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DigInTraCE

DigInTraCE

DIGITAL VALUE CHAIN INTEGRATION TRACEABILITY FRAMEWORK FOR PROCESS INDUSTRIES FOR CIRCULARITY AND LOW EMISSIONS BY WASTE REDUCTION AND USE OF SECONDARY RAW MATERIALS

D6.1

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This project has used a standard methodology already developed in the DigInTraCE project (Grant Agreement number: 101091801), following EU recommendations. Ad hoc modifications were added to comply with the Grant Agreement conditions for DigInTraCE (Grant Agreement number: 101091801)

Executive summary

The DigInTraCE project stands at the forefront of a transformative approach to waste management and sustainability in process industries. The report opens with an Introduction that sets the stage for the DigInTraCE project's objectives, followed by a Mapping Methodology that outlines the systematic approach to waste stream assessment. The general description of DigInTraCE demonstrators provides insights into the innovative valorization strategies employed across four distinct sectors: polyesters, wood, resins, and waste electrical and electronic equipment plastics. A waste stream assessment per demo site analyzes the current practices and proposed optimizations, highlighting the project's impact on enhancing circularity through advanced digital traceability tools. The assessment covers the Belgian, Spanish, Greek, and Italian demonstrators, each contributing unique solutions to the challenges of waste management. The identification of gaps and best practices section follows a dual approach, analyzing demo sites findings and available literature, offering recommendations for bridging the gaps in current processes and adopting best practices for sustainability. This analysis is crucial for understanding the potential of the DigInTraCE project to contribute to industry standards. The document finalizes with a discussion of the state of the art in waste reuse, recycling, and upcycling, examining the regulatory impacts and identifying key actors in the value chains. Overall, it provides an overview of the project's contributions to the field and its alignment with European regulations.

Table of contents

List of Figures

List of Tables

List of abbreviations

Abbreviation	Definition
EU	European Union
WEEE	Waste from electrical and electronic equipment
PET	Polyethylene terephthalate
PF	Phenol-formaldehyde resin
AGRST	AGROINVEST
MXS	MENEXES
CTB	CENTEXBEL
SIOEN	SIOEN Industries
ASTI	Astigarraga
TECNL	Tecnalia
ICCS	Institute of Communication & Computer Systems
WEEE	Waste electrical and electronic equipment
SSP	Solid State Polymerization
NTUA	National Technical University of Athens
CHIMAR	CHIMAR Hellas S.A.
MDF	Medium-density fiberboard
VTT	Technical Research Centre of Finland
KPI	Key performance indicator

1. Introduction

The present report constitutes deliverable D6.1 "*Waste Streams Mapping*" within the framework of the DigInTraCE project. The following activities refer to work package WP6 "*Piloting and Demonstration*" and specifically to the task 6.1 "*Initial assessment (waste streams mapping) and systems design per demo*".

The WP6 is key to assess the current situation of the four demo sites of the DigInTraCE project, operate the proposed solutions to valorize wastes and improve the processes' circularity, establish the fingerprints and markets for recycled material content, implement digital tools for traceability, and finally, evaluate the performance and the impact of all steps for upscaling.

In the context of T6.1, **the main objective of this report is to set a baseline scenario for all value chains related to the demonstrators**. This baseline will help identify and map potential hotspots and key aspects that impact the value chains' sustainability and circularity. To achieve said objectives, the following activities have been carried out:

- Exchange with the demo sites to obtain accurate information on their value chains and byproduct streams.
- Drafting of maps of waste generation and collection points (fractions, content, etc.) in each involved value chain.
- Analysis of transportation data, final treatment, and alignment with EU waste hierarchy.
- Assessment of material efficiency and sorting degrees.
- Identification of gaps and best practices for the involved waste fractions.

This deliverable reports on the results of the above-mentioned activities. Recommendations and a critical analysis support the data gathered from the demo partners, and comparisons between the sectors are also included throughout the report. The next sections will describe the applied methodology for data gathering and mapping, a general description of each demonstrator, an assessment of each waste stream considered in the project, the identification of best practices and gaps, an overall discussion, and conclusions.

2. Mapping methodology

The DigInTraCE project aims at improving the circularity of value chains by implementing both waste valorisation strategies and an interoperable, decentralised traceability platform using advanced tracking, sensing, sorting and optimisation techniques. An inherent challenge of the project is to fully map and understand which kind of data can be obtained depending on the process, instrumentation, and valorisation pathways. As the main objective of T6.1 was to map the waste streams of the current processes – i.e., the *demo sites* – it was essential to gather information from the specific partners that act as supplier or that intermediate the supply of byproducts that will be valorised along the project (see section 3 for a general description of each valorisation pathway proposed). These partners are:

- Belgium demo – CENTEXBEL (post-industrial PET)
- Spanish demo – ASTIGARRAGA and TECNALIA (wood byproducts)
- Greek demo – AGROINVEST / (oilseed cakes) and MENEXES (wood byproducts)
- Italian demo – SIGIT (WEEE plastics)

To obtain a similar dataset from each partner, Table 1 was used to gather information and descriptions of processes and waste streams. From the obtained information, an analysis was jointly built for each demonstrator, showing both the current process and the improvements expected from the new value chains proposed at DigInTraCE. The resulting analysis shown in section 4 of this report. Furthermore, the current status of the innovations proposed in the demonstrators were assessed and compared to the baseline scenario to show improvements in terms of circularity.

Table 1. Data gathering from demo sites partners related to the supply of byproducts to the DigInTraCE demonstrators.

Needed information	Description
By product description	Description of the waste or byproduct stream to be valorised in the DigInTraCE demonstrator.
Annual byproduct production (ton/year)	How many by-products are produced per year?
Byproduct production based on primary raw material (ton/ton)	What is the amount of byproduct produced based on primary raw material?
Water usage (ton/ton)	What is the water usage per ton of raw material processed?
Energy usage (kWh/ton)	What is the energy usage per ton of raw material processed?
Current end of life	What is the current end of life of the waste/byproduct stream?
Collection point(s), transportation method(s) and distance(s)	Please describe at which step(s) of your process this stream is collected and how it is transported to the end of life, and for which distance. If energy is generated from this waste stream, please give an idea of how much is generated.
Pretreatment before end of life (if any)	Besides transportation, is there any pretreatment done to the waste before its end-of-life?
Byproduct main properties	Are any properties of this stream measured? Examples are particle size range, water content, main impurities, elemental composition, etc.

3. General description of DigInTraCE demonstrators

This section presents a preliminary description of each of the valorisation approaches explored in the DigInTraCE project, to serve as a basic description used as input for the mapping of waste streams and identification of challenges and opportunities.

- **Belgium demonstrator – polyesters sector**

  In the framework of DigInTraCE, polyesters (mainly PET) decontamination and upcycling will be evaluated. Post consumer PET recycling will be performed, and the produced recycled polyester will be processed into fibres, targeting particularly high tenacity yarns, which are valuable for technical applications such as roofing elements, conveyor belts, seat belts, membrane structures, among others. Polyester is the most widely used material for textiles, both for clothing and technical applications. Although polyester recycling is already advanced for some applications like bottles, the use of recycled polyester for high demanding textile applications is still limited. In this demo, polyester decontamination and upcycling are tested for end-of-life thermoplastics polyester.

An overview of the demonstrator and the involved partners is shown in Figure 1, with the following responsibilities:

Provision of produced recycled polyester and PET textile production by SIOEN. Processing of polyester will be performed on lab scale by CTB. Value chain mapping by CIRCE. Characterisation of recycled materials by CTB. Supply of secondary raw materials by EREMA (entity not part of the consortium but providing support to it).

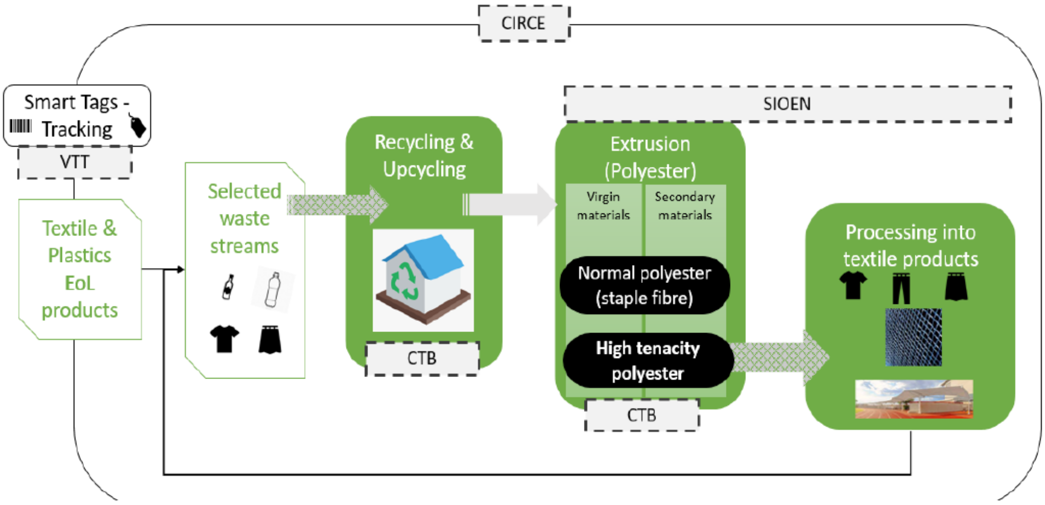

Figure 1. Overview of the Belgian demonstrator flows and partners Source: DoA. Grant Agreement — Horizon Europe DigInTraCE Project 101091801.

- **Spanish demonstrator – wood sector**

  In the framework of this project, wood by-products will be valorised in the manufacture of furniture. Specifically, the wood by-products consist of wood chips and sawdust, both derived from pure material of varied sizes (from original trestles and from furniture manufacturing). These secondary raw materials are free of contamination and impurities, as they come directly from primary processing.

  The goal is to enhance the value of wood-derived by-products through the application of digital technologies. At ASTI's facilities, a variety of by-products can be generated throughout the entire wood processing and furniture manufacturing process. These leftover materials include bark, sawdust, wood chips, wood scraps, sanding dust, and faulty or broken pieces.

  The demonstration aims to use ICCS-developed digital technologies to identify, characterise, quantify, and segregate these categorised by-products. This classification and the data collected will enable the tracking of all materials produced towards the next slab in the furniture value chain and their transition into other sectors such as construction, pulp & paper, and packaging.

  The accurate categorisation of the by-products will facilitate the production of new, value-added products by TECNL, such as high-value wood-based boards, insulation foams, and new wooden surfaces, as depicted in Figure 2. The demonstration's success will ensure the by-products' value retention, keeping the market value per cubic meter (or ton) of the by-products comparable to the current end product.

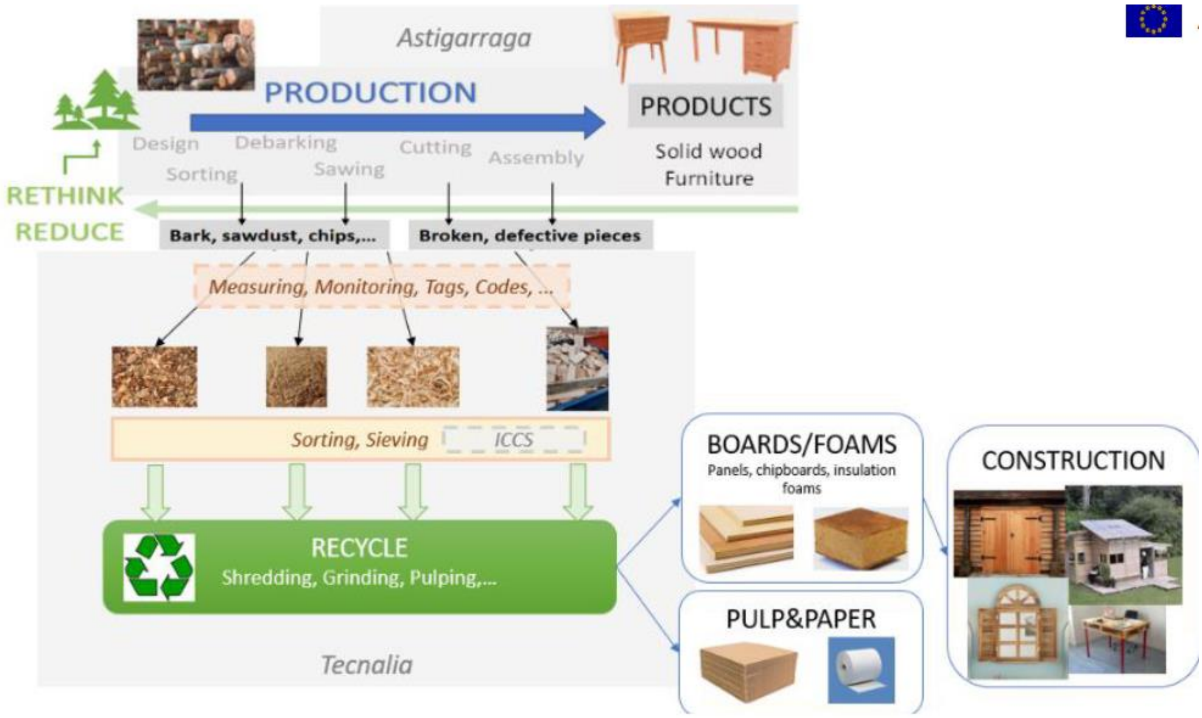

Figure 2. Overview of the Spanish demonstrator flows and partners. Source: DoA. Grant Agreement — Horizon Europe DigInTraCE Project 101091801.

- **Greek demonstrator – resins and wood sectors**

  In the framework of this project, sustainable wood panels will be prepared by incorporating waste streams from agroindustry, namely proteins and wood residues, in their manufacturing processes. In detail, the phenol component in the phenol-formaldehyde (PF) resin (adhesive) extensively used in plywood boards will be partially replaced by proteins extracted from oilseed cakes, which are pressed plant materials left after the production of vegetable oils. The oilseed cakes will be subjected to different extraction methods, targeting the isolation of proteins in high yields, and using green solvents and energy-efficient processes. The incorporation of proteins in the PF resins will be optimized to achieve maximum phenol replacement and the required properties of the final plywood panel. Furthermore, residual wood streams from furniture manufacturing will be subjected to a novel sorting step and the sorted wood will be re-introduced in the value chain to produce particleboards. Finally, methodologies will be developed for smart tags aiming at full traceability of the processes and the setup of a data management and storage to support end-of-life management and increase the overall sustainability and waste valorisation.

An overview of the demonstrator and the involved partners is shown in Figure 3, with the following responsibilities:

Biomass-derived byproducts supply (oilseed cakes and wood residues, respectively) by AGRST, MXS. Byproducts conversion (proteins extraction and incorporation in resins, respectively) by NTUA, CHIMAR. Byproducts sorting (sorting of residual wood stream) by ICCS. Manufacturing of new products (wood panels and furniture, respectively) by CHIMAR, MXS. Process digitalization (data acquisition, storage, traceability, and smart tags system) by ICCS, VTT.

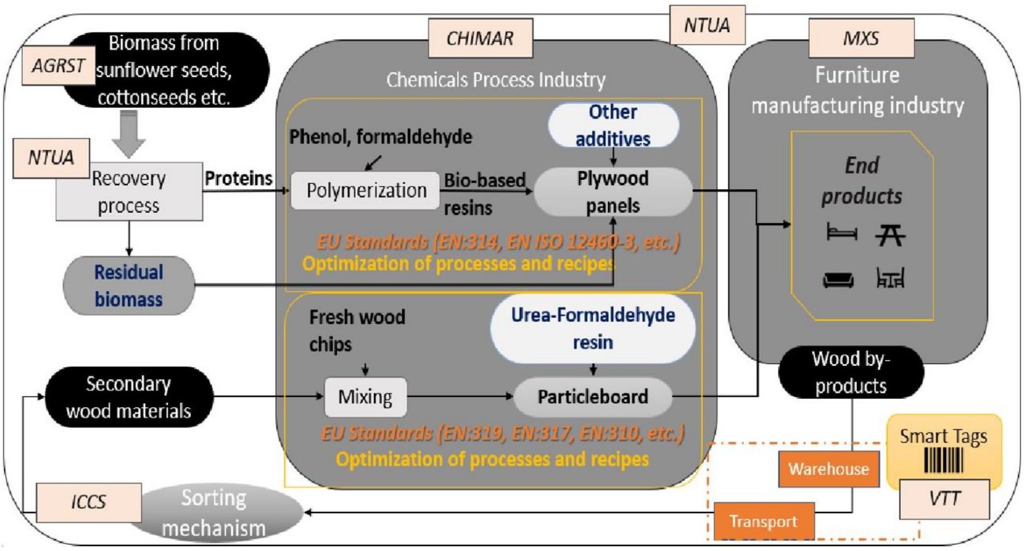

Figure 3. Overview of the Greek demonstrator flows and partners. Source: DoA. Grant Agreement — Horizon Europe DigInTraCE Project 101091801.

- **Italian demonstrator – WEEE plastics sector**

  This project focuses on the use of mixed polymeric materials obtained from the recovery of waste electrical and electronic equipment (WEEE). WEEE used is classified into three groups: Cold (refrigerators, freezers, air conditioners, etc.), Large household appliances (washing machines, dishwashers, ovens, etc.) and small household appliances (small electronic or digital appliances, lighting equipment, photovoltaic panels, etc.).

  The process starts with shredding the wastes and passing them through mechanical and magnetic screens to separate foreign materials like iron, powders, magnetic substances, glass, and paper. Flotation is then used to remove most of the metals and remaining materials from the plastics. Further cleaning involves removing wood, sponge, and rubber fragments through dry and wet flotation. The plastics containing flame retardants or with a density of 1.1 Kg/dm³ are separated. Next, the plastic materials are ground to achieve homogeneity. In subsequent stages, separation by density takes place, with Polyethylene and Polypropylene floating as they are lighter, while HIPS/ABS sinks due to higher density. The dry line focuses on separating polystyrene and ABS from rubber residues and wood. Electrostatic separators divide ABS and HIPS, and a flotation tank divides HIPS with additives from pure HIPS. Lastly, a colour selection can be conducted for final sorting, primarily for "white HIPS" from the “Cool” group recycling.

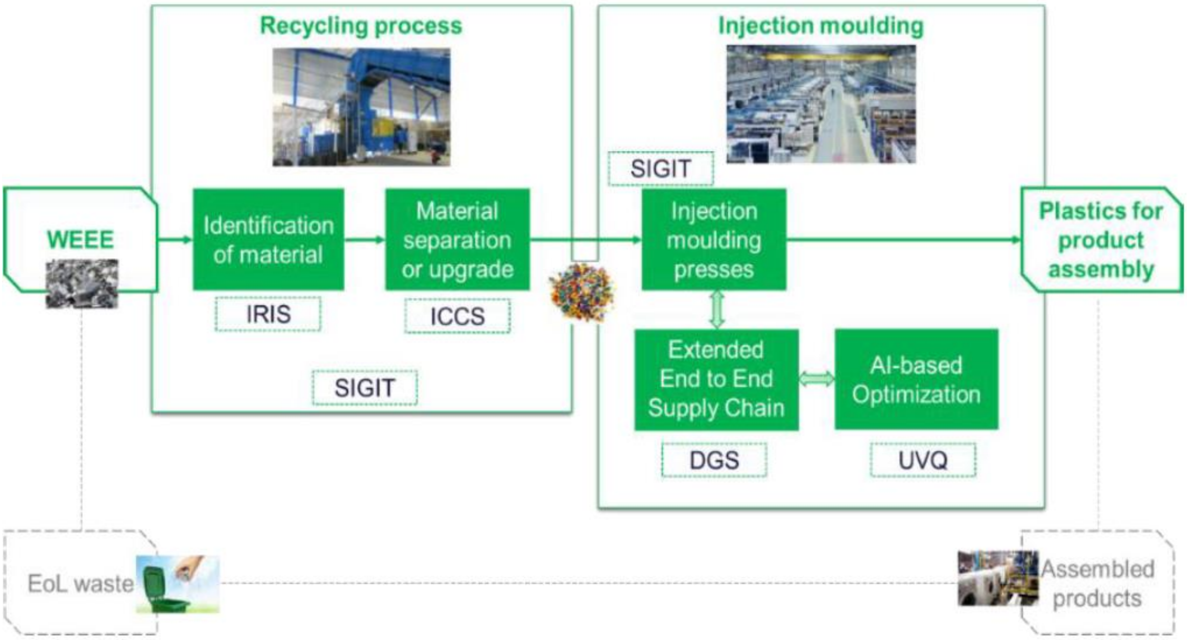

Figure 4. Overview of the Italian demonstrator flows and partners. Source: DoA. Grant Agreement — Horizon Europe DigInTraCE Project 101091801.

4. Waste streams assessment per *demosite*

In this section, each *demo site* is assessed with more detail with respect to its current production process and efficiency, generated waste streams, emissions, energy/water consumption and raw materials use, employees and community protection, product safety, and supply chain. The actual scenario is then compared to the optimizations proposed by the DigInTraCE demonstrators, aiming at a higher circularity for the value chains coupled with advanced sensing, sorting and digitalization tools for the traceability and assessment of economic and environmental indicators (KPIs) defined in the other WPs of the project. For each demo site, information was requested to demonstrators as per described in Section 2. Demonstrators' responses are provided in Section 9 as Annexes.

4.1. Belgium demonstrator – Polyesters sector

The main target of this demo is focusing on the qualities of PET that are resulting from polyester recycling, to fit textile applications. The potential waste streams being used are end-of-life plastics and textiles. Two types of recycled polyester qualities for textiles applications are being identified, normal PET (standard quality) and high tenacity (HT) PET. The goal is utilising recycled normal PET for fibre-to-fibre PET recycling, however, one of the main challenges that is hampering its wide uptake is that decontamination of suitable streams and thermoplastic recycling of the material is required (Boschmeier et al., 2023). In this demonstrator, two relevant waste streams are being considered: (i) polyester textile waste, where monitoring of the fingerprints of degradation molecules is being performed in order to monitor the impact of its use life on the properties of the recycled polyester and (ii) polyester packaging materials having a relatively short lifetime (e.g. bottles, trays, etc.), where ratios of polymers are being monitored. The bottlenecks are situated at several levels, e.g. sorting (where the digital tracking/DPP can help) but also dealing with the contaminations present in the sorted out 'monostreams' and being able to recycle and upcycle the PET material in a cost-efficient way, by processing it on an innovative recycling line combined with polymer upgrading using additives. The recycled polyester pellets are being characterized in terms of rheological properties, molecular weight, crystallisation behaviour, and other properties needed to assess the polymer behaviour and performance. The upcycled pellets are being processed on a textile extrusion line by CTB and upscaled by SIOEN. The properties of both the produced fibers and the final textile products are being evaluated and compared with that of reference conventional materials. In this demosite, DigInTraCE focuses on the production of a new polyester textile with maximum recycled content. Life Cycle Assessment (LCA) is continuously being applied for the evaluation of the environmental performance of the developed textiles.

The current status of the value chain where PET waste is converted into other value-added products is as follows:

The residue being used in this process is primarily post-industrial PET, with an annual quantity of approximately 1,000 tons. The PET waste stream should be 100% PET as no sorting capacity is available. Contamination in this waste stream can occur due to spin finish and may contain other polymers if packaging material accidentally ends up in this waste stream. The potential contamination in other possible PET sources, such as PET bottles, packaging, clothing, etc., is currently unknown.

The proposed valorisation process aims to improve recycling processes to increase mechanical properties and reduce processing issues. One of the main bottlenecks is identifying relevant PET waste streams suitable for high tenacity PET yarns.

The suppliers involved in this process are currently only dealing with in-house PET waste. The material is shredded, regranulated (double degassing + 20µ filtration), and the molecular weight is increased through SSP[1] up to virgin level. Other potential sources of PET include PET flakes from bottles and other post-industrial or post-consumer PET waste streams.

The envisioned products are targeted for the same final uses and markets as virgin PET material, including truck tarpaulin, tensile architecture, geotextiles, and reinforcement scrims.

The foremost challenge today is techno-economic: the cost of achieving the desired mechanical properties is too high. This results from the combination of elevated raw material costs and suboptimal mechanical properties, limiting the ability to penetrate certain markets.

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[1] "Solid State Polymerization". This is a process used in the recycling of PET (Polyethylene Terephthalate) where the molecular weight of the PET is increased to a level similar to that of virgin material. This process improves the properties of the recycled PET, making it suitable for various applications, including the production of high-quality yarns. It's an important step in the valorisation process described, which aims to convert PET waste into value-added products.

4.2. Spanish demonstrator – Wood sector

The goal of this demo is the value retention and upgrading of wood-based by-products. Along the whole wood processing including furniture production line, different types of by-products (residual side streams) might be produced: bark, sawdust, wood chips, wood scraps, sanding dust and broken and defective pieces.

In this case the demo tries to identify, characterise, quantify and separate the classified by-products by means of digital technologies, to obtain new added-value products such as high-value wood-based boards, insulation foams, and new wooden surfaces.

The partner ASTI puts focus on the production of trestles. The process starts with natural drying of the wood, occasionally followed by forced drying in other facilities. The primary wood species used is insignis pine. In the sawmill two types of products, boards and planks, are manufactured, which determine the different sizes of the final product. The trestles manufacturing process involves an automated cutting process. There are multiple checkpoints to identify defects in the boards. Approximately 5.5% to 6% of the trestles are rejected.

In the demo, four different types of waste streams for new applications are being studied to valorise: bark, sawdust, sand dust and wood scraps.

The current status of the value chain where wood by-products are converted into other new value-added products is as follows:

- During the manufacturing step, wood is cut to the required size and thickness for furniture and trestles under a digitally controlled process, generating byproducts such as scraps, sawdust, shavings, and sanding dust. Additionally, at the sawmill, bark is produced during the debarking process.
- Table 2and Table 3 show byproducts generated each year by the Spanish demo site.

Table 2. Byproducts generated each year by the Spanish demo site.

Byproduct	Annual Production (tons)
Scraps	1,944
Sawdust	1,000
Shavings	1,000
Sanding Dust	292
Bark	3,042

Table 3. Amount of byproduct generated by the Spanish demo site based on the primary raw material.

Byproduct	% Based on Log	% Based on Dry Plank
Scraps	5.8%	13.4%
Sawdust	2.9%	6.7%
Shavings	2.9%	6.7%
Sanding Dust	0.9%	2.0%
Bark	9.0%*	-

*Note: Bark is only referenced in relation to the log during the sawmill process.

- Related to water aspects, the water usage per ton of raw material processed is zero, indicating that no water is used in the processing of the raw material.
- About the energy usage (kWh/ton), the energy usage per ton of raw material processed can be determined from ASTI total electricity consumption in 2023, which was 2,688.3113 kWh. It is important to note that the electricity consumption in offices is irrelevant. The company operates for 48 weeks a year in double shifts of 8 hours each. Annually, 14,500 tons of dry wood (not logs) are processed.
- The current end of life for the waste/byproduct stream includes various uses for different byproducts. Scraps are subjected to coarse chipping and used for particle board cores or pellets. Shavings and sanding dust are also processed into pellets. Sawdust is burned internally in AKL's oven, and bark is used for gardening mulching.
- According to the collection points, transportation methods, and distances, it must be highlighted that the collection and transportation of the byproduct stream occur at various steps of the process. Scraps are collected and subjected to coarse chipping, then transported 120 km to their end-of-life destination. Shavings and sanding dust are transported 50 km for further processing into pellets. Bark is collected during the sawmill process and transported 50 km for use as gardening mulch.
- Material efficiency in sorting processes: The assessment of material efficiency and sorting degrees involves using different containers for each product, ensuring that each type of byproduct is efficiently separated and managed.
- Pretreatment/treatment before end of life: Apart from transportation, there is no pretreatment or treatment done with the waste before its end of life.
- Related to the byproduct main properties, the examples are particle size range, water content, main impurities, elemental composition, etc. the moisture content is as follows: Bark 50%, Scraps (9.5-14.2) % and Shavings, sawdust and sanding dust (9.5-13.5) %.

Taking into account the above-described information, Figure 5 shows the Sorter Draft Design within the Spanish demonstrator.

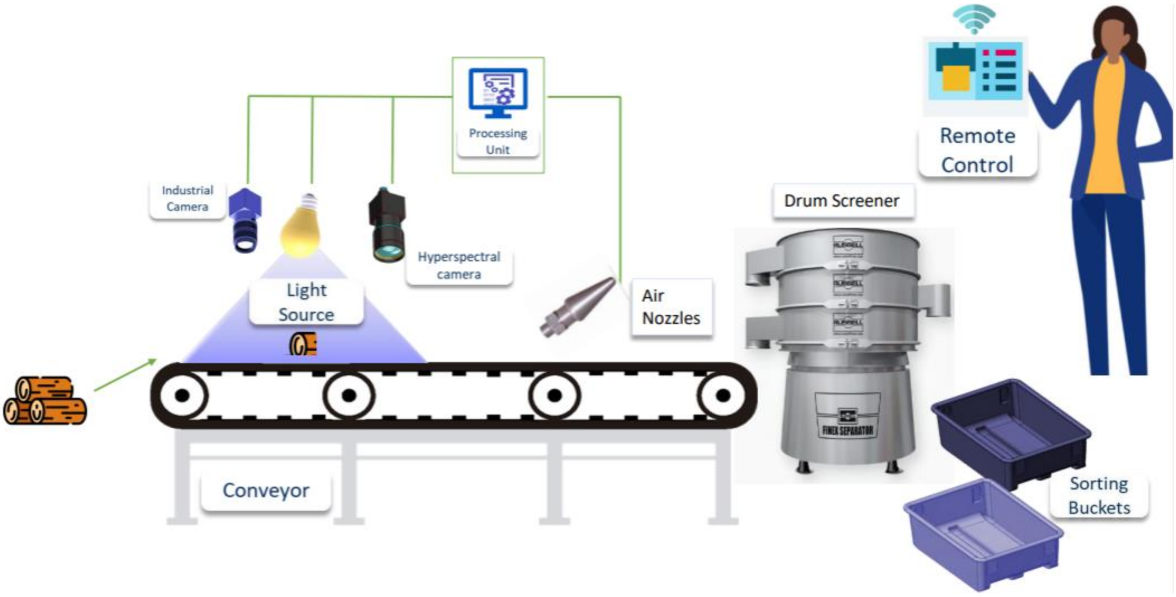

Figure 5. Sorter Draft Design Source: ICCS.

4.3. Greek demonstrator – Resins and wood sectors

Two different value chains are involved in the DigInTraCE Greek demonstrator: vegetable oil production from oilseed crops and manufacturing of woody furniture. In the first one, AGRST is responsible for processing *ca.* 300 kton/year of oilseed crops, mainly sunflower, rapeseed and cotton. The current process involves the extraction of oils from the crops, generating two streams: vegetable oils (primary product) and the remaining oilseed cakes after oil extraction (main byproduct). The oilseed cakes can correspond to 20 – 60 wt% depending on the type of crop, which means 60 – 180 kton of byproduct generated yearly. The estimated use of water and energy are of 58 kg and 54 kWh per ton of raw material, respectively. Considering the average processing of 300 kton/year, this means a yearly usage of 17.4 kton of water and 16200 MWh of energy. The byproduct is fully used in the same site as a raw material for animal and fish feed, as it is considered a good source of energy and protein. For instance, about 95% of the nitrogen content is present as true protein (Abedini et al., 2022). The quality parameters evaluated are moisture, fat, crude fiber and protein contents.

Besides serving as valuable feeds for livestock, these agricultural residues may be used to produce biogas, biofuels, biopolymers, and bioactive compounds such as antioxidants. Furthermore, oilseed cakes can serve as substrates to produce enzymes, antibiotics, mushrooms, among others (Švarc-Gajić et al., 2020). A particularly promising application for non-edible vegetable proteins are adhesives. For instance, the adhesives industry is seeking for alternative raw materials to replace petro-based ones, both to increase the products sustainability, safety, and biodegradability, as well as to avoid the price fluctuations from petro-based building blocks. A clear example is phenol, largely used to produce phenol-formaldehyde resins (PFs, a known class of wood adhesives) and with a price varying from ca. 0.6 US$/kg to 1.5 US$/kg in the last three years (BusinessAnalytIQ, n.d.). Many plant proteins do have adhesive properties in native form, but the use in industrial adhesive formulations require further research and development. Their suitability depends on factors such as its adhesive strength, durability, physical properties (as viscosity, flow and curing behavior may vary) and chemical compatibility with the other components in the formulation (Fetzer et al., 2020). In the framework of DigInTraCE, different methods to isolate protein from the oilseed cakes will be developed by NTUA using different techniques such as pressurized liquid extraction, microwave-assisted extraction, and ultrasound-assisted extraction. The obtained proteins will be used by CHIMAR in the formulation of novel wood resins where a significant fraction of phenol is replaced by said proteins without impacting final performance. The plywood panels glued by this biobased adhesive will be then used by MXS in the manufacturing of woody furniture. Figure 6 shows an overview of the current valorisation process of oilseeds and the DigInTraCE innovation with its main steps and material flows, where: F0 is the inlet of oilseed cakes, W0 and F1 are the residue after protein extraction and the extracted protein, respectively, and P1 is the plywood panel ready to be used in furniture manufacturing.

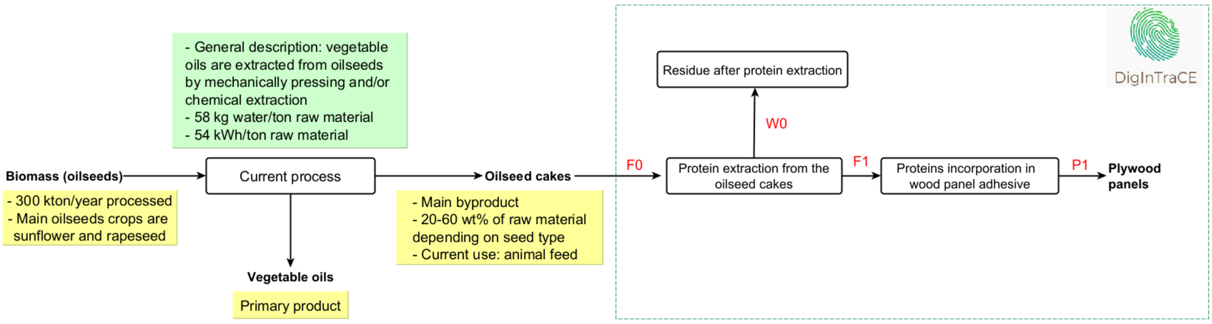

Figure 6. Overview of current process using oilseed crops and the innovation proposed by the Greek demonstrator of DigInTraCE.

Figure 7Figure 6 shows an overview of the current valorisation process of woody biomass and the DigInTrace innovation with its main steps and material flows, where: F2 is the inlet of woody biomass residues, W1is the off-spec wood from the sorting step, F3 are the wood byproducts and P2 is the particleboard.

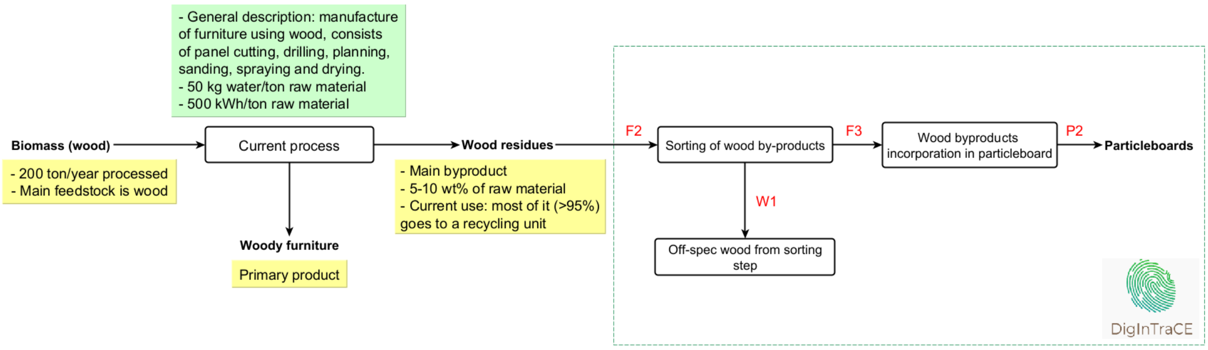

Figure 7. The second value chain involved in the demonstrator is the manufacture of woody furniture, where MXS processes ca. 200 ton/year of virgin wood as raw material.

The Cottonseed press cake has a shelf life of approximately 1 year and is primarily used as animal feed, particularly for milk-producing animals such as cows. This represents the current end-of-life for the byproduct.

In terms of logistics, the press cake is collected after the cottonseed oil production stage. It is then packed in bulk or in big bags and transported via trucks to end users. These are usually located within the country or in neighboring countries, typically within a range of 100-700 km.

There is no sorting process involved in the handling of the press cake. However, a drying step might be performed as a pretreatment before the end-of-life stage.

The press cake has several key properties, including residual oil content, protein content, fat content, moisture, and crude fiber. These properties make it a valuable resource, particularly in the context of animal feed.

4.4. Italian demonstrator – WEEE Plastics sector

The DigInTraCE Italian demonstrator includes a valorisation process for the polymers present in the three types of WEEE (Waste Electrical and Electronic Equipment), which are:

- Class W1: Cool (refrigerators, freezers, air conditioners, etc.)
- Class W2: Large household appliances (washing machines, dishwashers, hoods, ovens, etc.)
- Class W4: Small household appliances (small appliances, electronic or digital appliances, lighting appliances, photovoltaic panels, etc.)

After the selection process, which involves preliminary shredding and the valorization of other materials, a bulk mixture of plastics with flakes of various sizes and colors is obtained. These flakes can be classified according to their size and color as shown in Table 4 and Table 5.

Table 4. Classification of plastics with flakes according to their size.

Flake Size Category	Size (≥ mm)	Average Weight (g)
Small	≥ 10	80
Medium	≥ 30	187
Large	≥ 90	328

Table 5. Classification of plastics with flakes according to their color.

Flake Color	Percentage of Total
Black	38.5%
White	33%
Dark-colored	11.5%
Other colors	9.5%
Transparent	7.5%

The plastic recycling process begins, as previously mentioned, with the shredding of waste, which then passes through mechanical and magnetic sieves. In this stage, foreign materials such as iron, dust, magnetic materials, glass, and paper are separated. This multi-step procedure is carried out in a specific section of the plant, resulting in a mixture of thermoplastics as one of the materials produced.

Subsequently, the plastics undergo a flotation process to remove most of the metals and other residual materials, although not entirely. During the cleaning phase, fragments of wood, sponge, and rubber elements are removed through dry and wet flotation. Plastics containing flame retardants (e.g., brominated) or with a density greater than 1.1 Kg/dm³ are then separated.

Next, the plastic materials are shredded to make them homogeneous and more easily separable in subsequent stages, reducing their size to less than 10-12 mm. In the final phases, a density separation is performed: polyethylene (PE) and polypropylene (PP) float due to their lower density, while high-impact polystyrene (HIPS) and acrylonitrile butadiene styrene (ABS) fractions sink because they are denser.

The dry line of the process is dedicated to separating polystyrene and ABS from rubber waste, wood, and other small impurities. Through electrostatic separators, ABS and HIPS are divided. Subsequently, in a flotation tank, HIPS with some additives is separated from HIPS without them. Finally, a color selection can be carried out as the final classification process, for "almost" white-colored HIPS originating from W1 recycling.

As a result of this process, which is represented in Figure 8, the industrial recycling plant has a processing capacity of up to 30,000 tons per year (t/y), distributed as shown in Table 6.

Table 6. Processing capacity by the industrial recycling plant in the Italian demo site.

Material Type	Percentage (%)
PS (Polystyrene)	37%
Heavy Plastics	33%
PC/ABS/FR	16%
ABS	10%
PP/PE	4%

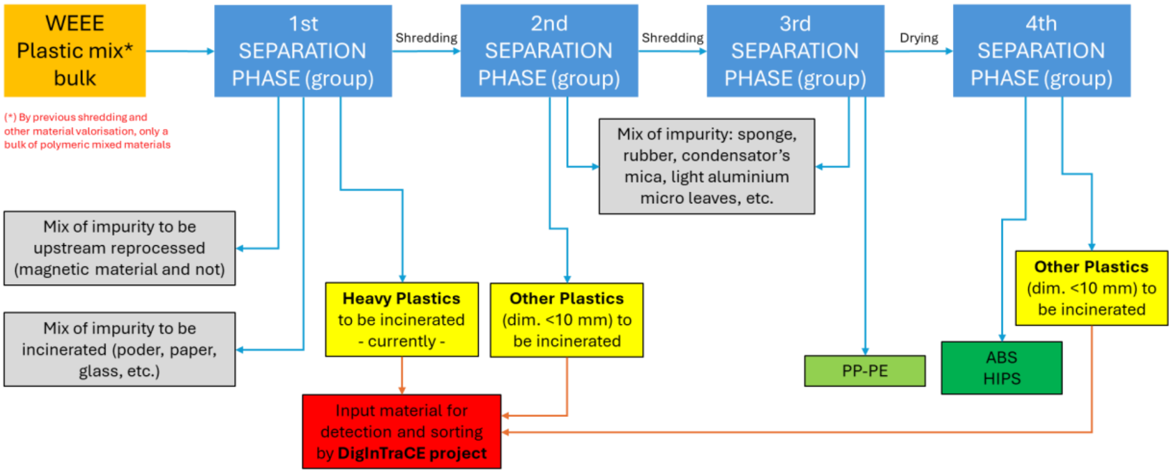

Figure 8. Macro scheme of the WEEE valorisation process.

5. Identification of gaps and best practices

In this section, gaps and best practices will be explored for each *demo site*, taking into consideration both their traditional processes and the current status of the innovations proposed in the DigInTraCE demonstrators.

5.1. Belgium demonstrator – Polyesters sector

As described above, the current state of the value chain involves the conversion of PET waste into other valuable products. The primary residue utilized in this process is post-industrial PET, with an annual volume of around 1,000 tons. The PET waste stream is expected to be 100% PET, as there is no capacity for sorting. Contaminations can occur in this waste stream due to spin finish or the accidental inclusion of other polymers if packaging material ends up in this waste stream. The potential contamination in other possible PET sources, such as PET bottles, packaging, clothing, etc., remains unknown.

The proposed valorisation process is designed to enhance recycling processes, increase mechanical properties, and mitigate processing issues. A significant bottleneck is the identification of relevant PET waste streams that are suitable for high tenacity PET yarns. Currently, the suppliers involved in this process are handling only in-house PET waste. The material undergoes shredding, regranulation (double degassing + 20µ filtration), and the molecular weight is increased through SSP to reach the virgin level. Other potential PET sources include PET flakes from bottles and other post-industrial or post-consumer PET waste streams.

The products intended from this process target the same final uses and markets as virgin PET material, such as truck tarpaulins, tensile architecture, geotextiles, and reinforcement scrims. However, a significant techno-economic challenge exists today. The cost of achieving the desired mechanical properties is prohibitively high, stemming from increased raw material costs and inferior properties. This barrier restricts access to certain markets.

The innovation developed by the Belgian demo partners is an advancement in the field of polyester textile development, specifically in the context of recycling and upcycling PET (Polyethylene Terephthalate) waste. The process involves the use of two types of virgin PET with different intrinsic viscosity (IV) values, sourced from SIOEN, in a slow-speed monofilament extrusion process. The PET with an IV of 0.64 exhibits good processability and high strength, while the PET with an IV of 1, although having good processability, shows higher strength and a specific shrinkage rate when heated. This innovative approach not only enhances the recycling processes but also increases the mechanical properties of the final product, thereby reducing processing issues. It represents a significant step towards sustainable textile manufacturing, aiming to convert PET waste into high-quality polyester textiles.

The system begins with a winding machine with four winding positions (Figure 9), operating at a maximum speed of 200 meters per minute. This feeds into a series of godets with adjustable temperature and stretching zones. There are four sets of these godets in total. After each set of godets, the material passes through an oven. The first two ovens are hot air ovens, and the third is a steam oven. These ovens help to heat and condition the material. Finally, the material passes through a hybrid quenching machine. This machine features a standard water bath and an air-cooling system with chill rollers. The quenching process helps to cool and solidify the material.

The throughput of the system is between 0.2 to 5 kg per hour, indicating its capability to handle a range of operational scales. This innovative system represents a significant advancement in the plastic value chain, offering enhanced control over the processing of PET materials. It is designed to convert PET waste into high-quality polyester textiles, potentially opening new markets and applications for recycled PET materials.

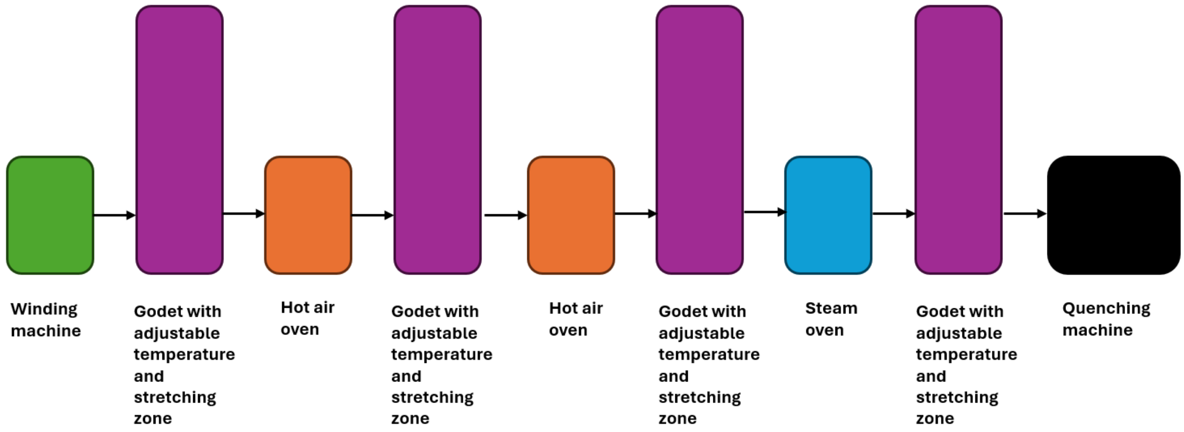

Figure 9. Schematic representation of the processing of PET materials.

Table 7 summarizes the innovations developed in DigInTrace, focusing on two distinct processes of PET conversion. The first process involves the monofilament extrusion of virgin PET with varying intrinsic viscosities, demonstrating different strengths and shrinkage properties. The second process explores the use of recycled PET, testing different in-house materials and adjusting the extrusion temperature accordingly. This table provides a comprehensive comparison of these innovative processes, highlighting their unique characteristics and potential applications in the textile industry.

Table 7. Virgin and Recycled PET Conversion Processes in DigInTrace.

Process 1	Process 2
This process involves the slow-speed monofilament extrusion of virgin PET with intrinsic viscosities (IV) of 0.64 and 1, sourced from SIOEN. The PET with an IV of 0.64 demonstrates good processability and yields a product with a strength of approximately 55-60 cN/tex. On the other hand, PET with an IV of 1 also shows good processability but results in a higher strength of around 66-68 cN/tex. Additionally, this material has a shrinkage percentage ranging from 14.4 to 16.4% when subjected to a temperature of 150°C for five minutes.	This process also involves slow-speed monofilament extrusion, but it uses recycled PET (rPET) with IVs of 0.6 and 1. Three different in-house rPET materials are tested in this process. Adjustments are made to the extrusion temperature to accommodate the different properties of rPET compared to virgin PET. A notable issue encountered during this process is pressure fluctuation within the extruder, which affects the consistency and quality of the output. Moreover, there is an observable change in coloration where the yarn acquires a yellowish hue. This process represents an innovative approach to recycling and reusing PET materials in textile manufacturing.

In addition to the main processes, the DigInTraCE project also conducts a series of tests on other materials as part of its innovative approach to plastic valorisation. These tests included the use of virgin bottle grade PET, in discussion with SIOEN, and recycled bottle PET sourced via European Plastic Converters. The project also explores the use of post-consumer waste provided by the NGO Waste Free Oceans[2]. Looking ahead, the project plans to optimize the extrusion of rPET20_IV, evaluate both virgin and recycled bottle PET, and boost the intrinsic viscosity (IV) of recycled materials through solid-state polymerization (SSP) or chain extension. This will involve sourcing different types of recycled PET (rPET) materials. These additional tests and future steps highlight the project's commitment to advancing the field of plastics valorisation into novel materials.

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[2] https://www.wastefreeoceans.org/

In the valorisation of polyesters, particularly PET, several gaps have been identified (Table 8). These include limited applications of recycled polyester, inconsistent quality due to varying waste stream sources, processing challenges related to decontamination and thermoplastic recycling, logistical issues with sourcing PET waste, market demand limitations due to high costs, and environmental concerns associated with the current recycling process.

Table 8. Gaps identified with respect to the valorisation of Polyesters.

Gap	Description
Limited applications	The use of recycled polyester is currently limited to certain applications. High demanding textile applications are still a challenge due to the need for high-quality recycled PET
Inconsistent quality	The quality of recycled PET can vary depending on the source of the waste stream and the presence of contaminants
Processing challenges	The decontamination of suitable streams and thermoplastic recycling of the material is required, which can be challenging
Logistical issues	The current suppliers are only dealing with in-house PET waste, limiting the potential sources of PET
Market demand	The high cost of achieving the desired mechanical properties prevents certain markets from being reached
Environmental concerns	The current process involves shredding and regranulating PET waste, which can have environmental impacts

Note: Table partially prepared with information found elsewhere (Subramanian et al., 2022).

To address the above-described gaps, best practices could be implemented such as exploring the production of value-added products like high-quality regenerated fibers, implementing rigorous quality control measures, automating sorting processes, expanding PET waste sources, conducting market research for potential new markets, and adopting environmentally friendly processes like biomass-based polyester production. These practices could significantly improve the efficiency, sustainability, and marketability of recycled PET products. However, feasibility studies are recommended before implementation.

Table 9. Best practices identified with respect to the valorisation of Polyesters.

Gap	Description
Value-added products	Explore the potential of producing high-quality regenerated fibers from PET waste. This could open new applications for recycled PET.
Quality control	Implement rigorous quality control measures to ensure the consistency of the recycled PET.
Efficiency processing	Automate the sorting processes using spectroscopic methods that detect chemical composition differences between materials.
Logistical solutions	Expand the sources of PET waste to include post-consumer waste such as PET bottles and other packaging materials.
Market development	Conduct market research to identify potential new markets for products made from recycled PET.
Environmental sustainability	Implement environmentally friendly processes such as biomass-based polyester production. This could improve the sustainability of the process and reduce its environmental impact.

Note: Table partially prepared with information found elsewhere (Podara et al., 2024; Wang & Salmon, 2022).

5.2. Spanish demonstrator – Wood sector

In wood waste management, it is essential to identify and address both gaps and best practices to maximize valorisation and minimize environmental impact. Each type of wood waste, from bark to wood scraps, presents unique challenges and opportunities. Understanding these aspects is crucial for developing innovative and sustainable solutions that not only enhance the efficiency of waste management processes but also open new avenues for utilizing these materials.

In this section, the main gaps and best practices related to the most common wood wastes will be explored: bark, sawdust, sanding dust, and wood scraps. We will analyze the limitations in their use and management and effective strategies being implemented to convert these wastes into valuable resources. This approach will optimize the wood value chain and contribute to a more sustainable and profitable model in the industry.

According to the analysis done in section 4.2, a comprehensive identification of main gaps that could affect all of the wood residues within the scope of this project can be seen (bark, sawdust, sanding dust and scraps). On the other hand, some best practices are proposed to solve the gaps identified.

5.2.1. Bark

Bark is often limited to low-value applications such as mulch or biofuel, missing out on potential higher-value uses. Additionally, the variability in bark quality can affect its usability in different applications, and processing challenges arise due to its tough, fibrous nature. Gaps identified with respect to the valorisation of bark are shown in Table 10.

Table 10. Gaps identified with respect to the valorisation of Bark.

Gap	Description
Limited applications	Bark is often relegated to low-value applications such as mulch or biofuel. This underutilization means that the full potential of bark as a resource is not being realized. There is a lack of widespread knowledge and technological development to transform bark into higher-value products.
Inconsistent quality	The quality of bark can vary significantly depending on the type of tree, the conditions under which it was grown, and the method of harvesting. This variability can affect its suitability for different applications, leading to challenges in standardization and consistent product quality.
Processing challenges	Bark is inherently tough and fibrous, making it difficult to process using standard equipment designed for softer wood materials. This can result in higher processing costs and the need for specialized machinery, which may not be readily available or cost-effective for smaller operations.
Logistical issues	Due to its bulkiness and lower density compared to other wood residues, bark can be costly and cumbersome to transport. Efficiently moving large quantities of bark from the point of collection to processing or end-use sites can be a logistical challenge.
Market demand	The market demand for products derived from bark is often limited and fluctuates based on seasonality and regional preferences. This inconsistency can make it difficult for businesses to invest in bark processing technologies without a guaranteed return on investment.
Environmental concerns	Improper handling and disposal of bark can lead to environmental issues such as soil contamination and increased carbon emissions. There is a need for sustainable practices to ensure that bark is processed and used in an environmentally friendly manner.

Note: Table partially prepared with information found elsewhere (Neiva et al., 2024).

Technologies are being developed to convert bark into value-added products like biochar, pharmaceutical extracts, or construction materials. Stringent quality control measures must be implemented to ensure consistency and investments are needed in advanced processing techniques to handle the toughness of bark efficiently. Best practices identified with respect to the valorisation of bark are shown in Table 11.

Table 11. Best practices identified with respect to the valorisation of Bark.

Gap	Description
Value-added products	Investing in research and development to create value-added products from bark can significantly enhance its economic viability. Examples include biochar for soil amendment, extracts for pharmaceuticals and cosmetics, and composite materials for construction and manufacturing. Developing such technologies can open new markets and increase the demand for bark-based products.
Quality control	Implementing stringent quality control measures can help standardize the properties of processed bark, making it more attractive for various applications. This includes monitoring moisture content, particle size, and contamination levels to ensure consistent product quality.
Efficiency processing	Advancements in processing technology can help overcome the inherent challenges of working with bark. High-efficiency chippers, grinders, and pelletizers specifically designed for fibrous materials can reduce processing time and costs. Additionally, pre-treatment methods such as drying and shredding can make bark easier to handle and process.
Logistical solutions	Developing efficient logistics for bark transportation is crucial. This can include optimizing transportation routes, using compacting techniques to reduce volume, and establishing regional processing hubs to minimize transportation distances. Collaboration with logistics companies specializing in bulk materials can also improve efficiency.
Market development	Proactive market development strategies can help stabilize demand for bark-based products. This can involve marketing campaigns to raise awareness of the benefits of these products, establishing partnerships with industries that can use bark derivatives, and exploring export opportunities to regions with higher demand.
Environmental sustainability	Adopting environmentally sustainable practices in the handling and processing of bark is essential. This includes using renewable energy sources for processing operations, implementing waste management systems to handle byproducts, and adhering to regulations to minimize environmental impact. Developing green certification programs for bark-based products can also enhance market acceptance and demand.

Note: Table partially prepared with information found elsewhere (Vangeel et al., 2023).

5.2.2. Sawdust

Sawdust can create dust hazards in the workplace and during transportation, posing health risks. Managing and disposing of large quantities of sawdust efficiently can be challenging, and the market for sawdust-based products can be limited and region-specific. Gaps identified with respect to the valorisation of sawdust are shown in Table 12.

Table 12. Gaps identified with respect to the valorisation of Sawdust.

Gap	Description
Dust control	Sawdust generates fine particulate matter that can create dust hazards in the workplace and during transportation. These particles pose respiratory health risks to workers and can lead to non-compliance with occupational health and safety regulations if not properly managed.
Waste management	Managing large quantities of sawdust can be challenging. Without effective disposal or utilization strategies, sawdust can accumulate and pose environmental and logistical problems. In many cases, sawdust is discarded or burned inefficiently, contributing to waste and pollution.
Limited Market	The market for sawdust-based products is often limited and region-specific. This restriction is due to a lack of awareness about potential applications and an underdeveloped market infrastructure to support the widespread use of sawdust products.
Contamination	Sawdust can be contaminated with chemicals, resins, or other impurities during the wood processing stages, which can limit its reuse in high-value applications. Ensuring the purity of sawdust is crucial for it to be used in sensitive industries such as food processing or pharmaceuticals.
Storage and handling	Sawdust is bulky and can be difficult to store and handle, especially in large quantities. It requires dedicated storage facilities to prevent it from becoming a fire hazard or degrading due to moisture absorption.
Energy Efficiency	Processing sawdust into secondary products like pellets or boards often requires significant energy input. If the energy source is not renewable, this can offset the environmental benefits of using sawdust as a recycled material.

Note: Table partially prepared with information found elsewhere (Mallakpour et al., 2021).

Dust control systems must be implemented in production and transportation stages to reduce health hazards. The use of sawdust must be promoted in various industries such as energy (pellets), agriculture (animal bedding), and manufacturing (particleboard), and new markets and applications can be explored for sawdust-based products. Best practices identified with respect to the valorisation of sawdust are shown in Table 13.

Table 13. Best practices identified with respect to the valorisation of Sawdust.

Gap	Description
Dust Suppression	Implementing advanced dust control systems, such as vacuum extraction systems, sealed conveyors, and regular wetting down of sawdust piles, can significantly reduce dust hazards. Using personal protective equipment (PPE) for workers and maintaining proper ventilation systems in the workplace can also help manage dust levels effectively.
Recycling and Reuse	Promoting the recycling and reuse of sawdust in various industries is essential. Sawdust can be used for manufacturing wood pellets, particleboard, medium-density fiberboard (MDF), and as an absorbent material in spill kits. It can also be used in agricultural applications as animal bedding or as a soil conditioner, enhancing soil aeration and water retention.
Market Expansion	Expanding the market for sawdust-based products involves raising awareness about its potential applications and benefits. Developing marketing strategies, forming industry partnerships, and investing in research to find innovative uses can help create a more robust market. Government incentives and support for businesses using recycled materials can also boost market growth.
Quality Assurance	Implementing quality control measures to ensure the purity of sawdust is crucial. This can involve regular testing for contaminants and maintaining clean processing environments. Using untreated wood and avoiding contamination during the collection and processing stages can enhance the quality of sawdust for high-value applications.
Efficient Storage and Handling	Developing efficient storage solutions for sawdust can prevent it from becoming a fire hazard and maintain its quality. Using moisture-resistant storage facilities and compacting sawdust into bales or pellets can reduce storage space requirements. Implementing proper handling techniques and equipment can also make transportation and usage more efficient.
Energy Optimization	Investing in energy-efficient processing technologies can reduce the energy footprint of converting sawdust into secondary products. Using renewable energy sources, such as solar or biomass energy, for processing operations can further enhance the sustainability of sawdust recycling. Implementing energy recovery systems, like cogeneration, can also improve overall energy efficiency.

Note: Table partially prepared with information found elsewhere (Emenike et al., 2024).

5.2.3. Sand dust

Fine sanding dust poses respiratory health risks to workers and can be difficult to collect and contain due to its fine particle size. Moreover, there are fewer high-value applications for fine sanding dust compared to other wood wastes. Gaps identified with respect to the valorisation of sand dust are shown in Table 14.

Table 14. Gaps identified with respect to the valorisation of Sand dust.

Gap	Description
Health Hazards	Fine sanding dust particles pose significant respiratory health risks to workers. Prolonged exposure can lead to serious conditions such as chronic obstructive pulmonary disease (COPD), asthma, and other respiratory issues. Ensuring worker safety requires stringent control measures which are not always adequately implemented.
Collection and Containment	Due to its fine particle size, sanding dust is difficult to collect and contain effectively. Traditional dust collection systems may not be efficient enough to capture these particles, leading to contamination of the work environment and surrounding areas.
Limited High-Value Application	Compared to other wood residues, sanding dust has fewer high-value applications. Its fine nature limits its use in many traditional wood recycling applications, reducing the economic incentives for its collection and reuse.
Disposal Challenges	Improper disposal of sanding dust can lead to environmental issues, such as soil and water contamination. Many facilities lack the appropriate disposal methods for fine wood dust, which can exacerbate environmental impacts.
Regulatory Compliance	Compliance with environmental and occupational health regulations regarding fine particulate matter can be complex and costly. Many small to medium-sized enterprises may struggle to meet these regulatory requirements, leading to potential legal and financial repercussions.
Technical Limitations	Current technologies for processing and repurposing sanding dust are often inadequate. There is a lack of innovative solutions and equipment specifically designed to handle fine wood dust, which limits its effective utilization.

Note: Table partially prepared with information found elsewhere (Baatjies et al., 2023).

Advanced dust collection and filtration systems must be implemented to minimize health risks. Investments are also needed in efficient dust extraction and containment systems, and research and development of new applications for fine sanding dust is needed, such as additives in composites or fillers. Best practices identified with respect to the valorisation of sand dust are shown in Table 15.

Table 15. Best practices identified with respect to the valorisation of Sand dust.

Gap	Description
Advanced Dust Collection Systems	Implementing advanced dust collection and filtration systems is crucial to mitigate health hazards. High-efficiency particulate air (HEPA) filters and industrial vacuum systems can capture fine sanding dust more effectively. Regular maintenance and monitoring of these systems ensure they operate at peak efficiency.
Personal Protective Equipment (PPE)	Providing workers with appropriate PPE, such as respirators, masks, and protective clothing, can significantly reduce exposure to harmful dust particles. Training workers on the correct usage and maintenance of PPE is also essential to ensure their effectiveness.
Innovative Uses	Exploring innovative uses for sanding dust can create new markets and applications. For instance, fine dust can be used as a filler material in composites, as an additive in bio-based plastics, or in specialty papers. Research and development into these new applications can unlock the economic potential of sanding dust.
Sustainable Disposal Methods	Developing sustainable disposal methods for sanding dust can mitigate environmental impacts. Options include converting the dust into bioenergy through gasification or combustion, using it as a soil amendment to improve soil properties, or incorporating it into eco-friendly construction materials.
Regulatory Adherence and Support	Ensuring strict adherence to environmental and occupational health regulations is essential. This involves regular audits, compliance checks, and staying updated with regulatory changes. Additionally, seeking support from governmental and non-governmental organizations for compliance assistance and funding can help businesses manage regulatory requirements effectively.
Technological Advancements	Investing in technological advancements specifically designed for processing and utilizing fine sanding dust can enhance its value. Innovations such as precision sieving, pelletizing, or compacting systems can facilitate easier handling and transportation. Collaborative research initiatives with academic institutions and industry experts can drive these technological innovations.
Worker Training and Awareness	Educating workers about the risks associated with sanding dust and the importance of safety measures is crucial. Regular training sessions and awareness programs can instill a culture of safety and compliance within the workplace, ensuring that best practices are followed consistently.

Note: Table partially prepared with information found elsewhere (Cesprini et al., 2020).

5.2.4. Wood Scraps

Larger wood scraps are often not fully utilized, leading to material waste. Additionally, scraps can be bulky and difficult to handle and store, and the market demand for recycled wood scraps can be inconsistent. Gaps identified with respect to the valorisation of wood scraps are shown in Table 16.

Table 16. Gaps identified with respect to the valorisation of Wood scraps.

Gap	Description
Underutilization	Wood scraps are often underutilized, with large quantities ending up in landfills or being incinerated. This represents a significant waste of material that could be repurposed for various applications. The lack of awareness and infrastructure for recycling wood scraps contributes to their underutilization.
Handling and Storage	Due to their bulkiness and irregular shapes, wood scraps can be challenging to handle and store efficiently. They require substantial space and specific handling equipment, which can be costly and difficult to manage, especially for small to medium-sized enterprises.
Market Fluctuations	The market demand for recycled wood scraps can be inconsistent, fluctuating based on economic conditions and industry trends. This variability can discourage businesses from investing in the collection and processing of wood scraps without a reliable return on investment.
Quality and Contamination	Wood scraps can vary significantly in quality and may be contaminated with nails, adhesives, paints, or other substances. This contamination can complicate the recycling process and limit the potential applications of the recycled material.
Lack of Standardization	There is often a lack of standardization in the classification and processing of wood scraps. This can lead to inefficiencies and inconsistencies in the recycling process, making it difficult to achieve economies of scale and quality assurance.
Regulatory Challenges	Navigating the regulatory landscape for the disposal and recycling of wood scraps can be complex and burdensome. Regulations may vary by region, adding to the complexity and cost of compliance for businesses looking to recycle wood scraps.

Note: Table partially prepared with information found elsewhere (Garcia & Hora, 2017).

Recycling of wood scraps into high-value products like furniture, flooring, or decorative items must be promoted. The development of efficient systems for handling, sorting, and storing wood scraps is needed, as well as work towards stabilizing the market for recycled wood products through innovation and marketing strategies. Best practices identified with respect to the valorisation of wood scraps are shown in Table 17. Effective management of wood waste requires a deep understanding of existing gaps and the implementation of best practices for each type of waste. Addressing the challenges associated with bark, sawdust, sanding dust, and wood scraps not only helps reduce environmental impact but also creates opportunities for innovation and the development of higher-value products. By applying advanced technologies and market strategies, it is possible to transform these byproducts into valuable resources, contributing to a more circular and sustainable economy.

Table 17. Best practices identified with respect to the valorisation of Wood scraps.

Gap	Description
Recycling and Repurposing	Promoting the recycling and repurposing of wood scraps can significantly reduce waste and create new value streams. Wood scraps can be used to produce particleboard, medium-density fiberboard (MDF), or engineered wood products. They can also be repurposed for furniture, flooring, and decorative items, thus extending the lifecycle of the wood material.
Efficient Logistics and Storage	Developing efficient logistics and storage solutions is crucial for handling wood scraps. This includes investing in compacting and shredding equipment to reduce the volume of wood scraps and optimizing storage facilities to prevent degradation. Implementing just-in-time collection systems can also reduce the need for extensive storage.
Market Development	Expanding and stabilizing the market for recycled wood products involves creating awareness and demand for these materials. This can be achieved through marketing campaigns, partnerships with construction and manufacturing industries, and exploring export opportunities. Government incentives and support can also encourage the use of recycled wood products.
Quality Control and Decontamination	Implementing rigorous quality control measures ensures that wood scraps are suitable for recycling. This includes sorting and cleaning processes to remove contaminants such as nails, adhesives, and paints. Advanced decontamination technologies, such as magnetic separators and washing systems, can enhance the quality of recycled wood.
Standardization and Certification	Establishing standards for the classification and processing of wood scraps can improve efficiency and consistency in recycling operations. Certification programs for recycled wood products can also help build consumer trust and demand, ensuring that recycled wood meets specific quality and safety criteria.
Regulatory Compliance and Support	Staying informed about regulatory requirements and ensuring compliance is essential for businesses involved in wood scrap recycling. This includes understanding regional regulations and obtaining necessary permits. Seeking support from industry associations and governmental bodies can also help navigate regulatory challenges and access funding for recycling initiatives.
Innovative Uses and Research	Investing in research and development to find innovative uses for wood scraps can open new markets and applications. This can include exploring bio-based composites, biochar production, and innovative construction materials. Collaborative efforts with academic institutions and industry experts can drive innovation and technological advancements in wood scrap recycling.

Note: Table partially prepared with information found elsewhere (Cesprini et al., 2020).

The adoption of best practices and the closing of gaps in wood waste management are crucial steps towards a more efficient and responsible industry. As research and development of new applications for these materials continue, global collaboration is essential for sharing knowledge and experiences. With a concerted approach and a long-term vision, the sustainability and profitability of the wood industry can be significantly improved, ensuring that every piece of wood is utilized optimally and beneficially.

5.3. Greek demonstrator – Resins and wood sectors

The DigInTraCE Greek demonstrator involves two distinct value chains: vegetable oil production from oilseed crops and the manufacturing of wooden furniture. In the first value chain, AGRST processes approximately 300 kton/year of oilseed crops, primarily sunflower, rapeseed, and cotton. The current process extracts oils from the crops, resulting in two streams: vegetable oils (the primary product) and the remaining oilseed cakes after oil extraction (the main byproduct). The oilseed cakes, which can account for 20 – 60 wt% depending on the crop type, are fully utilized on the same site as a raw material for animal and fish feed. This process is efficient in terms of resource usage, requiring only 58 kg of water and 54 kWh of energy per ton of raw material. However, there is a potential gap in the process as the byproduct could be further valorized beyond its use as animal feed.

The DigInTraCE project proposes an innovation where different methods to isolate protein from the oilseed cakes will be developed by NTUA. The obtained proteins will be used by CHIMAR in the formulation of novel wood resins, replacing a significant fraction of phenol without impacting final performance. This innovation could potentially increase the value of the byproduct and contribute to the circular economy.

In the second value chain, MXS processes approximately 200 ton/year of virgin wood as raw material for the manufacture of wooden furniture.

Overall, the DigInTraCE Greek demonstrator explores best practices in the valorisation of byproducts and the use of digital technologies to enhance the value of these byproducts. However, there are potential gaps in the current processes that could be addressed to further increase the value of the byproducts and contribute to the circular economy. These gaps could be explored in future research and development efforts.

In the valorisation of resins, several gaps have been identified (Table 18). These include limited applications of oilseed cakes, inconsistent quality of extracted proteins, processing challenges in protein extraction and incorporation, logistical issues among partners, unexplored market demand for new products, and unaddressed environmental concerns.

Table 18. Gaps identified with respect to the valorisation of Resins.

Gap	Description
Limited applications	The oilseed cakes are currently only used as animal feed. There is potential for further valorisation of this byproduct.
Inconsistent quality	The quality of the proteins extracted from the oilseed cakes and their performance in the wood resins may vary depending on the extraction method and the type of crop.
Processing challenges	The extraction of proteins from oilseed cakes and their incorporation into wood resins require the development of new methods and optimization of existing ones.
Logistical issues	The supply and conversion of biomass-derived byproducts involves multiple partners, which could lead to logistical challenges.
Market demand	The market demand for the new wood panels and furniture made with the novel wood resins is not mentioned.
Environmental concerns	While the project aims to increase sustainability, the environmental impact of the new processes and products is not discussed.

Note: Table partially prepared with information found elsewhere (Arrutia et al., 2020).

To bridge these gaps, best practices could be implemented such as exploring value-added products from proteins, ensuring quality control, optimizing processing efficiency, coordinating logistical solutions, understanding market demand, and assessing environmental sustainability (Table 19). These practices aim to enhance the valorisation process, contributing to a more sustainable and circular economy. Further research and development efforts are needed to validate and implement these practices.

Table 19. Best practices identified with respect to the valorisation of Resins.

Gap	Description
Value-added products	Explore other high-value applications for the proteins extracted from oilseed cakes, such as bioplastics or biofuels.
Quality control	Implement rigorous quality control measures to ensure the consistent performance of the proteins in the wood resins.
Efficiency processing	Optimize protein extraction methods to maximize yield and minimize energy use.
Logistical solutions	Develop a coordinated logistics plan among involved actors to streamline the supply and conversion of the biomass-derived byproducts.
Market development	Conduct market research to understand the demand for the new products and develop a marketing strategy accordingly.
Environmental sustainability	Carry out a life cycle assessment to evaluate the environmental impact of the new processes and products and identify areas for improvement.

Note: Table partially prepared with information found elsewhere (Kover et al., 2022).

5.4. Italian demonstrator – WEEE Plastics sector

Currently, the waste electrical and electronic equipment (WEEE) plastics sector faces several challenges, among which the following stand out:

- Low collection rates
- Sorting and separation challenges
- Low recycled plastic quality and demand
- Lack of data and research
- Presence of hazardous flame retardants

Given all this, among the best practices currently being applied to improve the recycling of WEEE plastics are:

- Implementing extended producer responsibility (EPR) systems to incentivize better product design and collection.
- Investing in advanced sorting and separation technologies.
- Developing processes to remove hazardous substances and improve the quality of recycled plastics.
- Increasing awareness and consumer participation in WEEE collection.
- Conducting further research to fill information gaps and find solutions.

In the case of the Italian demonstrator, the primary concern lies in the significant amount of wasted mass destined for incineration and the hazardous substances that will accumulate in the ashes. The objective is to optimize the process by enhancing the detection of flakes in pure polymers that were previously unfiltered, identifying reusable compounds, and incorporating pure polymers mixed with high-molecular-weight substances. This preparation aims to refine the input for chemical recycling processes such as pyrolysis and/or methanolysis.

The valorisation of WEEE plastics presents several gaps (Table 20). These include limited applications due to the mixture of thermoplastics, inconsistent quality of the recycled materials, complex and resource-intensive processing, logistical challenges in handling and sorting plastic flakes, lack of market demand for mixed plastics, and environmental concerns related to hazardous ingredients.

Table 20. Gaps identified with respect to the valorisation of WEEE plastics.

Gap	Description
Limited applications	Current valorisation processes results in a mixture of thermoplastics. Thus, different plastics need to be sorted by type, which is challenging. This limits the potential applications of the recycled plastics.
Inconsistent quality	Mixing these plastics in the recycling process has negative effects on material qualities like flexibility, hardness, or durability.
Processing challenges	The process involves multiple stages of shredding, separation, and cleaning, which can be complex and resource intensive.
Logistical issues	The process requires the handling and sorting of various sizes and colors of plastic flakes, which can be logistically challenging.
Market demand	There is a lack of local markets for mixed plastics, which affects the demand for recycled plastics.
Environmental concerns	Plastics containing hazardous ingredients, mainly legacy brominated fire retardants and heavy metals, pose environmental risks.

Note: Table partially prepared with information found elsewhere (Maris et al., 2015).

To address these gaps, several best practices could be implemented (Table 21). These include developing new applications for recycled plastics, implementing rigorous quality control measures, optimizing the recycling process for efficiency, developing effective logistical solutions, working on market development for mixed plastics, and implementing measures to mitigate environmental risks. These practices aim to enhance the value of recycled plastics, ensure their quality and consistency, streamline the processing, improve logistics, stimulate market demand, and promote environmental sustainability. However, the feasibility of these practices should be thoroughly assessed considering the specific circumstances and resources available.

Table 21. Best practices identified with respect to the valorisation of WEEE plastics.

Gap	Description
Value-added products	Develop new applications for the recycled plastics to increase their value. This could involve researching and developing new products that can make use of the specific properties of the recycled plastics.
Quality control	Implement rigorous quality control measures to ensure the consistency of the recycled plastics. This could involve regular testing and monitoring of the physical properties of the plastics.
Efficiency processing	Optimize the recycling process to make it more efficient. This could involve investing in advanced machinery or technology that can automate some of the stages of the process.
Logistical solutions	Develop effective logistical solutions for handling and sorting the plastic flakes. This could involve using automated sorting systems or improving the layout of the recycling plant to streamline the process.
Market development	Work on developing local markets for mixed plastics. This could involve partnering with local manufacturers or promoting the benefits of recycled plastics to potential customers.
Environmental sustainability	Implement measures to mitigate the environmental risks associated with recycling plastics. This could involve safely disposing of hazardous materials or investing in cleaner technologies.

Note: Table partially prepared with information found elsewhere (Buekens & Yang, 2014).

6. Discussion

6.1. Current state of the art and the contributions of DigInTraCE in terms of reusing, recycling, and upcycling of polyesters, wood, resins and WEEE plastics

The Belgian demonstrator in the polyester sector showcases the upcycling potential of post-consumer PET into high-tenacity yarns for technical applications. This approach not only enhances the value of waste but also explores new avenues for recycled polyester in high-demand textile uses. Success in this initiative could lead to significant advancements in textile recycling and reuse, particularly in the polyester industry.

In the wood sector, the Spanish demonstrator emphasizes the value of wood-derived by-products in furniture manufacturing. By leveraging digital technologies to identify, characterize, quantify, and segregate these by-products, the initiative aims to preserve their value and integrate them into sectors such as construction, pulp & paper, and packaging.

Meanwhile, the Greek demonstrator focuses on making wood panels more sustainable by incorporating waste streams from agroindustry, such as proteins and wood residues, into phenol-formaldehyde resin used in plywood boards. This innovative approach not only valorizes waste but also enhances the sustainability of the wood industry.

Lastly, the Italian demonstrator in the WEEE plastics sector concentrates on recovering and reusing mixed polymeric materials from waste electrical and electronic equipment (WEEE). Through stages of separation and cleaning, the process ensures the purity of plastics, which are then homogenized through grinding. This initiative promises to significantly reduce plastic waste and foster a circular economy in the plastics sector.

Together, these demonstrators provide valuable insights into integrating digital value chains to enhance circularity and reduce emissions across various sectors (Table 22). They underscore the importance of waste valorization and secondary raw material use, contributing to the sustainability and circular economy of these industries. Continued refinement of these processes and exploration of new digital integration strategies are crucial for further advancing circularity and emissions reduction.

Table 22. Current state of the art and the contributions of DigInTraCE in terms of reusing, recycling, and upcycling of the materials treated by the four demos.

Material	Current State of the Art	Contributions of the Project
Polyesters **(Belgian demo)**	Polyester recycling is already advanced for some applications like bottles. However, the use of recycled polyester for high-demanding textile applications is still limited.	DigInTraCE is pioneering in the field of textile recycling by upcycling post-consumer PET into high tenacity yarns for technical applications. This could lead to significant advancements in the textile industry, particularly in the recycling and reuse of polyester.
Wood **(Spanish demo)**	Wood by-products are often viewed as waste. However, there is a growing interest in using these by-products for the manufacture of furniture.	DigInTraCE demonstrates the potential of digital technologies in the wood sector. By using these technologies to identify, characterize, quantify, and segregate wood by-products, DigInTraCE shows how to turn what was once considered waste into valuable resources.
Resins **(Greek demo)**	The use of waste streams from agroindustry in the manufacturing processes of wood panels is still a relatively new concept.	DigInTraCE innovates in the field of sustainable materials. By incorporating waste streams from agroindustry into the manufacturing processes of wood panels, it shows how these products could be more sustainable.
WEEE Plastics **(Italian demo)**	The recovery and reuse of mixed polymeric materials from WEEE is a complex process that involves several stages of separation and cleaning.	DigInTraCE leads the way in the field of plastic recycling. By recovering and reusing mixed polymeric materials from WEEE, it shows how plastic waste could be reduced and how a circular economy scheme could be implemented in the plastics sector.

Note: Table prepared with information from the original source (Víctor Fernández et al., 2023).

6.2. Regulatory Impact on Reuse, Recycling, and Upcycling of Materials in Europe

The regulatory frameworks in Europe play a significant role in shaping the reuse, recycling, and upcycling of materials such as polyesters, wood, WEEE plastics, and resins (Table 23). These regulations can both facilitate and pose challenges to the implementation of these practices. The EU's focus on promoting a circular economy is a significant facilitator. Regulations such as the Waste Framework Directive and the Packaging Waste Directive aim to reduce waste and promote recycling and recovery. The Plastics Strategy and Textiles Strategy further emphasize making all plastics recyclable by 2030 and reducing plastic waste. The establishment of clear standards and targets for recycling and recovery, as seen in the WEEE Directive and the Industrial Emissions Directive, provides a clear path for industries to follow. The EN 50625 series of standards for WEEE treatment facilities is another example of setting clear guidelines for recycling. The restrictions on the use of certain hazardous substances in electrical and electronic equipment through the RoHS Directive and the REACH Regulation protect human health and the environment and encourage the development of safer alternatives. The complexity of materials, particularly in WEEE plastics and resins, poses a significant challenge. The presence of hazardous substances and the difficulty in separating different types of materials make recycling and upcycling more difficult. While the WEEE Directive promotes the collection and recycling of electronic equipment, it does not specify the treatment of flame retardants, a major component of WEEE plastics. This lack of specific guidelines can hinder the recycling process. The economic viability of recycling and upcycling is another challenge. The cost of identifying restricted substances during the recycling process and the lack of a profitable market for recycled materials can discourage these practices. While the regulatory framework in Europe provides a strong foundation for the reuse, recycling, and upcycling of materials, there are still significant challenges to overcome. Continued innovation and development of more effective recycling technologies, along with further refinement of regulations, will be key to overcoming these challenges and achieving a more sustainable and circular economy.

Table 23. Comparative Analysis of Regulatory Frameworks for Polyesters, Wood, WEEE Plastics, and Resins in Europe.

Material	Key Regulations	Main objectives	Challenges
Polyesters	Plastics Strategy, Packaging Waste Directive (94/62/EC), Textiles Strategy.	Make plastics recyclable by 2030, reduce plastic waste, improve recyclability of plastics, increase demand for recycled plastic content, restrict use of microplastics.	High production rates and use of fossil-based raw materials can cause significant environmental issues if recycling or re-use routes are not deployed.
Wood	Waste Framework Directive, Directive 94/62/EC on packaging and packaging waste, Directive (EU) 2018/852, Regulation (Eu) No 305/2011, Regulation (EC) No 1907/2006	Encourage waste prevention, preparation for re-use, recycling and other forms of recovery, set recycling and recovery targets, establish requirements for packaging materials and packaging waste.	Lack of trust and standardization practices to guarantee the quality of recycled construction and demolition waste.
Resins	Industrial Emissions Directive (2010/75/EU), Eco-design Directive (2009/125/EC), Construction Products Regulation (EU) No 305/2011, REACH Regulation (EC) No 1907/2006	Minimize negative environmental impact of industrial activities, promote a circular and sustainable textile industry, set safety, performance and sustainability requirements for wood and wood-based products used in construction, protect human health and the environment from the harmful effects of chemicals.	Difficulty in recycling traditional resins, as during the curing step, irreversible bonds are created in the polymer, and it cannot be re-melted.
WEEE Plastics	WEEE Directive, RoHS Directive, REACH Regulation, European List of Wastes (LoW), EN 50625 series of standards	Promote the collection and recycling of electronic equipment, restrict the use of certain hazardous substances in electrical and electronic equipment, protect human health and the environment from the harmful effects of chemicals, set out the regulatory requirements for the collection, transport and treatment of WEEE.	Lack of information about the specific composition of the plastic waste arriving at the recycling facility, content of recycled plastics introduces a risk of unknown contaminants.

Note: Table prepared with information from the original source (Víctor Fernández et al., 2023)..

6.3. Potential pathways and main actors in the value chains of polyesters, resins, wood, and WEEE plastic waste materials.

Table 24 provides a comparative analysis of potential pathways and main actors within the value chains of four different materials: Polyesters, Resins, Wood, and WEEE Plastics. “Potential pathways” refer to the possible strategies or methods that could be employed to improve the efficiency of secondary raw materials market for each material. These pathways are based on the analysis of the current situation, challenges, and opportunities in the transition towards a more circular economy for each material. They include actions such as the creation of new platforms and systems for live information exchange, new public administration policies to encourage recycling, the presence of industrial actors in each region or country, and the promotion of the reuse of waste by establishing repair centers. “Main actors” refer to the key stakeholders who play a crucial role in ensuring the efficient handling and sustainable management of these materials. These stakeholders encompass actors from different sectors, each with their own responsibilities, perspectives, and contributions. They collectively address the challenges and opportunities of the transition to a more circular economy for each material. The main actors include digital developers, waste producers, waste managers, public administrations, households, resin manufacturers, waste pretreaters, waste recyclers, technology developers, standardization and certification bodies, and governmental authorities and policymakers. The table provides a high-level comparison of the potential pathways and main actors within the value chains of these materials. It is important to note that the specifics can vary depending on the context and the particularities of each material and region.

Table 24 serves as a starting point for further exploration and discussion on how to improve the efficiency of secondary raw materials market for each material. It highlights the need for collaboration among various stakeholders and the importance of innovative strategies in achieving a more sustainable and circular economy.

Table 24. Comparative analysis of potential pathways and main actors in the value chains of polyesters, resins, wood, and WEEE plastic waste materials.

Material	Potential pathways	Main actors
Polyesters	• Creation of new platforms and systems for live information exchange. • New public administration policies to encourage recycling. • The presence of industrial actors in each region or country. • Promote the reuse of polyester waste by establishing repair centers.	• Digital developers. • Polyester waste producers. • Waste managers. • Public administration. • Households.
Resins	• Resins vary widely, with recycling challenges. • Advances and laws push for greener resins. • Better sorting could enhance recycling value. • New resins may allow easier, efficient recycling. • Innovative recycling resins are emerging.	• Resin manufacturers and waste stream collectors. • Waste pretreaters. • Waste recyclers and technology developers. • Standardization and certification bodies. • Governmental authorities and policymakers.
Wood	• Creation of new platforms and systems that enable live information exchange. • New public administration policies to encourage the reuse and recycling of wood residues. • The presence of industrial actors in each region or country. • Promote the reuse of wood waste by establishing repair centers.	• Digital developers. • Wood waste producers. • Waste managers. • Public administration. • Households.
WEEE Plastics	• Collection of WEEE. • Dismantling/Disassembly and sorting. • Waste trading. • Plastic sorting. • Plastic treatment and recycling / energy recovery.	• Consumer and WEEE producer. • Wast handling, collectors and retailers. • Sorting facilities. • Recyclers.

Note: Table prepared with information from the original source (Víctor Fernández et al., 2023)..

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7. Conclusions

The DiginTraCE project represents a significant step towards integrating digital value chains for enhanced circularity and reduced emissions in process industries. Through the comprehensive assessment of waste streams and the implementation of innovative valorisation strategies, DigInTraCE demonstrates a contribution to a more sustainable and more efficient management of multiple wastes.

The Belgian demonstrator highlights the potential of recycled PET in high-value textile applications. By focusing on decontamination and upcycling processes, it addresses the critical challenges of sorting and contamination. The demonstrator commitment to producing a new polyester textile with maximum recycled content and continuous environmental performance through LCA might set a benchmark for sustainable practices in the industry.

The Spanish demonstrator’s approach to valorizing wood by-products through digital technologies is worth of recognizing. The detailed mapping of waste streams and the efficient use of resources, such as zero water usage and optimized energy consumption, exemplify the potential for significant environmental impact. The demonstrator’s success in creating high-vaue wood-based products from by-products ensures the retention of material value and supports the transition to a circular economy within the sector of wood-based products.

The Greek demonstrator’s innovative use of oilseed cakes as a sustainable alternative to petro-based adhesives in wood products is a significant contribution to the field of bio-based adhesives. This initiative not only utilizes agricultural residues effectively but also contributes to the development of biodegradable and safer products. The demonstrator’s focus on resource efficiency and the exploration of various applications for byproducts aligns with the goals of circularity and sustainability.

The Italian demonstrator showcases an effective recycling process for plastics from WEEE, addressing the critical need for sustainable management of electronic waste. The detailed classification and separation processes ensure the purity and quality of recycled materials, contributing to the reduction of emissions and the promotion of a circular economy.

The demonstrators of the DigInTrace project show potential in enhancing the reuse, recycling, and upcycling of polyesters, wood, resins, and WEEE plastics. The DigInTraCE’s innovative approaches, as demonstrated in Belgium, Spain, Greece, and Italy, have shown that waste can be valorised and secondary raw materials can be effectively used. This not only contributes to the sustainability of various industries but also promotes a circular economy. However, continuous refinement of these processes and exploration of new ways to further integrate digital value chains are crucial.

The regulatory frameworks in Europe play a pivotal role in shaping the reuse, recycling, and upcycling of materials. While these regulations facilitate the implementation of these practices, they also pose challenges, particularly in terms of the complexity of materials and the economic viability of recycling and upcycling. Continued innovation, development of more effective recycling technologies, and further refinement of regulations are key to overcoming these challenges.

The transition towards a more circular economy for each material requires the collaboration of various stakeholders and the implementation of innovative strategies. The creation of new platforms and systems for live information exchange, new public administration policies to encourage recycling, and the promotion of the reuse of waste are some of the potential pathways. The main actors, including digital developers, waste producers, waste managers, public administrations, households, resin manufacturers, waste pre-treaters, waste recyclers, technology developers, standardization and certification bodies, and governmental authorities and policymakers, play a crucial role in this transition.

In conclusion, DigInTraCE seeks to make contributions to the reuse, recycling, and upcycling of materials. However, there are still challenges to overcome. The regulatory frameworks, while supportive, need further refinement, and the potential pathways need to be explored further. The collaboration of various stakeholders is crucial in this transition towards a more circular economy. The findings of this report could serve as a valuable resource for future research and policy-making in this area.

Disclaimer of Warranties

This project has used a standard methodology already developed in the DigInTraCE project (Grant Agreement number: 101091801), following EU recommendations. Ad hoc modifications were added to comply with the Grant Agreement conditions for DigInTraCE (Grant Agreement number: 101091801).

The information and views set out in this deliverable are those of the authors and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the following information.

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9. Annexes

Table 25. Data gathering from *demo sites* partners related to the supply of byproducts to the DigInTrace Greek (AGROINVEST & MENEXES) demonstrator.

Suppliers →	**AGROINVEST (AGRST)**	**MENEXES (MXS)**
Byproduct description	Byproducts from oilseed crops (sunflower, rapeseed, and cotton press cake) from agri-food industry	Byproducts from furniture manufacturing: - Big wood waste pieces from panel cutting - Smaller wood pieces and wood dust along production line - Wrapping (plastic bubble wrap) and packing (carboard/wooden box/palettes)
Annual byproduct production (ton/year)	60 – 180 kton/year depending on the seed	25 tons/year
Byproduct production based on primary raw material (ton/ton)	20% - 60wt% depending on the seed	5 - 10wt%
Water usage (ton/ton)	58 kg/ton of raw material	50 kg/ton of raw material (spraying/painting steps)
Energy usage (kWh/ton)	54 Kwh/ton of raw material	500 Kwh/ton of raw material About 40% comes from PV panels.
Current end of life	Animal feed and fish feed raw materials	24 tons are directed to a recycling unit and 1 ton ends up in landfill
Collection point(s), transportation method(s) and distance(s)	N/A	Road (truck) transportation, approx. 50 km to landfill and 2 km to recycling unit.
Pretreatment before end of life (if any)	None	None
Byproduct main properties	Quality parameters: Moisture, fat, protein, crude fiber	No properties are measured.

Table 26. Data gathering from *demo sites* partners related to the supply of byproducts to the DigInTrace. Spanish (TECNALIA) demonstrator.

Needed information	Description
Byproduct description	At the manufacturing step, wood is cut to the size and thickness required for the furniture and trestles to be manufactured under a digitally controlled process. By-products Scraps Sawdust Shaving Sanding dust At the sawmill¸ Bark is produced in the debarking process
Annual byproduct production (ton/year)	How much byproduct is produced per year? Scraps accounting for 1.944Ton Sawdust accounting for 1.000 Ton Shaving accounting for 1.000 Ton Sanding dust around 292 Ton ¸ Bark: 3.042 Ton
Byproduct production based on primary raw material (ton/ton)	Scraps; 5,8% (considering the log), 13,4% (considering the dry plank) Sawdust 2,9% (considering the log), 6,7% (considering the dry plank) Shaving 2,9% (considering the log), 6,7% (considering the dry plank) Sanding dust 0,9% (considering the log), 2% (considering the dry plank) Bark represents the 9% of the sawmill process (reference the log)
Water usage (ton/ton)	No water used
Energy usage (kWh/ton)	Astigarraga's electricity consumption in 2023 was 2,688.3113 kWh. - Electricity consumption in offices is irrelevant. - Work is carried out 48 weeks a year in a double 8-hour shift. Tons of wood processed (dry, not logs): 14500 tons per year.
Current end of life	Scraps: Coarse chippingà Particle board cores/ Pellets Shaving and sanding dust: Pellets Sawdust: Burned internally at AKL'S oven Bark; Gardening mulching
Collection point(s), transportation method(s) and distance(s)	Scraps; Coarse chippingà 120 km Shavings + sanding dust à 50 km Bark in the sawmill processà mulching 50 Km
Material efficiency in sorting processes	Different containers for each product
Pretreatment/treatment before end of life (if any)	No

Table 27. Data gathering from *demo sites* partners related to the supply of byproducts to the DigInTrace Belgian (CENTEXBEL) demonstrator.

Needed information	Description
Description of the residue (general composition, quantity per year, particle size ranges, main impurities)	Currently postindustrial PET. In the project we will also look at PET bottles and other possible streams like packaging, clothing etc. but the stream should be 100% PET as CTB and Sioen both do not have any sorting capacity. Contamination is spin finish and may contain other polymers if by human error packaging material ends up in this waste stream (for the postindustrial PET waste). The other possible PET sources it is currently unknow what the contamination might be. Quantity? +/- 1 000 T/y
General description of the proposed valorisation process and what are the main bottlenecks	Improving recycling processes in order to increase mechanical properties and reduce processing issues. Identifying relevant PET waste streams suitable for high tenacity PET yarns
Suppliers (sectors and types of companies, which pretreatments are done to the residue and by whom)	Currently only in-house PET waste The material is shredded, regranulated (double degassing + 20µ filtration) and molecular weight is increased through SSP up to virgin level PET flakes from bottles Other post-industrial or post-consumer PET waste streams
Which final uses and markets are targeted for the envisioned products?	Same as for the virgin PET material being: Truck tarpaulin Tensile architecture Geotextiles Reinforcement scrims
Which technical norms and legislation (national and EU) are followed?	No information was provided.
Which markets cannot be reached and why?	No information was provided.
Technical and/or legislative impediments?	Main challenges today are techno economical: it is too expensive to reach the desired mechanical properties due to a combination of higher raw material cost and lower properties.