ***IMA***: Produces 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 the different types of magnets by composition (NdFeb or Sr-ferrite); (2) Sort for magnets by characteristic (isomagnet or anisomagnet); (3) Remove coating from the magnet surface before processing (for sintered Sr-ferrite magnets the coating can heavily contaminate the magnet with impurities decreasing magnetic properties) – so far, the pilot has not received coated magnets yet, so this can be seen as potential challenge and not a real one.

  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 (possible challenge but expectations are that this will not happen); (3) Sr-Ferrite bonded 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; (4) Produce a new mould that allow less scraps creation (Bonded Ferrite); (5) Reprocess the scraps created when producing Bonded Ferrite magnets.

Figure 9. Final Transformation Stage of the WEEE for Magnets FCVC

Final Productions and Distribution

- **Output:** IMA to produce new bonded 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, defence).
- **Target markets (geographies)**: Worldwide except those prohibited by the European Commission.
- **Target markets (company size/users)**: Medium and large companies.

Data

- **Data categories:** IMA needs to provide buyer with 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 (CSR); (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 10. Final Output Stage of the WEEE for Magnets FCVC

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 standardised 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 and better tools (e.g., moulds).
- 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 optimised 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 countries 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. With the support of Eurecat, the company expects to design how robots could help in the extraction of magnets in the dismantling process followed by Ferimet. Second company impacted is IMDEA, that within Plooto expects to understand how to better process the limited number of magnets (max 2 kgs of magnets per week, with weight variability according to the magnets' type) 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, the company is expecting to use self-develop methods for processing the materials, such as flash milling to process sintered Sr-ferrite magnets and casting-based polymerisation of the materials to prepare the bonded magnets. IMA is expecting the optimisation of proprietary production processes and is developing new moulds to improve the overall production process, reducing scraps produced. Looking at the broader impact scenario, IMA and IMDEA expects to improve their carbon footprint and saving costs (across multiple dimensions, e.g., optimisation, energy reduction).

IP Rights

- **IP rights and owner(s)**: No specific IP right will be requested. However, after the end of the project there could be the chance for a IPR discussion between IMA and IMDEA as a new process has been studied.
- **Beneficiary(ies)**: NA.

Figure 11. Final Value Creation Approach of the WEEE for Magnets FCVC

4.3 Final Expected Scenario and Recommendations for the WEEE for Magnets Pilot

For this pilot, no major changes have been made to the definition of the expected scenario, aside from some refinement in the role of EUT activities in support of Ferimet, the explication of the processing capacity available for IMDEA and the expected outcomes of the Plooto intervention on a part of IMA processes and tools.
The expected scenario reads as follows:

The objective of this pilot is to refine the overall process with minor adjustments. With the support of Eurecat, the company expects to design how robots could help in the extraction of magnets in the dismantling process followed by Ferimet. Second company impacted is IMDEA, that within Plooto expects to understand how to better process the limited number of magnets (max 2 kgs of magnets per week, with weight variability according to the magnets' type) 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, the company is expecting to use self-develop methods for processing the materials, such as flash milling to process sintered Sr-ferrite magnets and casting-based polymerisation of the materials to prepare the bonded magnets. IMA is expecting the optimisation of proprietary production processes and is developing new moulds to improve the overall production process, reducing scraps produced. Looking at the broader impact scenario, IMA and IMDEA expects to improve their carbon footprint and saving costs (across multiple dimensions, e.g., optimisation, energy reduction).

With Plooto's intervention, the companies within the pilot will initiate a groundbreaking activity on a small scale. The remanufacturing of EoL magnets (and other rare earth or critical materials) has long been neglected. Providing the necessary knowledge and competencies for this activity will be a critical step forward. As highlighted already, the small processing capacity provided by IMDEA will limit the scalability of this pilot, but solution to this can be easily identified.

After the project completion, the pilot could do to the following further boost the value chain:

- Implementing a more automated process for magnet identification and extraction that will significantly expand the market, not only for Ferimet in the Cataluña region but also by sharing knowledge and best practices across various green points in Europe.
- The main scalability problem of this pilot is the limited capacity of magnets that IMDA can treat per day (100g per day for sintered magnets and 500g-1kg for bonded magnets). Over a year, excluding an average of 14 public holidays, weekends, and a possible the organization's shutdown for paid time off, this amounts to roughly 22.5 kg of sintered magnets and 112.5-225 kg of bonded magnets. This is a limited capacity, that can be easily overcome with IMA taking on the responsibility also of the initial part of the magnet's treatment – from sorting to extrusion – or "outsourcing" the process to another manufacturing company.

- Similarly, it is important to note that the IMA-IMDEA collaboration existed prior to the Plooto project, demonstrating the synergies between the two companies. In this context, the partners are already discussing a potential joint intellectual property right request for aspects of the optimization process, particularly the optimized mould for magnet production and the reintroduction of injection scraps into the manufacturing process.
- Looking at the process itself, it is also possible to study new solutions to improve the production process, for instance the polymers used in the extrusion phase. With the advent of nanomaterials and the computing capability opened by AI, the exploration and testing of new polymers has accelerated, opening new opportunities for quality improvements but also material optimization.
- Sharing the knowledge and best practices discovered with other European producers to re-enter EoL magnets into the production cycle could benefit the broader community, reducing the dependency (highlighted already in D1.1 "Plooto Methodological Approach and Business Case Specifications V1") from external economies for rare earth or critical materials.

5 Citrus Processing Waste for Juice By-products – Deep Dive, Final Findings and Expected Scenario

In this section the final outcomes of the Framework for Circular Value Chains for the Citrus Processing Waste for Juice By-Products are presented, as well as final information about the overall pilot activity. The most relevant changes to what presented in the first deliverable about this pilot are:

- an update of the pilot's flowchart impacting the "Transformation process" description in the "Transportation Stage" of the FCVC
- new challenges that emerged in between M10 and M24
- a brief update of the final outputs that are produced and the target market reference for such products
- other minor updates.

5.1 New information and changes between M10 and M24

Flowchart Changes Impacting the Transformation Process

The new version of the flowchart (Figure 12) integrates more details around the full transformation processes and the production of wastewater (represented with the blue colour in figure 12). An adjustment has also been made after the "press dewatering" stage, to demonstrate and explain the possible outcomes for the material processed, which are:

1. Enter the liquor phase to obtain high value molasses,
2. Get processed to the dryer and produce citrus pellets,
3. Being directly packaged to create citrus silage – not effectively part of the project.

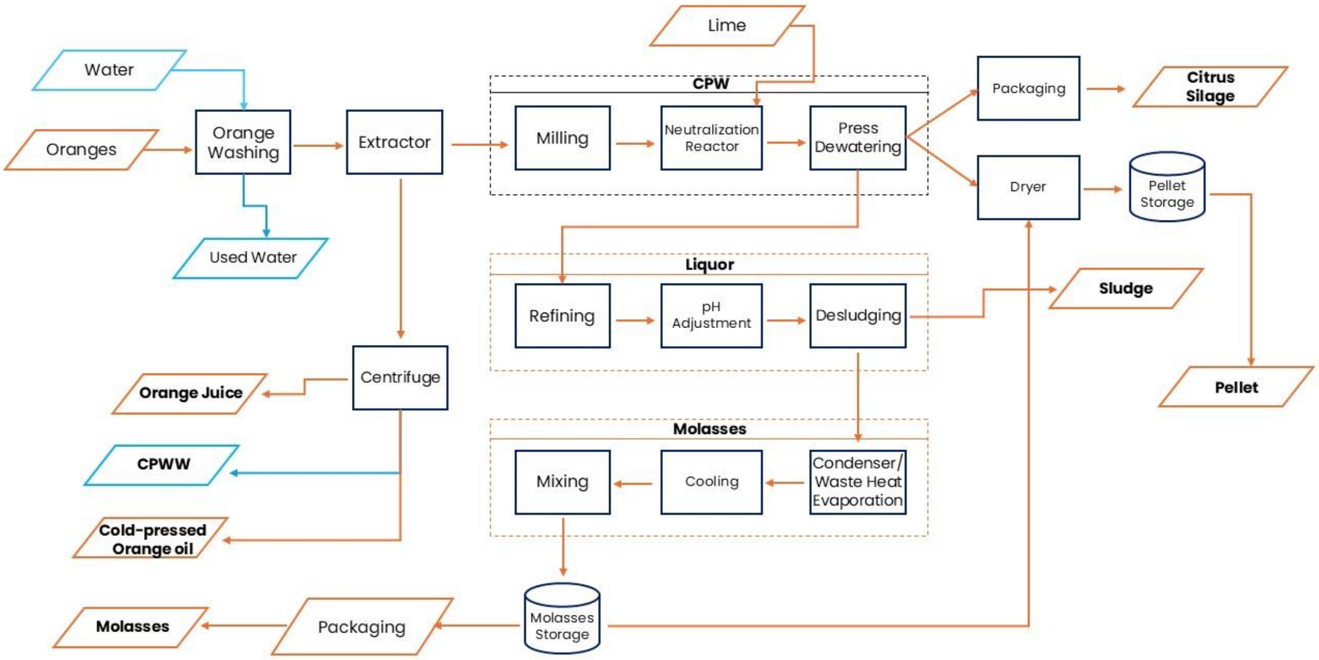

Figure 12. Citrus Processing Waste for Juice By-products Processes Flowchart – Updated

The refinements enhance clarity in presenting the interconnections and decision points within the production workflow. Overall, the new flowcharts detail the entire extraction-transformation-remanufacturing process step by step.

The adjustments in the processes and the more detailed flows have also been incorporated to the transformation process highlighted in the FCVC, for which the most updated version is shown in Figure 14.

Challenges emerged between M10-M24

Two new challenges were identified for the transformation phase. The first challenge is producing cleaner recovery water for reuse in the plant, which involves treating the water used or generated during the process to achieve a cleaner state for re-entry into the production process. The second challenge is reducing the energy consumption during the transformation process, which can be achieved through more precise process mapping and adjustment (e.g., correct temperature, time).

For the output stage, a minor update addresses the difficulties in communicating the higher nutritional value of the cattle feed produced through this process. The challenge lies in developing an effective marketing and communication strategy to support the amplification efforts.

Output specifications

This deliverable provides the final confirmation of the output produced in the pilot, including specifications about the target market and the estimated expected revenue (where available).

- For citrus molasses to be used in the cattle feed industry, the expected target market is the EMEA region (Europe, Middle East and Africa) where Greece could play an important role as a relevant launching pad for the product. ASPIS will be using its own sales and marketing channels, reaching directly customers who are interested in the product, expecting 2 million euros revenue.
- For citrus peel, still to be used for the cattle feed industry, the expected target market is Greece. Similar with the citrus molasses, ASPIS will directly connect with the customers.
- Citrus essential oil is a more precious product compared to the previous two; Aspis is planning to leverage its own sales channels to reach customers not only in Europe but also worldwide.

In addition to the output that can be directly monetized via sales channels and the offering of the products to the market, ASPIS is also seeking to obtain cleaner water (after the production process) to be re-entered into new productions.

Other output that APSIS is seeking, however not within the Plooto project scope, biogas energy production, connected to the investment in the biogas plan (mentioned in the following paragraph 5.3). ASPIS is expecting to cover part of its own energy needs and sell on the Greek market the energy produced.

Other minor changes

- As mentioned in chapter 6, APSIS is working with Plooto's analytics team to assess the possibility to collect data in real-time, easing the quality and control procedures but also to have more precise information and data to be added to the DPP.
- Development of advanced algorithms for detection of anomalies in production.
- As the overall Plooto intervention won't be concerning the creation of new processes but only adjustments on existing ones, there are no needs to request for intellectual property rights.
- The optimization activity won't be carried out for this specific pilot, as the process is already optimized. What will be required are refinements in the activities and in the support for analytics.

5.2 FCVC Final Version

As of the moment of the submission of the deliverable, M24 of the project, there are no visible future variations on the new version of the Framework for Circular Value Chain for the Citrus Processing Waste for Juice By-Products pilot. Some updates have been made to better reflect the new flowchart provided by TUC, which were highlighted in the section above. The FCVC has also been refined to correct typos, erroneous punctuation, and other types of errors.

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 – only one company involved in the full pilot from a purely manufacturing and transformation perspective.

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 also based on analytics and optimisation activities.

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 13. Final Input Stage of the Citrus Processing Waste for Juice By-products FCVC

Transformation Process and Special Equipment

- **Transformation process:**

For *Citrus silage*:

Extraction: The emulsion of water and oil is centrifuged to separate the water from the oil
Milling. Pulp and peel from oranges are trimmed into a fluid.
Neutralization: Lime is added to the milled fluid to adjust the pH.
Press *Dewatering*: Via mechanical press the fluid is separated from water.
Packaging: the material obtained is packaged to deliver citrus silage.

For *Pellet*: (after the press dewatering the material goes though):

Drying: the material is dried to create pellet that are stored before commercialization.

For *CPWW – Citrus Peel Wastewater and cold-pressed orange oil*: after the extraction the material is passed to

Centrifuge: that separated the orange juice, from the CPWW to the cold-presses orange oil.

For *Sludge:* (after the press dewatering stage, the material is subjected to other processing steps).

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 *Molasses*: (after the desludging, the residual watery waste enters)

Condensation: The water vapor obtained in the first condensation process is further condensed.
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.
Packaging: the molasses are packaged for the market.

- **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 datacentre 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; (3) Produce a cleaner recovery water to be reused in the plant; (4) Reduce the energy usage with precise process modifications.

Figure 14. Final Transformation Stage of the Citrus Processing Waste for Juice By-products FCVC

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 communicating the higher quality and benefits of the product coming from vegetable waste (e.g., proper marketing and communications campaigns).
- **Relevance of Product Passport**: 4 on a scale of 5.

Figure 15. Final Output Stage of the Citrus Processing Waste for Juice By-products FCVC

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.
- Organisations 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. 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)**: NA.
- **Beneficiary(ies)**: NA.

Figure 16. Final Value Creation Approach of the Citrus Processing Waste for Juice By-products FCVC

5.3 Final Expected Scenario and Recommendations

For this pilot, the main change made is the adaptation to reflect the fact that this pilot won't go through the optimization activity, and corresponding updates have been made to the definition of the expected scenario, that now reads as follows:

The primary objective of this pilot is to refine the transformation process of by-products to produce cattle feed. 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.

The interventions studied by the project aim to improve the circularity approach of the organization involved, closing the loop in the production of relevant and multiple by-products, while concurrently minimizing the high energy demands. Additionally, it also supports the recovery of water that is used during the production process or that is created during the process itself – e.g., wastewater from centrifuge or condensation. This is also expected to bring relevant monetary benefits to the organization, in terms of savings and revenues created.

After the project completion, the pilot could do to the following further boost the value chain:

- As the orange juice production is not the only product generated by ASPIS, the company could study similar valorisation of value chain processes also for other waste coming from fruit and vegetables. These new products could be integrated as additional nutritional value into the cattle feed but also could be redirected into other feed products.
- Reducing the energy consumption and water usage (as well as improving capabilities to treat water, cleaning it to re-introduce it into the production line). The valorisation of these precious asset has never been more relevant.
- As mentioned above, the organization can explore how waste from other production processes can provide benefits beyond the cattle feed industry (e.g., for fish). Additionally, waste can be utilized in the pharmaceutical or chemical industries (e.g., grape waste is often used in skincare beauty products due to its high antioxidant levels). This can be achieved by partnering with companies in these industries and selling them these by-products or waste.
- Enter the effective leftover from any type of production to create energy through waste-to-energy processes via a number of options available.

Last but not least, despite the fact that the project is not over yet, ASPIS is already looking forward, considering investments around a biogas facility to reduce the load of the waste stream and to use this waste to produce green energy. This is outside Plooto's scope and a world state project at a massive size with a mission to cover one third of APSIS energy needs.

6 Deep Dive on Digital Product Passport, Data and KPIs

Starting from the concept that the Framework for Circular Value Chains remain as presented in the first edition of this series of two deliverables, the changes over time and the maturation of the overall process pertain to the information and details around specific parts of the FCVC and other collateral components or information of the framework. These include the DPP, the availability and use of data, and a deeper understanding of the KPIs that will be deployed by each pilot.

A deep dive on these three topics is discussed in this chapter to extend the work presented in the FCVC, as supplementary information for the reader. This information presented below is not included in the FCVC in detail, but it is essential to have a full picture of other project's parts, included in other deliverables of this project.

Data

Data is crucial for ensuring that processes can be mapped easily and promptly, supporting analytics and optimization activities, as well as additional services available to pilots to meet sustainability requirements (e.g., identifying optimal processes to reduce energy consumption, on-line LCA to evaluate environmental impacts, help in detection of anomalies). It also aids in designing and delivering optimal digital twin mapping processes, detailing material and digital flows. Similarly, data spaces will help organizations achieve their goals and objectives within the broader ecosystem of partners and competitors by enabling secure and trustworthy data exchange.

Each pilot is showcasing different requirements of data and information that needs to be shared across partners, highlighting specificities and the need for dedicated steps.

CFRP waste for drones

- Process data. As already mentioned in the previous deliverable, process data entails sharing data and insights around how the material has been processed and stored. With the new requalification process studied by CETMA, also process data around the requalification process needs to be delivered to showcase how the waste has been treated. At this stage, the requalification process has been studied for two types of carbon fibre materials, providing an initial set of usable material.
- Product-related data. For this "Italian pilot", ACCELI – the company producing and assembling drones – needs to share with CC – the company producing the carbon fibre parts for drones – information and insights around the technical and mechanical properties of the materials, as well as the geometry and measures of the final parts that need to be produced.
- Materials data. Materials data for the CFRP pilots is the exchange of information pertaining to thermal and rheological properties (e.g., viscosity as function of the temperature),

mechanical properties (e.g., ILSS), and deviation of waste properties from the original material. With the creation of a new requalification process, also information on the requalified material needs to be shared and validated against the properties' requirements from the drones' producers (ACCELI) as well from the parts for drones producers (CC).

- Supply chain data. For this pilot, supply chain data entails information about the origin of the CFRP prepreg rolls and how after the expiration date or the cutting phase – sourced by HPC – these materials move from one actor to the other, completing the information provided by process and materials data. Important in these types of data is the provisioning of information around the sustainability of the procurement, information related to RFPs and services. Changes in the supply chain also affect the data flow. A new supply chain approach has been studied, where HPC sends only material samples to CETMA for requalification, not the full batch, impacting subsequent steps in how CC receives the material.

WEEE for magnets

- Product-related data. IMA, as the company in charge of the creation of the new magnets needs to provide specific information around the quality of the SRMs expected from the requalification process carried out by IMDEA. On top of the overall qualitative and quantitative properties of the material, there might also be specific insights requested by the final customer – though rarely impacting the magnets powder and pellet production rather more the injection step of the final product.
- Materials data. Information around the original source of the magnets can be a relevant asset for IMDEA and IMA, especially to define the original quality of the recycled magnets. Experts in the field know that magnets sourced externally to the European Union – especially from China – have a lower quality due to the initial lower quality of the material used. The understanding of this will clearly impact also the reintroduction of this material in the production process.

Citrus processing waste for juice by-products

The pilot, supported by the analytics activities, is studying and evaluating the possibility to collect historical and real-time data that support the creation of the DPP.

- Process data. Process data is relevant for this pilot, not to be shared with other partners, but for the minimization of the energy consumption of the full transformation process of the oranges, as well as for the more efficient production of the juice products and by-products.
- Product-related data. Product related data is clearly a requirement from the different ASPIS customers, who purchase from the company molasses for the cattle feed industry and d-Limonene for the cosmetics industry – just to name a few. This information is

extremely relevant due to the stringent regulations that these industries have to comply with, to secure consumer protection.

- Materials data. This type of data is critical in this case, in order to maintain higher quality products up to industry standards, requiring quality checks and assessments.

Digital Product Passport (DPP)

As outlined in D1.3 “Sustainability Balance Scorecard Framework v1,” the customer or the last company in the value chain will have access to a product passport. This passport will encompass information from the various product passports produced at each step and by each company involved in the process, similar to a matryoshka doll. In this way, the customer will be able to trace back information and data related to each process step, effectively providing insights for closing the value chain. An example of a DDP is presented in Figure 17, that specifically represents the WEEE for Magnets DDP structure. All other pilots will present a similar structure.

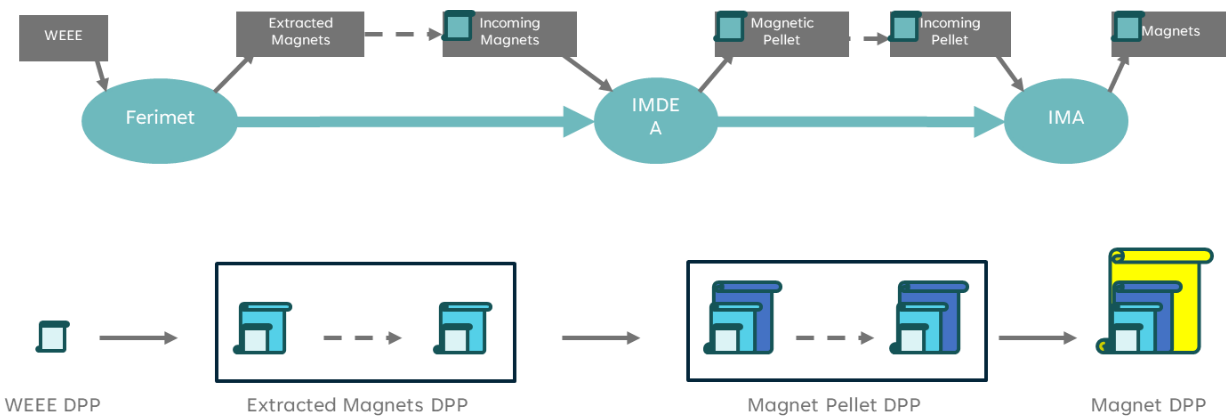

Figure 17. Example of Digital Product Passport aggregation for the WEEE for Magnets pilot

Therefore, at each stage the DPP will increase its relevance, and the number of information points integrated, creating a single and comprehensive document. Below some highlights about the DPPs of the three pilots. More information about the DPP available in D3.1 "Product Passport and Certification Tool V1", while for specific parameters and related metrics/and units for measurement please refer to deliverable D3.5 "Plooto Balanced Scorecard V1".

CFRP waste for drones

The DPP of the Italian pilot will include information from two out of four companies in the pilot (HPC and CETMA).

At the end of the full process, the CFRP waste for drones pilot's DPP will include the following information[1] :

[1] The look and feel presented does not represent the final look and feel of the DPP but is presented in this way to simplify the understanding of the information and data shown in the DPP.

Table 1. Information displayed in the DPP by company - Italian Pilot

Company	Info displayed	Parameter(s)
HPC	Material information as per original characteristics	Material identified code, LOT number, Expiry date, Process window parameters (time, pressure, and temperature)
	Type of material that has been used for requalification	Scrap/expired prepreg roll, Weight
CC	DPP originated from HPE, plus:	
	Production information	Production date, Production mode, Process window parameters (time, pressure, and temperature)
	Quality control	Visual inspection data (void content, thickness measurement)
	Requalification material[2]	% of the required material

As presented in the FCVC for the Italian pilot, the relevance of the DPP will be around 3/4 over a scale of 5 (info available in Figure 5). The DPP will be crucial in demonstrating the sustainability strategy of reusing expired prepreg rolls and carbon fibre scraps. It will support two manufacturing companies that generate waste material to be converted into SRM (HPC) and the company that manufactures drone parts using the requalified SRM (CC).

WEEE for magnets

For the Spanish pilots, the final DPP will include information from the three different companies involved in the magnets recycling process.

At the end of the full process, the WEEE for Magnets pilot's DPP will include the following information[3]:

Table 2. Information displayed in the DPP by company - Spanish Pilot

Company	Info displayed	Parameter(s)
Ferimet	Source of the magnet	WEEE category, Origin of the magnet, Region of the WEEE
	Physical properties and magnitudes	Quantity
IMDEA	DPP originated from Ferimet, plus:	
	Material Safety Data sheet (MSDS)	Material name, Polymer base, Magnetic powder and properties, Material density, Maximum temperature, PPE, Temperature to decompose
	Data Sheet	Required drying time, Pre-drying temperature, Maximum temperature, Temperature to Decompose, Temperatures for each injection zone,

[2] This information should be valorised by CC, knowing the percentage of the virgin material eventually used in the production.

[3] The look and feel presented does not represent the final look and feel of the DPP but is presented in this way to simplify the understanding of the information and data shown in the DPP.

Company	Info displayed	Parameter(s)
		Temperature nozzle, Required time for each injection zone, Required time wait before open the mould
	IMDEA sustainability data	% wt of recycled material, Quantity
IMA	DPP originated from IMDEA (including Ferimet's DPP), plus:	
	Material certificate	Dimensional values, Weight, Magnetic properties, Material Control, Magnetic Force, Coating thickness, Coating composition
	IMA sustainability data	Informative message, % wt of recycled material, Information for future recycling activities

As presented in the FCVC for the Spanish pilot, the relevance of the DPP for IMA in the final stage will be around 5 over a scale of 5 (see Figure 10). The DPP will not only play a pivotal role in showcasing the sustainability approach taken in the production of magnets, but also in presenting to the buyer the magnets' relevant information about the product in one single place, integrating multiple documents (e.g., MSDS from the pellets producer – IMDEA in this case). In having all the needed information in one single hub, the buyer can accelerate the time to sourcing as well as can easily integrate this information into its own DPP in case is needed (e.g., a manufacturing company in the automotive industry buying magnets to be assembled for brakes production).

Citrus processing waste for juice by-products

The DPP of the Greek pilot will display information uniquely from ASPIS, as the only manufacturing company involved in the pilot. The DPP will be specifically created for the molasses used for the production of cattle feed. This DPP will showcase information[4] around:

Table 3. Information displayed in the DPP by company - Greek Pilot

Company	Info displayed	Parameter(s)
ASPIS	Nutritional analyses	Chemical components (e.g., calcium, nitrogen, potassium), pH
	Specifications	Physical and chemical specification (e.g., polarization value, reducing sugars, colour), Microbiological specifications (e.g., yeast, moulds, aerobic plate count)
	Environmental impact (LCA – life cycle assessment)	Values for the LCA analysis in accordance with ISO 14040 series of guidelines (e.g., fossil depletion, freshwater consumption, ionizing radiation)

As presented in the FCVC for the Greek pilot, the relevance of the DPP for ASPIS in the final stage will be 4 over a scale of 5 (info available also in Figure 15). The DPP will not only play a pivotal role in showcasing the sustainability approach taken for the production of the molasses (minimization of energy requirements), but also the superior chemical and biological quality and nutritional

[4] Ibidem.

properties that organic and naturally sourced materials for the production of cattle feed have. This will be a strong selling point for ASPIS.

Key Performance Indicators (KPIs)

KPIs are crucial for assessing the progression of the pilots' activities towards the expected results. It is important to note that, at this stage — approximately two-thirds into the project — for some pilots, it is not yet possible to assess the status of some specific KPIs, due to the nature of the underlying processes involved.

For the **CFRP for drones pilot**, due to the complexity of the requalification process and the required time to performance – time from the production to usage and effective duration of the parts – it is early stage to assess most of the KPIs. In addition, some of the predetermined KPIs were positioned as aspirational, looking also outside the project time boundaries. It is expected to have more details in one of the last deliverables pertaining to the assessment of the work carried out in this pilot.

Table 4. Production-related KPI list with expected and current parameters measured - Italian Pilot

KPIs	Pre-project assessment	Post-Plooto project expected impact	Current measurement	DoA KPI
Prepreg shelf life	6 months	12 months	12 months	Yes
Reduce prepreg disposal in HP	30 tons/year	10 tons/year	NA	Yes
Increase the value of uncured prepreg scraps for HP	-300€/ton	+300€/ton	NA	
New jobs in partner facilities related to exploiting uncured prepreg scraps	0	5	NA	Yes
Unused CFRP waste in the production of composite material	Not currently measured	At least 20% of reduction of the existing CFRP waste	NA	Yes
Reuse of material to produce components for droned (% of material reused)	Not currently measured	To be determined based on the parts that will be identified to be produced	NA	No

Regarding the KPI "new jobs in partner facilities related to exploiting uncured prepreg scraps," this will be assessed after the completion of the Plooto project. The pilot expects to effectively implement the new processes and strengthen collaboration after the end of the project – due to the already mentioned complexities derived by the long time for study and requalification -, thereby opening new revenue streams through the production of drones using CFRP waste. This will open the opportunity to create new jobs in the partners' facilities.

At the current development state, ACCELI hasn't identified yet the exact parts that will be produced with requalified CFRP waste as the drone is still a prototype, therefore the "reuse of material to produce components for droned" KPIs cannot be quantified yet.

For the **WEEE for Magnets pilot**, some challenges have been highlighted in the current assessment of the KPIs due to the early stage and the limited transformation capacity currently in place at IMDEA. There will be most likely some rework in terms of the expected outcomes that will be communicated at a later stage.

Table 5. Production-related KPI list with expected and current parameters measured - Spanish Pilot

KPIs	Pre-project assessment	Post-Plooto project expected impact	Current measurement	DoA KPI
Reduction of WEEE landfilled (for the bonded material part)	24,8 tons/year	16,12 tons/year	NA	Yes
Usage of SRM (bonded NdFeb, Sr-Ferrite) in PM magnet's pellets' production origin (%)	Not currently measured	At least 30% increase	NA	Yes
Number of types of validated materials	0	3	NA	Yes
Recycling from leftovers and disregarded magnets (%)	60%	At least 75%	NA	Yes
Increase the usage of Sr-ferrite crushed pellets in magnets production	Currently 50%+ is scrap	40% or less to scrap	NA	No

The KPI "Reduction of WEEE landfilled," initially deemed feasible, is now considered too ambitious to achieve with the current pilot setup, especially given IMDEA's limited processing capacity (100g per day for sintered magnets and 500-1000g per day for bonded magnets). Achieving this KPI is only possible if the process is outsourced from a research laboratory (IMDEA) to an effective manufacturing company, such as IMA or a company outside the project's scope.

With the last KPI "Increase the usage of Sr-ferrite crushed pellets in magnets production" is expected to see a reduction in the final scrap created during the injection process. The injection process involves injecting material into a mould to create specific magnet shapes. However, these moulds are currently inefficient, resulting in over 50% of the injected material being labelled as scrap. With the optimization process results, IMA expects to develop new moulds that will reduce scrap creation to less than 40%. Additionally, the broader pilot aims to generate a new process to reintroduce the hopefully reduced scraps back into production for re-injection, enabling multiple recycling cycles.

For the **Citrus processing waste for juice by-products pilot** measurements of the KPIs originally identified are already in place, especially for the KPIs expressed in the DoA. For the two new KPIs discussed during the preparatory work of D1.1, the pilot is not able to measure them yet, as they are strictly related to the analytics activities that are currently in place.

At the current stage of maturity, assessed around M22-M24, this is the list of agreed KPIs, with indication around the impact assessment.

Table 6. Production-related KPI list with expected and current parameters measured - Greek Pilot

KPIs	Pre-project assessment	Post-Plooto project expected impact	Current measurement	DoA KPI
Production of animal feed	10,000-15,000 tons	At least 20,000 tons after project lifetime	15,000 tons	Yes
Production of high-quality molasses	2,000-2,500 tons	3,000-3,500 tons after project lifetime	2,000 tons	Yes
Production of d-Limonene	0.5-1.5 tons	At least 2 tons withing project lifetime	1.0 ton	
Volume of CPWW	150,000-250,000 tons	At least 10% decrease	200,000 tons	Yes
COD of CPWW	10,000	At most 2,000	10.000	Yes
Volume of CPWW that goes to biological treatment	100% (after 1+ cycle)	At least 40% decrease	100%	No
Revenues from animal feed	1 million (€)	2 million (€)	0.7 MIO Euros	Yes
Improve energy savings	NA	NA	NA	No
Improve cost savings	NA	NA	NA	No

Conclusions

This is the last deliverable in charge of T1.1, showcasing the final framework for circular value chain for the three pilots involved in the project.

Each pilot has its own strengths that have been identified and leveraged to succeed in the development of requalification (for the Italian pilot), remanufacturing (for the Spanish pilot), or reprocessing (for the Greek pilot). The existing and newly acquired knowledge will be crucial for these organizations, and hopefully for other European organizations through dissemination and education activities. This will help strengthen Europe's position in closing the value chain of existing products and enhance its commercial standing by reducing the need to source materials, components, and final products from non-European countries, where applicable.

Additionally, the challenges identified by the pilots in the two periods of analysis (in between M1 and M10, and then M10-M24) were crucial for addressing issues that required immediate attention — such as optimizing production processes — and those that could be deferred to a later stage — such as developing an effective marketing and communication strategy to convey the benefits of a specific product derived from a particular production process.

Expected benefits are invaluable. As stated in D1.1 "Plooto Methodological Approach and Business Case Specifications V1", McKinsey estimated that the transition to practice of the EU Circular Economy Action plan[5] could yield up to €1.8 trillion in benefits by 2030[6]. According to IDC, this is visible also in the point that sustainability is a strategic priority for 96% of European organisations, but it's so far highly complicated to implement effectively and efficiently these practices from organisations alone, as only 45% of them have implemented these practices[7].

This deliverable identifies for each pilot further actions that could be taken after project's completion to further strengthen their own value chain and sustainability strategies as pre-identified pool of companies, or on their own via the promotion of benefits to other organisations, but this is not enough.

For this reason, the intervention, across multiple levels and with different programs, of European regulatory and non-regulatory bodies, is critical to provide rules and guidelines for implementing practices, as well as incentives and funds supporting organisations in initiating or continuing sustainable actions and activities. Interventions also at lower level, from National and Local authorities can play a pivotal role.

When considering the involvement of national and international regulators and bodies, various types of monetary and fiscal incentives can be provided to companies that are actively

[5] https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en
[6] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[7] IDC Global Sustainability Readiness Index (Europe n=718, August 2023)

participating in closing the value chain. These incentives are designed to encourage and support companies' efforts to enhance the efficiency and sustainability of the value chain.

National and international regulatory bodies, along with various industries, share the responsibility of establishing public awareness and educational campaigns. These efforts may include creating advertisements and offering price incentives to encourage consumer support and sustain these initiatives. This approach helps the general public understand and endorse the recycling and remanufacturing focused market.