Digital Product Passport Concept v1

D2.4

DigInTraCE

A Digital value chain Integration Traceability framework for process industries for Circularity and low Emissions by waste reduction and use of secondary raw materials

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Legal Disclaimer

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List of abbreviations and acronyms

Abbreviation	Meaning
AI	Artificial Intelligence
BoM	Bill of Materials
CDTs	Cognitive Digital Twins
CEAP	Circular Economy Action Plan
CEI	Circular Economy Index
CEN	CEN, French: Comité Européen de Normalisation (European Committee for Standardization)
CLP	Classification, Labelling, and Packaging
Com	Compostability
CPI	Circular Economy Performance Indicator
CRIS	Circular and Resilient Information System
D	Deliverable
DF	Downcycling factor
DMA	Digital Markets Act
DoA	Description of Action
DPP	Digital Product Passport
DSA	Digital Services Act
EC	European Commission
ECHA	European Chemicals Agency
EPD	Environmental Product Declarations
EPR	Extended Producer Responsibility
ESPR	Ecodesign for Sustainable Product Regulation
EU	European Union
EUTR	European Union Timber Regulation
GD	the European Green Deal
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GPSD	General Product Safety Directive
GPSD	General Product Safety Directive
ICT	Information and Communications Technology
IDS	International Data Spaces
ISO	International Organization for Standardization
ISO/DIS	International Organization for Standardization/ Draft International Standard
ISO/IEC	International Organization for Standardization / International Electrotechnical Commission.
LCA	Life Cycle Analysis
LMT	light means of transport
M	Month

MCI	Material Circularity Indicator
MRS	Material Reutilization Score
O	Objective
P4P	Process4Planet
P4P	Process4Planet
PCR	Product Category Rules
PET	Polyethylene terephthalate
PLCM	Product-Level Circularity Metric
R	Recyclability
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RecC	Recycled Content
RenC	Renewable content
ReuR	Reuse Rate
RoHS	Restriction of Hazardous Substances
RR/RoR	Recycling rate or recycling output rate
SDS	Safety Data Sheets
SoA	State of the Art
SPI	Sustainable Product Initiative
SVHCs	on Substances of Very High Concern
T	Task
TRL	Technology Readiness Level
WEEE	Waste Electrical and Electronic Equipment

Executive Summary

D2.4 Digital Product Passport Concept v1 serves as a first step towards a strategic roadmap for the development of Digital Product Passports (DPPs) within the framework of the DigInTraCE project, which will be delivered in M24 in the form of *D2.5 Digital Product Passport Concept v2*. The primary objective is to intricately align the DPP formulation with existing product information schemes and regulatory frameworks, ensuring a seamless integration into the complex landscape of digital product management. The overarching aim is to orchestrate the effective deployment of DPPs within demonstrator projects, addressing both the intricate data considerations and the overarching system architecture.

At the heart of this conceptual development phase lies Task T2.2, a keystone in the refinement of regulated or voluntary product information schemes. This task involves a meticulous exploration of pertinent regulations and tools, ensuring that the developed DPPs are not only compliant but also adept at navigating the multifaceted challenges of contemporary product management. Furthermore, the task involves the delineation of diverse usage scenarios, envisioning a spectrum of applications that encompass the diverse needs of stakeholders. This work has been initiated and is presented in D2.4 with its continuation to result in final DPP concept to be described in D2.5 and implemented by *T4.1 Dynamically updated Digital Product Passport implementation* of the DigInTraCE project.

The envisioned DPPs, as elucidated in this document, are not mere static repositories of product information. Instead, they are dynamic entities with a versatile structure that captures the nuanced attributes and trajectories of products. This dynamic nature allows for continual benchmarking against multifaceted criteria, ensuring that the DPPs remain agile and responsive to evolving standards and requirements. A distinctive facet of the DPP framework is the assimilation of sustainability and circularity metrics, fostering a holistic approach to product management as expected by ongoing and upcoming legal regulations being prepared by European Commission. These sustainability metrics are dynamically curated through a responsive Life Cycle Assessment (LCA) environmental tool.

The pivotal facets of the project demonstrators are also presented, emphasizing their role in shaping the DPP landscape through approaching consultations to be performed during a thematic workshop in the framework of T2.2 activities. The document articulates the intricate integration of sustainability and circularity metrics within DigInTraCE, providing a roadmap for other initiatives aiming to embed similar principles in their digital product management strategies.

Moving into the specifics of DPP content, the document unpacks the metrics and indicators employed to gauge and enhance circularity within the DPP framework. This granular exploration provides a blueprint for structuring DPP content that goes beyond mere compliance, fostering a culture of circularity and sustainability in product lifecycles.

Identifying key stakeholders and users is a crucial aspect of DPP formulation, and the document details the envisaged roles of various entities interacting with and benefiting from DPPs. Additionally, the document candidly addresses the challenges encountered in the DPP formulation process and the strategic measures deployed to overcome them. This transparency

not only adds authenticity to the document but also provides valuable insights for similar initiatives navigating the complex terrain of digital product management.

Overall, from the detailed exploration of DPP development within the DigInTraCE initiative, the document can be seen as a comprehensive guide. It steers the reader through the intricacies of DPP formulation, shedding light on the challenges faced and the innovative strategies employed to forge a new paradigm in digital product information management from the early stage of the DPPs implementation stages.

1. Introduction

1.1. About DigInTraCE

The DigInTraCE project aims to create a transparent and interoperable Decentralized Traceability platform by employing innovative tracking, sensing, and sorting techniques. Emphasis is placed on dynamically updating Digital Product Passport (DPP) schemes to support certification and quality validation. Additionally, the project integrates AI-based decision-making mechanisms to optimize processes and lifecycles. DigInTraCE seeks to enhance the utilization of secondary raw materials through up-cycling, reuse, and upgrade technologies. The project also contributes to standardization efforts, ensuring open and easily accessible data. Exploring new business models, DigInTraCE aims to create economic opportunities, promote digital skills, and address regional social needs.

Driven by six objectives, DigInTraCE outlines its trajectory. The first objective (O.1) involves designing and implementing solutions to optimize the utilization of secondary raw materials and minimize waste within circular value chains. The second objective (O.2) focuses on developing and demonstrating innovative concepts for material tracing through a decentralized digital platform, facilitating the tracing and certification of secondary raw materials. The third objective (O.3) entails delivering cutting-edge real-time sensing and sorting mechanisms to enhance data exchange through a dynamic DPP. Additionally, the fourth objective (O.4) aims to improve accessibility to crucial material data by utilizing smart tags, smart contracts, open software, and immersive technologies. The fifth objective (O.5) centers on validating the efficacy of DigInTraCE technologies across four distinct value chains. Finally, the sixth objective (O.6) involves empowering local and regional entities by actively involving them in developing educational resources for workplaces and educational institutions. This collaborative effort fosters the adoption of DigInTraCE solutions within the broader community and facilitates knowledge transfer to maximize the project's impact.

1.2. Purpose of the deliverable

T2.2 *Conceptual development of dynamically updated Digital Product Passport* aims to prepare the ground for DPPs implementation in DigInTraCE demonstrators. T2.2 feeds two deliverables: D2.4 *Digital Product Passport Concept v1* and its continuation, D2.5 *Digital Product Passport Concept Final* due in M24 (December 2024), which have as overall objective to provide the concept of Digital Product Passport fit for implementation in DigInTraCE value chains. As described in the Description of Action (DoA) those documents should describe "*the required data captured and incorporated in DPPs in accordance with existing product information schemes and regulations, as well as a list of DPP features for the corresponding system's architecture*."

Considering that the deliverable consists of two versions, the objectives related to this deliverable have been achieved. In the light of the recent developments in the decision taking phase related to the Ecodesign for Sustainable Products Regulation (ESPR) proposal, and this document's significant relevance to the DPP's development within DigInTraCE, the submission of the D2.4 was postponed to M10.

1.3. Intended audience

The intended audience of the current document is mainly the DigInTraCE consortium, that will implement the design and follow the guidelines presented in the report. Many of the DigInTraCE partners will be either directly or indirectly involved in creation of the DPP and some of them have expressed their interest at the very early stages of the document preparation. It is though expected, that as the DigInTraCE DPP concept evolves towards the final version, that will be presented in D2.5, the audience and interested groups of stakeholders are expected to expand beyond DigInTraCE project partners including industrial stakeholders (producers, process industries, manufacturers, etc.) and academia and research community. Process4Planet (P4P) Partnership members are expected to especially benefit from this work, from both industrial and academia environments. Additionally, especially the content of the final document could potentially serve as a support for future delegated acts of relevant sectors to be prepared by the EC and could be of interest for standardization bodies like European Committee for Standardization and national standardization bodies.
Furthermore, due to its dissemination level set to public, this document is accessible to all the actors who might be interested in DPPs implementation for DigInTraCE sectors, but also to general public and citizens.

1.4. Structure of the deliverable and its relation with other work packages/deliverables

In terms of the DPP implementation, the critical aspects which need to be addressed are related to the DPP content and the actual technical implementation. Another key aspect is standardization, as indicated in Figure 1. The focus of T2.2 *Conceptual development of dynamically updated Digital Product Passport* is to prepare DPPs implementation in demonstrators in data and system architecture level, which will be further implemented by WP4 *Digital tools and platform development*. The aspects related to standardization are the subject of T7.1 *Standardization & certification schemes* and will be addressed separately. In terms of data content an update mechanism will be integrated feeding the DPP in terms of sustainability and circularity metrics using a live LCA tool developed in T3.5 *Online LCA computation tool based on Ex-Ante LCA.*

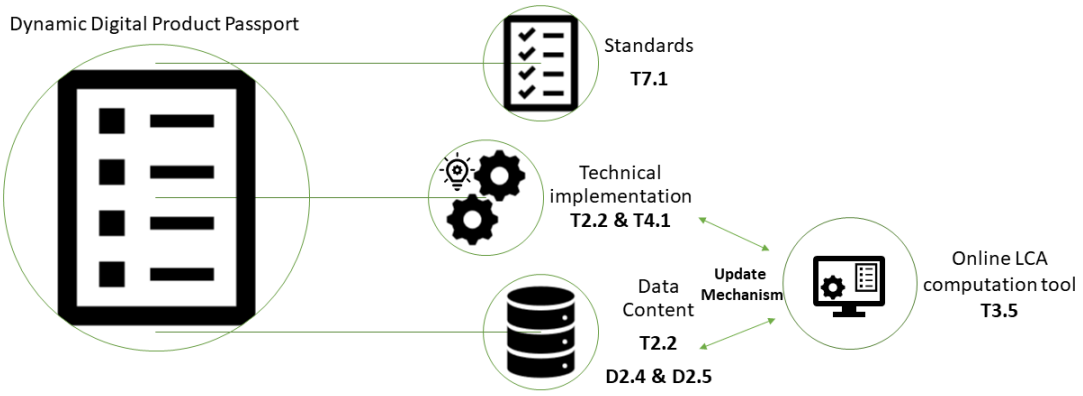

Figure 1. D2.4 relation to other tasks dealing with critical aspects in the DPP development.

The report presented here is a first step towards achieving task's T2.2 goal, namely to design the DPP, so that it can be implemented in the DigInTraCE demonstrators. In *Section 2*, an overview in terms of existing and ongoing legislation related to DPP, other DPP initiatives (projects, BoMs, etc.) and existing standards is presented. Based on this overview, an approach for new DPP development is presented in the context of DigInTraCE demonstrators in *Section 3*. *Section 3* focuses on the high-level conceptualization of the first version of the DigInTraCE DPP in terms of general cross-sectoral content with more sector specific content in terms of sustainability parameters and potential users. Use cases focusing on Greek demonstrator are presented as well. This is followed by a description of encountered challenges and strategies established to overcome them, followed by next steps leading towards the final DPP design. This report forms solid basis for further expansion, feeding D2.5, which will dive into details and present the final concept of the DPP with variations per value chain accommodated, with complete list of features and data and properties together with regulatory, environmental, quality and commercial criteria needed.

The results related to the DPP content and system architecture will be consulted with DigInTraCE demonstrators to assure stakeholder driven approach. Considering the obtained feedback, the final DPP concept will be developed to be implemented in T4.1.

2. DPP current status – an overview

In this section analysis of the current status in terms of DPP available information is presented, in order to identify the most relevant aspects for the DigInTraCE DPPs and set the context for the design and approach towards DigInTraCE DPPs implementation as described in *Section 3*. The overview includes the following aspects: EU legislation, standards, existing initiatives, including Battery Passport and similar e.g. Bill of Materials.

2.1. EU landscape

This section serves as a high-level exposition of the DPP related regulatory aspect and the primary focal point of this selection is firmly centered within the context of the European Union. The subsequent overview offers a concise yet indicative insight into significant legislations within the European Union with primary focus on **cross-sectoral legislation**. The following documents have been identified as closely linked to the DPP implementation across the sectors:

1. **ESPR Proposal (2022/0095)[1]:** The Ecodesign for Sustainable Products (ESPR) Proposal (2022/0095) exemplifies the EU's push towards ecodesign integration, promoting sustainable practices across various product categories.
2. **REACH Regulation (EC) No 1907/200 [2] :** As a cornerstone for chemical safety, the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation (EC) No 1907/2006 underscores the EU's commitment to protecting human health and the environment from potential hazards posed by chemicals.
3. **CLP Regulation (EC) No 1272/2008[3]**: EC No 1272/2008, the Classification, Labelling, and Packaging (CLP) Regulation, serves as a standardized framework for communicating chemical hazards, fostering safer handling and usage.
4. **GPSD Directive 2001/95/EC [4]** : The General Product Safety Directive (GPSD) sets fundamental safety requirements for products in the EU market, contributing significantly to consumer protection and confidence.

In order to make the analysis more complete, it is necessary to get acquainted with more **sector-specific legislation** in relation to the DigInTraCE project, namely acts related to the following areas:

- **Wood & Pulp and Paper**
- **Composite Wood & Furniture**
- **Plastic in the context of parts for ICT Equipment and Automotive Market**
- **Textile**

This overview aims to outline key regulatory frameworks that shape and govern activities within these distinct industrial domains, reflecting the project's comprehensive focus on sustainable and circular practices. It is essential to recognize that this is not an exhaustive list, and numerous other regulations contribute significantly to fostering sustainability, ensuring chemical safety, and advancing standardized hazard communication across diverse industries. These regulations underscore the EU's commitment to integrating environmental considerations into product development, a testament to its dedication to promoting responsible industrial practices.

2.1.1. Cross-Sectoral Legislation

EU policy has been evolving during the past years to reach the point where the document introducing the DPP has been adopted by the Parliament in July 2023. The **proposal for Ecodesign for Sustainable Product Regulation (ESPR)**[1] introduces a framework for ecodesign requirements to assure sustainable products with improved circularity and environmental performance. The ESPR is operating under the umbrella of Sustainable Product Initiative (SPI) and in the broader framework of the European Green Deal (GD) and builds on and complements several previous and upcoming policies like Industrial Strategy for Europe and its update, Circular Economy Action Plan, Proposal for a Directive on Green Claims, and others. Although the mentioned documents have been paving the road, it is the ESPR, that is an important milestone in the introduction of DPPs.

The ESPR proposal expands the scope of the Ecodesign Directive beyond the energy-related products and additional types of requirements, therefore repealing the previous document. The ESPR actually introduces the DPP and is considered the main legal document, that DigInTraCE DPPs should comply with. According to the ESPR, the DPP is understood as a tool facilitating management and sharing of required product related information between supply chain actors, consumers and authorities, therefore increasing transparency. More precisely, the following definition of the product passport is used in the ESPR: "*a set of data specific to a product that includes the information specified in the applicable delegated act adopted pursuant to Article 4 and that is accessible via electronic means through a data carrier in accordance with Chapter III* ". Chapter III describes the digital product passport and provides information in relation to how the content of DPPs will be defined with preliminary types of information that "shall or may" be included provided in Annex III. Chapter III points out the need to define actors and respective access rules and describes the technical aspects that need to be considered. Other topics included in ESPR proposal concern instructions on unique operator and unique facility identifiers enabling traceability and assuring interoperability, product passport registry to be created by Commission (A*rticle 12*) and its interconnection with the tool used by custom controllers (*Article 13*). ESPR will now be used during negotiations with EU governments on the new legislation on sustainable products. ESPR also introduces a ban on destruction of unsold consumer products.

The significance of this undertaking is reflected in the fact that, just a few groups of products (like food, feed, medicinal products and living organisms) are exempt from the ESPR proposal and therefore also DPP.

The Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH)[2], established by the European Union (EU) in 2007, is a robust regulatory framework designed to ensure the secure management of chemical substances while prioritizing human health, environmental protection, and innovation in the chemical industry. REACH mandates a thorough registration process for substances exceeding one tonne per year[5], involving comprehensive data submissions to the European Chemicals Agency (ECHA). The framework emphasizes on risk assessments to understand and mitigate potential dangers associated with chemical production and usage, particularly focusing on Substances of Very High Concern (SVHCs) that undergo rigorous authorization processes based on stringent criteria. Furthermore, REACH grants regulatory authorities the authority to restrict or prohibit hazardous substances, rooted in scientific evidence, and promotes the substitution of such substances with safer alternatives, fostering innovation for a safer and ecologically harmonious future.
In essence, the REACH framework plays a pivotal role in advancing sustainability and circular economy principles in chemical management. Its emphasis on consumer safety, innovation for sustainability, resource conservation, eco-design, holistic lifecycle considerations, global influence, and collaborative knowledge-sharing positions REACH as a cornerstone for a safer, more sustainable, and circular future. Its impact extends beyond the chemical industry, contributing to broader global goals of environmental responsibility and economic resilience.
In the wood and plastic sectors, the adoption of the REACH framework exemplifies the European Union's (EU) holistic strategy for advancing circularity and sustainability. Within the wood industry, REACH ensures responsible chemical use in preservation, promoting the recovery of secondary raw materials. The framework's scrutiny of wood treatments aligns with EU sustainability goals, fostering eco-friendly alternatives and minimizing harm to ecosystems. In the plastic sector, REACH ensures safe chemical use, driving innovation toward sustainable plastics in line with circular design principles. This supports EU initiatives like the Plastics Strategy[6,7] and the Single-Use Plastics Directive, reducing plastic waste and promoting recycling. Overall, REACH plays a pivotal role in harmonizing responsible chemical management with circularity and sustainability objectives in both sectors, contributing to a more sustainable and circular future.

ECHA oversees the **Classification, Labelling, and Packaging (CLP) Regulation[8]**, a cornerstone framework governing chemical within the European Union (EU). Rooted in scientific principles, the CLP Regulation safeguards human health and the environment through hazard communication. Aligned with the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)[9], the regulation harmonizes the classification of hazardous chemicals globally, fostering consistency in risk evaluation. Mandatory standardized labeling and Safety Data Sheets (SDS) serve as visual and informational tools, transcending linguistic barriers for hazard communication. The CLP Regulation also mandates a watchful notification and registration regime, reinforcing diligence and accountability in chemical management. Furthermore, the

regulation's adaptability to evolving scientific knowledge, reflected in regular updates, ensures its relevance and effectiveness in addressing emerging chemical risks.
Integrating CLP data into product passports enhances sustainability assessments, provides stakeholders with insight into products' environmental footprints and empowers decision-makers for eco-conscious practices. Enriched digital product passports facilitate tracing hazardous chemicals, promoting circularity and contributing to a sustainable, closed-loop economy. This harmonious fusion reinforces regulatory compliance, assures product safety, and fosters transparency, aligning with the EU's commitment to safer, environmentally responsible products and global chemical stewardship for a more sustainable future.

The **General Product Safety Directive (GPSD)**[4] serves as a pivotal regulatory framework within the European Union (EU), outlining essential safety requirements for products entering the market. This directive is fundamentally designed to ensure a robust level of consumer protection and confidence, imposing obligations on producers to introduce only safe products to the market. Its scope encompasses a wide array of consumer products, with specific exclusions for sectors governed by dedicated legislation. Crucial elements of the GPSD involve setting general safety requirements for products, delineating responsibilities for various economic operators (including manufacturers, importers, and distributors), stipulating risk assessment and monitoring obligations for producers, emphasizing the importance of providing transparent information to consumers, and establishing mechanisms for rapid information exchange between EU Member States to address serious risks. The GPSD's significance lies in its contribution to consumer protection, the establishment of high safety standards, the harmonization of safety measures, and the creation of a legal framework for addressing safety concerns related to consumer products.
The DPP, on the other hand, represents a contemporary approach to product information management, leveraging digital technologies to offer a comprehensive and dynamic record of a product's lifecycle. This record incorporates intricate details such as design specifications, materials, manufacturing processes, usage guidelines, and considerations for end-of-life management. The DPP functions as a digital representation of a product's journey, fostering improved traceability, transparency, and sustainability. The relationship between the GPSD and DPP is characterized by their collaborative role in enhancing product safety and information transparency. The DPP seamlessly integrates with the GPSD framework by incorporating safety-related information and dynamically updating it throughout the product's lifecycle. This ensures that the latest safety information is readily accessible to all relevant stakeholders. Furthermore, the DPP contributes to GPSD compliance by providing a detailed and easily accessible repository of safety-related information, enabling quicker and more informed decision-making by regulatory authorities, manufacturers, and consumers to ensure product safety. In summary, the DPP aligns with the objectives of the General Product Safety Directive by offering a technologically advanced platform for recording and sharing safety-related information throughout a product's lifecycle. This collaboration contributes to creating a safer, more transparent, and sustainable marketplace within the EU.

2.1.2. Regulatory Insights: DigInTraCE Project's Focus on EU Legislation in Key Demo Sectors

In this section an insight into significant legislations related to specific demonstrator context of industrial sectors of the DigInTraCE project, namely: Wood & Pulp and Paper, Composite Wood & Furniture, Plastic Parts for ICT Equipment and Automotive Market, and Textile, is provided. The main document has been identified and will be further used for extraction of DPP related information and for consultation with DigInTraCE partners involved in demonstrators.

Wood & Pulp and Paper Legislation & Composite Wood & Furniture Legislation:
The legislation specific to the Wood & Pulp and Paper, and Composite Wood & Furniture industries focuses on sustainable forestry, responsible sourcing, and stringent safety standards for related products.

- **European Union Timber Regulation EU No 995/2010 (EUTR)[10]:** EUTR combats illegal logging and promotes sustainable forestry by prohibiting the introduction of illegally harvested timber into the EU market.
- **Harmonized Standards[11]:** Harmonized standards within this sector establish comprehensive safety benchmarks, ensuring the integrity and quality of specific product categories
- **Furniture Fire Safety National Standards[12]:** National standards supplement EU standards to ensure additional layers of fire safety in furniture, aligning with stringent safety protocols.
- **Blueprint for The EU Forest-Based Industries[13]:** The Blueprint serves as a strategic guide for woodworking, furniture, pulp & paper manufacturing, and converting industries, providing a roadmap for integrating environmental stewardship.

Plastic Parts for ICT Equipment and Automotive Market:
Regulations for Plastic Parts in ICT and Automotive sectors are driven by imperatives of energy efficiency, environmental sustainability, and the restriction of hazardous substances.

- **Ecodesign Directive (2009/125/EC) [14] :** The Ecodesign Directive establishes ecodesign requirements for energy-related products, including plastic parts in ICT and automotive applications.
- **Energy Labelling Regulation (EU) 2017/1369[15]:** This regulation sets a framework for energy labeling, providing consumers with information about the energy efficiency of products, including plastic components.
- **RoHS Directive (2011/65/EU)[16]:** The RoHS Directive regulates the presence of hazardous substances in electrical and electronic equipment, ensuring that plastic parts conform to stringent environmental standards.
- **WEEE Directive (2012/19/EU)[17]:** Focused on waste electrical and electronic equipment, the WEEE Directive encourages responsible recycling practices for plastic parts, minimizing environmental impact.

Textile Legislation:
Textile regulations enhance transparency, enabling consumers to make informed choices by providing precise information about the composition of textile products.

- **Textile Regulation (EU) No 1007/2011[18]:** EU Regulation No 1007/2011 governs textile fiber names and the associated labelling and marking of the fiber composition of textile products. This regulation ensures that consumers have accurate and comprehensive information about the composition of textile products, promoting informed choices aligned with sustainability goals.

The summary of relevant cross-sectoral legislation and demo related legislation discussed in *Section 2.1* can be viewed in Figure 2.

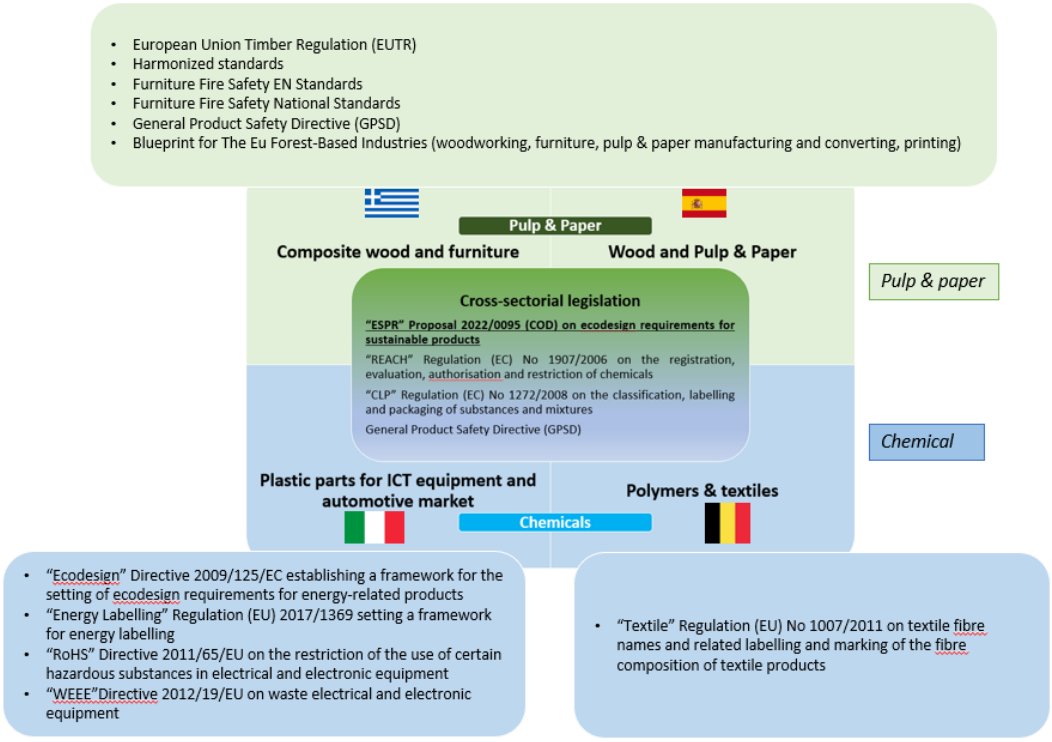

Figure 2 Overview of relevant legislation in the context of DigInTraCE demonstrators

2.2. Other initiatives

Several initiatives related to Digital Product Passports (DPPs) have been recognized, encompassing both commercial solutions and those developed within EU-funded projects or state initiatives. To ensure efficiency, our focus is on reviews that analyze various initiatives and on multiple scientific projects specifically dedicated to DPPs.

DigInTraCE together with two other projects CE-RISE and PLOOTO were selected to receive funding under Horizon call (HORIZON-CL4-2022-RESILIENCE-01), topic Circular and low emission value chains through digitalisation, being one of the **Processes4Planet Partnership** topics. Collaboration and exchange of knowledge between the three sister projects is considered essential, with first cluster event organized by European Health and Digital Executive Agency on

13th of March 2023, where participants had the opportunity to get familiar with all 3 projects and their objectives. Additionally, collaboration in terms of DigInTraCE is interested to exchange information on approaches and lessons learned in relation to the DPPs development in different sectors, starting from the early stage of project implementation. It is considered that to achieve consensus at EU/global level common approach and understanding of the concept is necessary.

CE-RISE[19] will develop "Circular Economy Resource Information System" for electronic products facilitating effective reuse and recovery of raw materials. DPPs will be implemented and tested in five case studies focusing on ICT products, printers, solar panels, batteries and heating systems. CE-ISE was launched in January 2023 and will last until December 2026.

PLOOTO[20] stands for Product Passport Through Twinning of Circular Value Chains. The project will develop a digital platform and related tools, with the aim to facilitate collaborations and alliances leading to the implementation of circular value chains.

CIRPASS[21] stands for "Collaborative Initiative for a Standards-based Digital Product Passport for Stakeholder-Specific Sharing of Product Data for a Circular Economy". It is an 18-month project receiving funding from European Commission under the Digital Europe Programme. The aim of CIRPASS is to set the scene for gradual implementation of the DPP by preparing a roadmap for prototypes in three sectors: batteries, textiles, electronics. The CIRPASS DPP prototype is understood as "a simple description of a DPP including agreements and suggestions on all aspects including: data, technical, semantic, organizational and legal"[22]. At the same time, CIRPASS aims s to build a cross-sectoral DPP system with established terminology and to create and inclusive forum, that has common understanding of the topic. CIRPASS started in October 2022 and will last until March 2024. One of the important contributions of CIRPASS project provides an organized analysis of 70 existing DPP related initiatives. Different aspects of those initiatives are being analyzed: information requirements data models, system architecture as well as standards. The sampled initiatives belonged to different sectors with the most concerning textile products , electronic products and batteries and other initiatives defining themselves as cross sectoral. Automotive, construction and food sector-based initiatives were also reported. For the needs of this report special attention was given to the CIRPASS D2.1 *Mapping of legal and voluntary requirements and screening of emerging DPP-related pilots* which includes among others results collected from the survey in relation to the information requirements deployed in currently existing initiatives. CIRPASS and DigInTraCE follow similar methodological approaches on that matter. In order to outline the initial set of data to be included in the DPPs both approaches consider the existing legislation (cross- sectoral and sector specific) and existing initiatives. The most important aspects relevant to DigInTraCE cases can be summarized as follows:

- CIRPASS uses **data provider perspective**, distinguishing between upstream (cradle to gate) and downstream stakeholders (gate to grave) internally within the value chain and external value chain stakeholders having to do with compliance and being represented by bodies providing certification, performing standardization or inspection, etc.
- There seems to be **disambiguation** in the understanding of term **"traceability"**, which can be relevant to supply chain traceability or product traceability, with most initiatives

attempting to address both through data exchange within the supply chain, but also concerning the product

- CIRPASS distinguishes between **cross-sectoral** and **sector specific legislation** and uses "EUR-LEX" to identify relevant documents
- CIRPASS categorizes the **information types** into following groups:
    - Generated within the upstream value chain and related to identification (of product and stakeholder), functional and technical specifications, composition, design and different types of instructions and manuals including information of disassembly, repair or recycling
    - Generated within the downstream value chain related to the history of product usage, repair and end of life
    - Compliance; obligatory (like standards and certifications) and non-mandatory (labels) and circularity information (labels, indicators)

CIRPASS project has also developed a classification methodology for the IT architectures used in existing DPP related initiatives [23], that constitutes valuable material for the next steps of DigInTraCE workflow, which includes the development of the system architecture.
In DigInTraCE we follow a similar approach through legislation analysis in the initial stage of the project and consultations with stakeholders after initial set of parameters is available.
Another report which provides structured analysis of 76 DPP initiatives was presented by Wuppertal Institute [24]. The report analyses the initiatives in terms of 13 criteria, including technologies, granularity level, sectors, countries of origin.
The findings outlined in these reports will be given additional attention as we advance with T2.2 and WP4. The initiatives presented in CIRPASS deliverables (D2.1 and D3.1) and the report from Wuppertal have been or will be assessed for their pertinence to the sectors covered by DigInTraCE. In this regard, the following initiatives have been identified as relevant (Table 1):

Table 1 Other relevant initiatives

Project	Objectives
CE-RISE	• Develop and pilot an integrated framework and resource information system. • Identify optimal solutions for material reuse, recovery, and recycling. • Create criteria to assess the viability of reusing, repairing, refurbishing, and recycling products. • Integrate information into a Digital Product Passport (DPP) for supply chain traceability. • Incorporate data on the environmental footprint and socio-economic impacts. • Facilitate confidential information sharing across value chains. • Offer an open-access software application for stakeholders to access assessments of reuse and recycling criteria, environmental impacts, and socio-economic considerations.

PLOOTO	• Introduction of Circular and Resilient Information System (CRIS) • Support for manufacturers in green, digital, and circular transitions • CRIS ensures waste reduction and end-to-end traceability of Secondary Raw Materials • Interconnected digital services for real-time decision-making, monitoring, and material/product certification • Development of a transformation framework • ICT tools designed for modeling product and supply chains • Cognitive Digital Twins (CDTs) for individual components • Creation of data spaces dedicated to material certification • Implementation of a circular sustainability balanced scorecard
CIRPASS	• Phased introduction of Digital Product Passports (DPPs) starting in 2023 • Initial focus on electronics, batteries, and textiles • Collaborative effort involving diverse stakeholders • Design and implementation of the European DPP • Emphasis on transparency and interoperability across sectors • Engagement of leading European organizations in the project • Aim to establish common principles and roadmaps • Extensive stakeholder consultations on key DPP aspects

2.2.1. Batteries regulation: The Implementation of Digital Product Passports in the EU Batteries market

Batteries serve as the keystone for a sustainable shift towards low-carbon mobility and renewable energy, holding the key to achieving the goals outlined in the Paris Climate Agreement[25]. To realize this vision, the circular and sustainable management of batteries is paramount.

The EU's commitment to sustainable battery management predates ESPR, marked by the introduction of a groundbreaking Battery Regulation. This regulation, poised to replace the existing Battery Directive 2006/66/EC[26] and amend regulation 2019/1020[27], is a pioneering piece of legislation. It uniquely covers the entire life cycle of batteries, mandating transparency in carbon footprint, specifying performance classes and maximum thresholds, setting metal-specific recycling rates, imposing recycled content quotas, and introducing corporate supply chain due diligence obligations. At its core, it marks the introduction of the digital battery passport, the inaugural DPP at the European level.

Following a provisional political agreement reached between the European Parliament and the Council in December 2022[28], the Battery Regulation[29] is primed to become legally enforceable in the imminent future. The Digital Battery Passport, articulated in Article 65 of the EU Battery Regulation, will be mandatory for batteries in light means of transport (LMT), industrial batteries

exceeding 2 kWh in capacity, and electric vehicle batteries placed or put into service in the EU market.

The Digital Battery Passport[30] operates as a sophisticated digital record system, facilitating the seamless exchange of critical information across the battery value chain, from manufacturers to consumers to recyclers. This trove of data encompasses unique battery identifiers (UDI), battery chemistry, capacity, manufacture dates, performance data, and recycling information. Accessible via a secure digital platform, it promises heightened transparency and traceability throughout the battery life cycle, enabling sustainable and circular battery management practices, empowering consumer choices, and reducing costs along the circular business model spectrum.
Moreover, the battery passport champions transparent and digitized supply and end-of-life chains, synergizing with the transition towards a more sustainable and digital economy. By bridging information gaps along the product life cycle, it holds the potential to unlock significant value for all stakeholders, from manufacturers to consumers to recyclers.
In addition to the EU Battery Regulation, other EU frameworks and regulations, such as the ESPR, General Data Protection Regulation (GDPR), Digital Services Act (DSA), and Digital Markets Act (DMA), play crucial roles in the implementation of digital product passports for batteries. The GDPR regulates the processing of personal data, including that stored in digital product passports, while the DSA and DMA introduce new rules for online platforms and digital markets, further shaping the landscape for these innovative passports.
The journey towards implementing digital product passports for batteries is a complex endeavor requiring the collaborative efforts of all stakeholders within the battery value chain. However, the potential benefits are substantial, and the EU remains steadfast in its commitment to transforming digital product passports into a tangible reality.

2.2.2. Bill of Materials

A Bill of Materials (BOM) is a comprehensive document serving as the intricate blueprint for product construction, cataloging components, parts, and raw materials. Its significance has evolved beyond traditional inventory management, becoming a pivotal instrument in championing the principles of the circular economy and sustainable resource management[31, 32].
In the circular economy, focused on maximizing resource efficiency and minimizing waste, the BOM plays a critical role. It provides a structured inventory with attributes for each material, empowering stakeholders to make informed decisions aligned with circular economy principles. Its multifaceted contributions include providing transparency on materials used, guiding sustainable product design, and facilitating resource efficiency.
The BOM acts as a guiding force for circular product design, serving as a blueprint for decisions related to disassembly, remanufacturing, and recycling. Products designed with circularity in mind are inherently easier to deconstruct, enabling efficient material separation for recycling or upcycling, thus extending product lifecycles and minimizing waste generation.
In the realm of secondary raw materials/resources, the BOM becomes indispensable. It allows industries to evaluate the suitability of recovered components and materials for upcycling,

remanufacturing, or other value-added processes. Identifying opportunities to reintegrate secondary resources into new products or applications, the BOM actively contributes to the circular economy's objective of closing resource loops and minimizing the extraction of virgin materials.

Transparency and traceability across the supply chain are vital for sustainable and circular product management. BOM systems have adapted to encompass comprehensive data on material origins, facilitating detailed traceability and addressing challenges of sustainable sourcing. Emerging technologies like blockchain are explored to ensure data integrity, offering robust means to trace a product's journey from raw material sources to end-of-life processes with transparency and accuracy.

Within the European Union (EU), BOM management is a critical component of the ambitious Circular Economy Action Plan[33]. This strategy represents a paradigm shift, emphasizing resource efficiency, sustainable product design, and circular business models. The EU recognizes BOMs as indispensable tools underpinning the realization of sustainability objectives.

The Eco-design Directive[34] is a cornerstone of EU policy actively encouraging the integration of BOMs into product evaluation and design processes. This directive comprehensively assesses the environmental impact of products throughout their life cycle, fostering a cultural shift towards sustainable design practices. BOMs empower manufacturers to make choices aligned with circularity and resource efficiency objectives.

The EU is actively advancing the development of Digital Product Passports relying heavily on BOM data. These passports are envisioned as accessible, transparent documents providing comprehensive information about the environmental and circular performance of products. BOMs lie at the core, serving as the data foundation for informative and accurate Digital Product Passports. The expansion of Extended Producer Responsibility (EPR) schemes within the EU highlights the pivotal role of BOMs in the circular economy context. Manufacturers are obliged to incorporate detailed data within their BOMs, explicitly accounting for recycling and remanufacturing processes. BOMs become repositories of data enabling responsible product management throughout the lifecycle, guiding decisions on materials, components, and design choices that maximize recyclability and minimize waste generation.

Overall, BOM management within the EU has undergone a profound transformation driven by the imperatives of the circular economy and sustainability. Notable progress has been made, but challenges remain, including standardization, life cycle assessment integration, end-of-life considerations, ethical sourcing, and global data harmonization. In the EU context, BOM management is seamlessly integrated into a comprehensive sustainability agenda, with regulatory initiatives and emerging practices actively propelling circularity and transparency in product management, contributing significantly to a more sustainable and circular future within the EU and globally.

2.2.3. European data sharing initiatives

In order to effectively foster the development of the circular economy, it is essential that the architecture of the DPP system is comprehensive and accommodating, addressing the needs of diverse stakeholders and seamlessly integrating a multitude of independent, often legacy,

technical systems. Achieving interoperability among these systems should encompass legal, organizational, semantic, and technical dimensions thus requiring advanced and standardized data sharing practices.

The European Data Strategy is a comprehensive initiative launched in 2020 by the European Commission to unlock the economic and societal potential of data in the European Union. The Strategy strongly promotes the concept of secure and interconnected data ecosystems or environments that allow for data sharing and collaboration while respecting data privacy, sovereignty, and protection. These kind of data ecosystems are called DataSpaces and their design takes into account interoperability on all aforementioned levels. (reference could be e.g. https://design-principles-for-data-spaces.org/) Therefore, DataSpaces can also be leveraged for the implementation of DPPs, because they can provide tools and services that enable DPP data to be shared and accessed securely, enhancing collaboration among manufacturers, suppliers, regulators, and consumers. DataSpaces can also ensure the protection of sensitive product data and compliance with data protection regulations.

International Data Spaces (IDS) and Gaia-X are examples of the European dataspace initiatives that foster existing standards and open technologies. There are already several DPP projects that incorporate IDS and Gaia-X principles in their DPP system architecture. E.g., CircThread project[35] builds on IDS architecture to create DPP for electric appliances and Catena-X[36] has created DPP for batteries utilizing Gaia-X compatible Eclipse DataSpace.

2.3. Standards

As DPPs gain prominence in the EU, the development and adherence to robust standards are paramount. Standards are the foundational pillars that will help to uphold the integrity, consistency, and reliability of DPPs within the EU. Standards encompass diverse facets, including data structuring, data quality, integration, and security. By adhering to these standards, DPPs can ensure that the information they contain is uniformly structured, meets stringent EU requirements, and seamlessly communicates across different systems and platforms within the EU.

The significance of DPPs transcends geographical borders, making global harmonization and interoperability essential for their effective implementation. In a world where goods and information flow freely across nations, DPPs must adhere to international standards to fulfil their potential. The International Organization for Standardization (ISO) plays a central role in establishing these global standards, serving as a unifying force in the development of DPPs worldwide.

ISO standards provide a common language and framework that enable DPPs from different regions to seamlessly interact and exchange information. This harmonization ensures that DPPs developed within the EU can readily integrate with their counterparts on a global scale, fostering interoperability and consistency in product information management.

Furthermore, regional standards organizations, such as the European Committee for Standardization (CEN, French: Comité Européen de Normalisation), collaborate closely with ISO to bridge the gap between EU-specific standards and global ones. This collaboration ensures that

DPPs created within the EU align with international norms, facilitating their adoption and integration into the global marketplace.

In essence, DPPs have the potential to become a transformative force not only for EU businesses but also for industries worldwide seeking to enhance transparency, sustainability, and traceability in product management. By adhering to global standards and fostering international collaboration, DPPs can contribute to the creation of transparent, sustainable, and interconnected product ecosystems on a global scale, driving positive economic, environmental, and societal impacts.

The successful implementation and adoption of DPPs hinge on a solid foundation of standardized practices and protocols. These standards encompass a wide array of technical specifications and data management guidelines that collectively define the structure, quality, and interoperability of DPPs. In this section, we embark on an exploration of the "Overview of existing DPP-related standards," where we delve into the key standards that underpin the development and functionality of DPPs. From data structuring and quality assurance to integration and security, these standards play a pivotal role in shaping the landscape of DPPs, both within the European Union and on a global scale. Through an overview presented in Table 2, we aim to shed light on a number of critical aired existing standards that are related to DPPs, ensuring their effectiveness in fostering transparency, sustainability, and traceability in product management and contributing to the realization of circular economy principles. It's important to highlight that the list provided here is not exhaustive, and we anticipate ongoing additions and expansions especially in the light of upcoming standardization work planned within the EC, since a set of standards related to IT architecture is to be developed in order to back the DPP implementation[37].

The standards presented in Table 2 have been grouped into three categories based on their content. There is a group of standards on general classification which are more related to the data content of the DPP. The other group concern technical aspects of the DPP implementation. And the third group, are LCA related standards.

Table 2 Overview of existing DPP related ISO standards

Standard	Short Description	Relevance to DigInTraCE	Ref.
General classification			
ISO/DIS 59040	ISO/DIS 59040 outlines a methodology and requirements for enhancing circular economy-related information accuracy through a Product Circularity Data Sheet, ensuring inclusive business-to-business data exchange across organizations of varying sizes while safeguarding confidentiality.		38
EN 61512-1	EN 61512-1 holds significance in addressing batch control processes, focusing on the management and execution of processes involving batch production of goods. This standard provides models and terminology to facilitate the design, implementation, and communication of batch control systems. By fostering a shared understanding among stakeholders, EN 61512-1 contributes to increased efficiency, reliability, and safety in batch production environments.		39
ISO 26324:2012	ISO 26324:2012 is a key standard for the Digital Object Identifier (DOI) system, offering a robust framework. DOIs, unique alphanumeric identifiers for digital		40

	documents, ensure persistent and reliable links to online resources. The standard defines DOI structure and resolution protocols, playing a crucial role in academic publishing and digital content management for efficient resource discovery and referencing.		
Technical system			
ISO/IEC 9075	ISO/IEC 9075, a collaborative effort by ISO and IEC in information technology, standardizes SQL (Structured Query Language) to ensure a consistent language for database operations across various systems, promoting compatibility, data sharing, and application portability. It comprehensively covers data definition, manipulation, access control, and transaction regulation for robust database management in diverse applications.	Data Processing	41
ISO/IEC 11179	ISO/IEC 11179, a pivotal standard in information technology, focuses on metadata registries (MDR) to provide structure and context to data. It aims to standardize metadata management, fostering data integration and interoperability, and offers guidelines for developing and maintaining metadata registries. Compliance enhances data consistency, reusability, and accuracy, simplifying data discovery and retrieval for efficient interpretation and effective data sharing, governance, and quality management.	Data Carriers and Unique Identifiers Interoperability Data Processing Data Authentication Data Security and Privacy Data Storage	42
ISO/IEC 15961	ISO/IEC 15961, a notable standard in information technology, focuses on data protocols in radio frequency identification (RFID) systems for item management. It precisely defines RFID system data protocols and encoding rules, ensuring compatibility among diverse RFID devices. The standard covers crucial aspects like data formats, structures, and communication protocols, facilitating consistent and accurate data exchange in RFID-based item management. Compliance enhances inventory accuracy, streamlines supply chain processes, improves asset tracking, and boosts operational efficiency, maximizing the potential of RFID technology for item management.	Data Carriers and Unique Identifiers Interoperability Data Processing Data Authentication Data Storage	43
ISO/IEC DIS 23634:2021-04	In the realm of automatic identification and data capture techniques, ISO/IEC DIS 23634:2021-04 plays a pivotal role, particularly focusing on the JAB code polychrome barcode symbology specification. Unlike traditional monochromatic barcodes, JAB code utilizes multiple colors to encode data, resulting in improved data density and visual distinctiveness. ISO/IEC DIS 23634:2021-04 provides precise definitions for the symbology, encoding rules, and decoding procedures of JAB code, unlocking its potential for diverse applications, such as product labeling, inventory management, and logistics. This standard promotes accurate and efficient data capture, facilitating seamless information flow and the integration of polychrome barcodes into various data capture processes.	Data Carriers and Unique Identifiers Interoperability Data Processing Data Authentication	44
ISO/IEC 15459-1	ISO/IEC 15459-1 through ISO/IEC 15459-6 comprise an extensive collection of standards in the field of automatic	Data Carriers and Unique Identifiers	45

	identification and data capture, with a specific focus on unique identification. As an integral component of this series, ISO/IEC 15459-1 concentrates on individual transport units, including items such as shipping containers, pallets, or individual packages. This standard offers guidelines and specifications for assigning distinctive identifiers to these transport units, thereby improving supply chain visibility and efficiency. It facilitates smooth tracking and tracing of these units throughout their logistical routes.	Interoperability Data Processing Data Authentication Data Security and Privacy Data Storage	
ISO/IEC 15459-2	ISO/IEC 15459-2 complements ISO/IEC 15459-1, delving into the registration procedures for unique identification in automatic identification and data capture techniques. This standard specifies processes and requirements for registering unique identifiers and maintaining associated data in a centralized or distributed registration system. The standard ensures consistency and accuracy in identification processes, fostering reliable and up-to-date information within identification systems.		46
ISO/IEC 15459-3	ISO/IEC 15459-3 is instrumental in establishing universal rules for automatic identification and data capture, offering comprehensive guidelines for assigning and managing unique identifiers. It addresses key elements like identifier structure, allocation rules, data formats, and synchronization, fostering interoperability and compatibility across diverse sectors.		47
ISO/IEC 15459-4	ISO/IEC 15459-4 targets automatic identification and data capture techniques, focusing on unique identification for individual products and product packages. The standard outlines precise requirements and procedures for assigning unique identifiers to products and their corresponding packages, facilitating streamlined tracking, inventory management, and product authentication throughout the supply chain.		48
ISO/IEC 15459-5	ISO/IEC 15459-5 is a vital standard in automatic identification and data capture, focusing on unique identification for returnable transport items (RTIs) crucial in supply chain operations. It offers guidelines for assigning unique identifiers to RTIs, enhancing their tracking, management, and efficient utilization in supply chain processes.		49
ISO/IEC 15459-6	ISO/IEC 15459-6 concentrates on automatic identification and data capture techniques, particularly emphasizing unique identification for groupings. It establishes requirements and procedures for assigning unique identifiers to collections of items, improving handling, tracking, and inventory management of grouped items. This standard promotes efficiency in managing diverse sets of items by facilitating streamlined group identification and handling processes.		50

ISO/IEC 22603	ISO/IEC 22603 stands as a pivotal standard in information technology, precisely defining data structures, formats, and encoding rules for digitized product information. This standard promotes seamless integration and exchange of product data across various systems and platforms, fostering efficient collaboration and data sharing among stakeholders in the supply chain and product lifecycle.	Data Carriers and Unique Identifiers Interoperability Data Processing Data Authentication Data Security and Privacy Data Storage	51
ISO/IEC 15418:2016	ISO/IEC 15418:2016 is a crucial standard in information technology, specifically addressing GS1 Application Identifiers (AIs) and ASC MH10 Data Identifiers. It offers detailed guidelines for these identifiers, ensuring uniform and accurate data encoding and decoding processes for efficient and reliable data communication and exchange.	Data Carriers and Unique Identifiers Data Authentication Data Security and Privacy	52
ISO 27001	ISO 27001 is a paramount standard in information security, offering a comprehensive framework for Information Security Management Systems (ISMS). It employs a risk-based approach to identify and manage security risks, ensuring the protection of sensitive information and data. Organizations certified under ISO 27001 demonstrate a commitment to effective security risk management, instilling confidence in stakeholders and customers regarding their information security practices.	Data Authentication Data Security and Privacy Access Right Management	53
LCA related standards			
ISO 14040	ISO 14040 is a standard series outlining principles and framework for conducting life cycle assessments (LCA), offering a systematic approach to evaluate environmental impacts throughout a product's life cycle. It covers stages from goal and scope definition to interpretation of results.	LCA related data	54
ISO 14044	ISO 14044 is a standard within the ISO 14000 series, providing guidelines and requirements for conducting a life cycle assessment (LCA), emphasizing consistency and transparency in evaluating the environmental aspects and potential impacts of a product or system throughout its life cycle stages.		55
ISO 14067	ISO 14067 is an international standard within the ISO 14000 series that provides guidelines for assessing and quantifying the carbon footprint of products, helping organizations measure and communicate the greenhouse gas emissions associated with their goods and services.		56
ISO 14025	ISO 14025 is an international standard within the ISO 14000 series that establishes principles and procedures for developing Environmental Product Declarations (EPDs). EPDs are concise, standardized reports providing information about the environmental performance of products, enabling consumers and other stakeholders to make informed choices based on environmental considerations.		57
ISO/TS 14027:2017	ISO/TS 14027:2017 is a technical specification within the ISO 14000 series, providing guidelines for the development and use of Environmental Performance		58

	Evaluation (EPE) in the context of type I environmental labeling. It outlines principles and procedures for evaluating and communicating the environmental performance of products and services, assisting organizations in making credible and transparent claims about their environmental achievements.		

In addition to ISO Standards, GS1 Digital link[59] standard has also been proposed for digital product passport, specifically related to data carriers with QR code as the main option. GS1 Digital Link standard is an open standard that defines how identifiers, location and organisation identifiers, can be encoded in a URL to provide item level identification.

3. DigInTraCE approach to DPP design

3.1. Introduction

In this section the proposed initial approach towards DPPs design in DigInTraCE demonstrators is presented. The backbone of the DigInTraCE approach is formed by the ESPR proposal as the upcoming legal obligations, that businesses including those represented by DigInTraCE sectors will face, will be based on this document. At the current stage, this approach does however pose some challenges and requires proactiveness in many aspects from the DigInTraCE team. The ESPR, being the first legal act actually introducing DPP, focuses rather on the general approach paving the way for more specific sector/product related legislation. The ESPR proposal does not set criteria and requirements, which will be provided through delegated acts (described in *Article 4*). The first delegated acts which will cover separate product groups are expected to be adopted between 2024 and 2027. Therefore, there was a need to create a flexible approach on how to proceed in terms of designing DigInTraCE DPPs without product specific guidelines being available at the design and, possibly, also at the implementation stage of the project.

Following a general-to-specific methodology, the starting point in DigInTraCE was to define **cross sectoral data categories** based on information from the ESPR proposal. These categories will be complemented by more detailed **flow/product specific** content based primarily on the **sector specific** legislation, which has been identified and presented in section *2.1.2.* In addition, specific attention was given to the sustainability and circularity indicators. This type of data constitutes critical part of the DPP content and, at this early stage of the project, an attempt was made to follow a more sector/flow specific approach as described in detail in section 3.3.

Section 3 of this deliverable describes the DigInTraCE context, the initial design of the DigInTraCE DPPs in terms of data content, the potential users of the DPP and how rights concerning editing and viewing the content could be formulated. Having identified the need to anticipate the upcoming delegated acts, this section concludes with a summary of the challenges encountered until now and the strategies developed to address them, followed by next steps and summary of findings.

3.2. The DigInTraCE context

The value chains for implementing and showcasing the overarching concept of DigInTraCE are deliberately selected from industrial sectors emphasized in the P4P roadmap. This selection also enables the validation of closed-loop supply chain solutions, incorporating concepts like recycling, reuse, and material upgrades through the deployment of optimized chemical processes.
The solutions developed within DigInTraCE are projected to reach Technology Readiness Level (TRL) 6 by the project's conclusion. The project's solutions will be demonstrated in two sectors: **Pulp & Paper**, specifically in composite wood and furniture; and **Chemicals**, focusing on plastic parts for Information and Communication Technology (ICT) equipment and the automotive market, as well as polymers and textiles.
In the upcoming sections, a concise overview of each project pilot is provided, focusing on its primary objectives and the sector-specific characteristics that distinguish it in order to better provide the context for the DPPs to be developed.

3.2.1. Greek Demonstrator

In the Greek demonstrator of the DigInTraCE project, the focus lies on the chemicals industry, emphasizing binders and biopolymers, as well as the pulp & paper and wood industry (Figure 3). Key partners, including CHIMAR, NTUA, AGRST, MXS, VTT, and ICCS, collaborate to address value chains involving agricultural by-products from oilseed crops and wood by-products. NTUA extracts proteins from oilseed crops, supplying them to CHIMAR to produce bio-based adhesives. Wood by-products from MXS are utilized by CHIMAR to manufacture various wood-based composites, contributing to furniture production by MXS. VTT develops methodologies for smart tags and data management, while ICCS designs a wood sorter.
This approach aligns with the overall concept of the demonstrator, which aims to replace petrochemical-based phenol-formaldehyde resins with bio-based alternatives. Proteins and amino acids from oilseed crops will be used in phenolic bio-based resins by CHIMAR, characterizing properties and mixing them with additives to produce wood composites, including plywood panels. Additionally, secondary raw materials from the wood industry, provided by MXS, will be mixed to create particleboards. DigInTraCE aims to lead to the production of two new wood-based composites, enhancing sustainability, health and safety, performance characteristics, and environmental profiles.

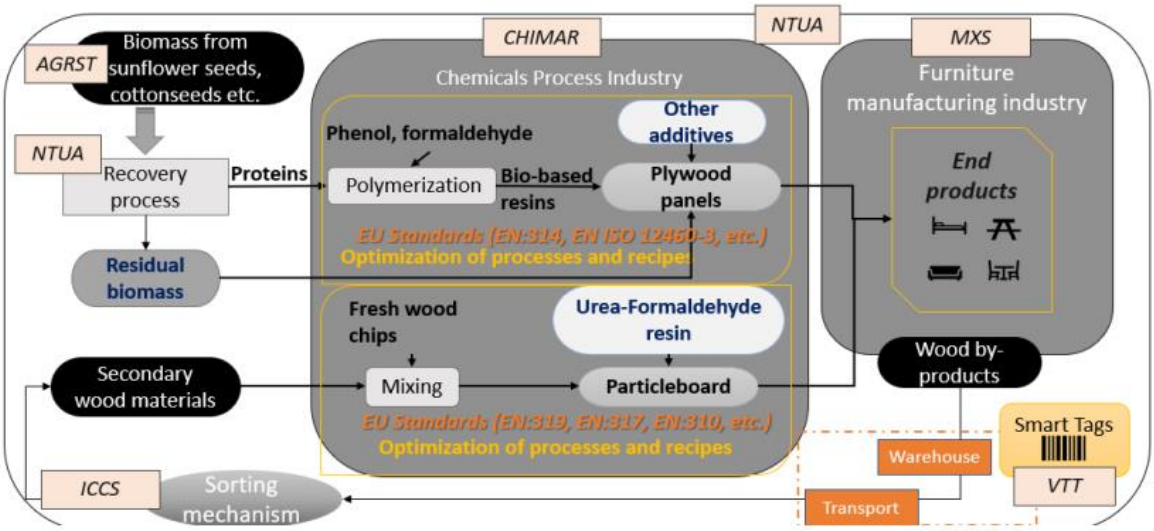

Figure 3 Greek demonstrator scheme

3.2.2. Spanish Demonstrator

In the Spanish demonstrator, the focus is on the Pulp & Paper and Wood industry, specifically in the production of composite wood-based panels. ASTI serves as the technical partner and demo owner, while TECNL takes on the role of the demo leader, with ICCS contributing as a technical partner (Figure 4). ASTI, a company encompassing the entire wood value chain, engages in the initial processing of tree trunks, sawmill operations, and the production of solid wood furniture. The demo's overarching objective is the retention and enhancement of value from wood-based by-products, employing digital technologies. At ASTI's premises, various by-products are generated throughout wood processing including bark, sawdust, wood chips, scraps, sanding dust, and defective pieces.

The demo aims to identify, characterize, quantify, and separate these classified by-products using ICCS-developed digital technologies. This classification, along with collected data, facilitates tracing materials through the furniture value chain and their potential utilization in different sectors such as construction, pulp & paper, and packaging. Proper classification enables TECNL to manufacture new, high-value wood-based products like boards, insulation foams, and innovative wooden surfaces. The success of the demo ensures the retention of value in by-products, maintaining comparable market value per cubic meter (or ton) with the current end product.

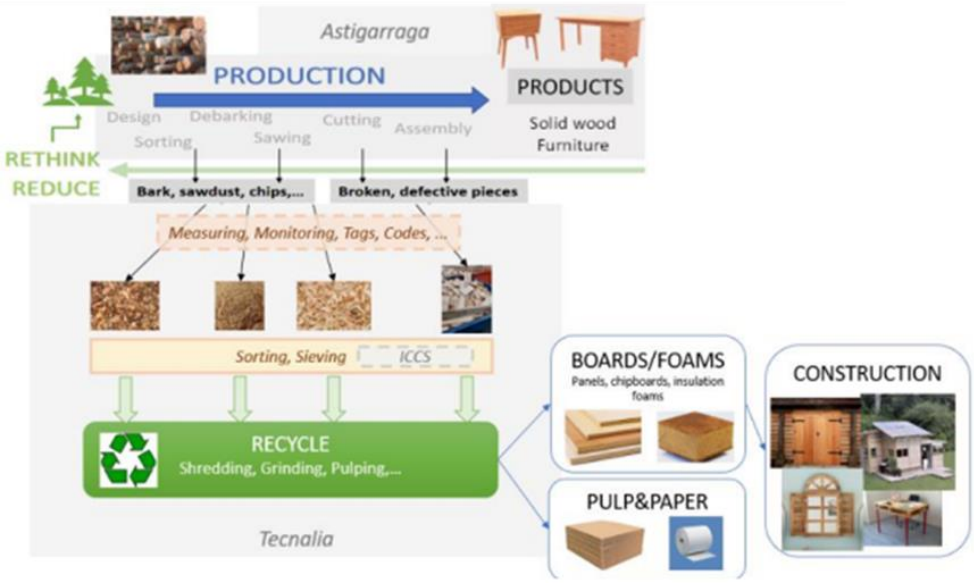

Figure 4 Spanish demonstrator scheme

3.2.3. Belgian Demonstrator

In the Belgian Demo, the focus is on the Chemicals Process Industry, specifically polymers and textiles. The demonstrator involves key partners such as CTB as the lab-scale coordinator, SIOEN representing PET textile production, CIRCE contributing to value chain mapping, IRIS focusing on the development of monitoring systems, and VTT serving as a research partner with expertise in smart tags and data management (Figure 5). This demonstration centers on polyester, which is the predominant material in textiles. The demonstration activities explore decontamination and upcycling processes for end-of-life thermoplastic polyester. CTB conducts lab-scale processing of polyester, producing recycled polyester supplied to SIOEN for PET textile production. CIRCE supports the pilot through value chain mapping, and CTB, as the demo coordinator, manages lab-scale PET recycling and material characterization. EREMA provides secondary raw materials.

The demo aims to enhance the qualities of recycled PET for textile applications, focusing on normal PET and high tenacity PET. Challenges include decontamination, sorting, and efficient recycling, with digital tracking/DPP assisting in sorting processes. The demonstrator considers polyester textile waste and packaging materials, monitoring degradation molecules and polymer ratios. The concept involves processing recycled polyester pellets into fibers and textiles, evaluated against reference materials. DigInTraCE aims to produce a polyester textile with maximum recycled content, with continuous Life Cycle Assessment ensuring the environmental performance of the developed textiles.

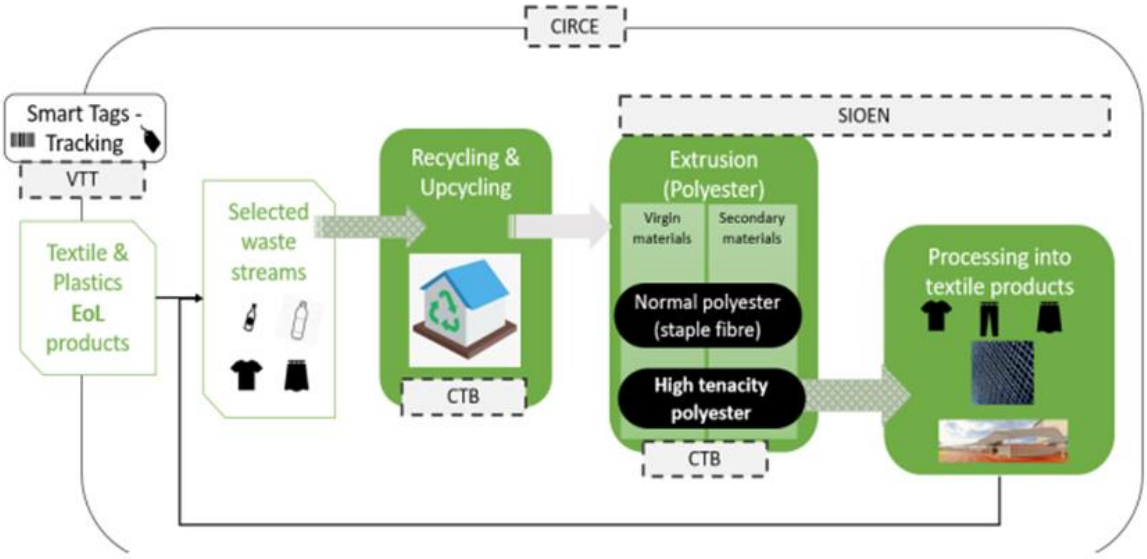

Figure 5 Belgian demonstrator scheme

3.2.4. Italian Demonstrator

In the Italian Demo, the focus is on the process industry that produces plastic components for the automotive market. The demonstrator is led by SIGIT as the demo owner, with DGS serving as the demo coordinator, UVQ as the demo research partner, IRIS contributing to the development of monitoring systems, and ICCS involved in the development of sorting systems. This demonstration targets the improvement of a circular economy flow of recycled polymeric materials specifically for injection molding, handling up to 2000kg/h of flakes that are heavy and contaminated plastics. The main objectives include enhancing polymers' detection efficiency, enabling the detection and recycling of polymeric compounds, and reducing the incineration of materials.

The overall concept involves covering all steps of the plastics value chain, from the purchase of raw materials to transformation, molding, and the release of finished products (Figure 6). This is supported by sales planning and scheduling with a focus on tracking and tracing circular practices to increase the utilization of recycled materials. By effectively managing of BOMs in plastic molding cycles, the pilot aims to improve the quality of produced materials and reduce raw material waste, thereby increasing the reuse of recycled materials. Tracking production waste associated with BOMs enables the maximization of recycling for unsold products. The multi-level BOM, including components, subassemblies, semi-finished products, and raw materials, provides information about the origin of materials (first choice, second choice, recycling), allowing for comprehensive tracking and tracing of all necessary materials and components. The circularity aspects of the project will be realized by managing the reuse of waste materials, considering different natures of recycled materials or components, such as upcycling (direct reuse without transformation) or downcycling (transformation and reuse in production).

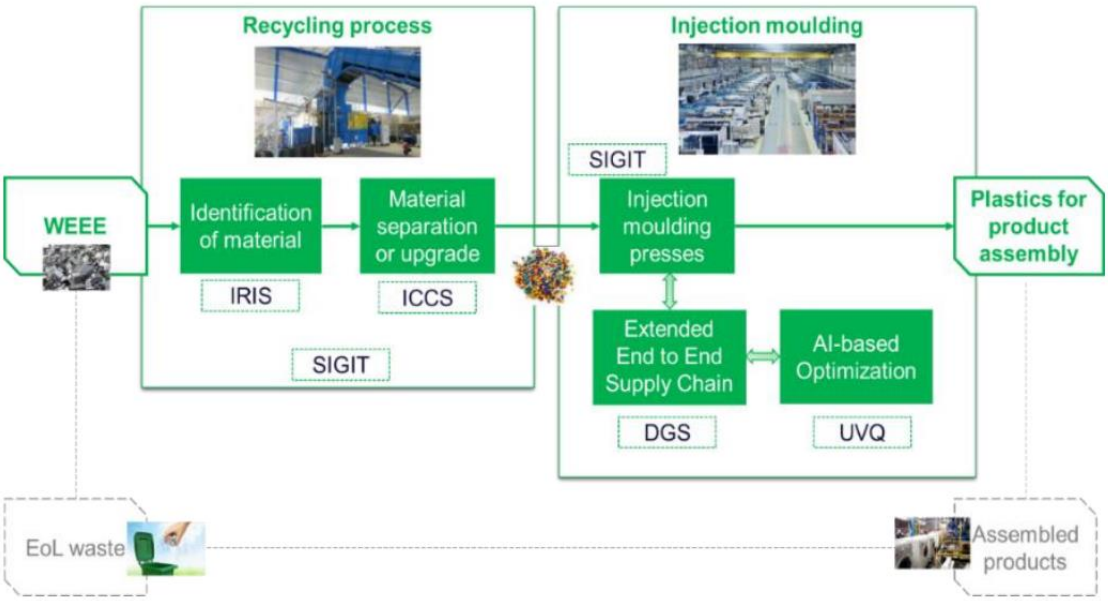

Figure 6 Italian demonstrator scheme

3.3. Sustainability and circularity metrics - the DigInTraCE approach

The ESPR proposal aims to make sustainable products the norm in the European Union (EU) market by introducing more Eco-design criteria for a wide range of products. In order to achieve this goal, the implementation of the ESPR requires the utilization of appropriate indicators to ensure accurate ecolabelling of products.

DigInTraCE will develop and integrate into its platform an online LCA calculation tool to evaluate the environmental performance of the different value chains of the demonstrator projects. The properties of the final products obtained in the projects will be evaluated and compared with those of conventional reference products. However, to understand the complete product performance, it is useful to assess not only environmental performance, but also circularity. Circularity is defined as the part of a product that comes from re-use[60], or the rate in which a product conserves its quantity and quality[61]. In this way, indicators are useful to measure the sustainability and circularity of the value chains in the project. The use of LCA indicators is useful in measuring sustainability because it assesses the environmental impacts at a whole value chain level. To give an example, when understanding the impacts of a new sorting technology, it might occur that energy consumption is reduced in the sorting processes. However, this might cause energy consumption to be increased in the recycling process that comes after the sorting due to an increased flow of materials. By using LCA indicators, all the processes which consume energy are considered and the energy consumption indicator at a systemic, value chain level is assessed. Thus, this avoids impacts being traded off amongst life cycle stages. Additionally, using circularity indicators adds value to the decision-making process because they complement LCA indicators,

making up for those difficulties that LCA indicators might show in terms of measuring circularity. For example, they are easier to communicate than LCA indicators and provide a complete assessment of circularity, since LCA methodologies can offer difficulties related to modelling approaches in open recycling loops[62] and changing material quality accounting[63]. To assess environmental sustainability performance, a rigorous selection of indicators allows to communicate the environmental sustainability improvements in the environmental impact assessment stage of the LCA. For this reason, the recommendations of the Product Category Rules (PCRs) for each product obtained from the demonstrator projects have been considered. The intended application of a PCR is to establish guidelines for the development of environmental product declarations (EPDs) for the product to be evaluated. The following paragraphs examine the relevance of EPD indicators in justifying the usage of ecolabelling for sustainable products in the EU.

The ESPR framework[64] elaborates on specific requirements related to various product characteristics, including durability and reliability, reusability, upgradability, reparability, and maintenance. From an environmental perspective, several requirements are found in the ESPR, such as including the presence of substances of concern, energy and resource efficiency, recycled content, remanufacturing and recycling, carbon and environmental footprints, and waste generation.

The ESPR proposal emphasizes the importance of considering relevant information available from other Union activities and technical documents. Apart from the documents described in Section *2.1.1,* other documents worth attention include Regulation (EC) No 66/2010 on the EU Ecolabel, Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) and the Green Public Procurement criteria (which integrates regulations such as Packing and packaging waste and EU Green Public Procurement criteria for Furniture). These documents provide valuable insights and technical information that are specific to the ecolabelling of certain products.

To materialize the actions of the ESPR, the Ecodesign and Energy Labelling Working Plan 2022-2024 serves as a roadmap for integrating sustainability measures and ensuring the correct ecolabelling of products. This working plan contains a series of tasks integrated into a methodology for the Ecodesign for Energy-related Products. One of the tasks described in the methodology includes the use of LCA to understand which eco-design requirements should be set for the products that are being considered[65]. In this view, LCA is a robust methodology which evaluates the environmental burdens and impacts associated with all stages of a product's life cycle, from raw material extraction to disposal. It is supported by the ISO 14040[52] and ISO 14044[53] standards which provide requirements, guidelines, and principles for conducting LCA studies[66]. Apart from the LCA standards, other several standards serve as support systems for the development of the ESPR. For example, ISO 14067[54] addresses the carbon footprint of products[67]. Also, the ISO 14025[55] and ISO/TS 14027:2017[56] focus on environmental labels and declarations, including the development of product category rules which are part of EPDs[68].

EPDs serve as transparent and reliable sources of information that present verified, objective, and comparable data on the environmental performance of products and services. The fundamental basis of an EPD lies in carrying out an LCA. In accordance with the LCA, the PCRs are the support

for the development of an EPD specific to different product categories. In this way, certain products have a set of PCRs associated with the most relevant environmental indicators needed for their correct ecolabelling.
The EPD International System integrates the LCA related standards to create a harmonized platform for the accurate ecolabelling of products [69]. By utilizing PCR indicators, the EPD International System provides a comprehensive and standardized approach to assess and communicate the environmental performance of products. This system ensures transparency, comparability, and credibility in ecolabelling, enabling consumers to make informed choices regarding sustainable products in the EU. Thus, the utilization of PCR indicators is crucial for ensuring the correct ecolabelling of products in the EU, as mandated by the ESPR.
In summary, PCR indicators use the LCA methodology, facilitating an accurate assessment of the environmental performance of products.

3.4. DPP content

The careful definition of the DPP content is critical for the actual usability and advantage that the DPP is expected to bring. It is crucial, that all the necessary information is included. At the same time every piece of information in the DPP should be justifiable and should serve its purpose in order not to overwhelm the users with information, which might be difficult to analyze.
As described in *Article 9* of the ESPR proposal the information in the DPP should concern the item, the model or the batch, depending on the indication in the delegated acts to be adopted in the future for specific product groups. In DigInTaCE it is T2.1 *Methodologies for digital tracing across value chains* that will evaluate the granularity.

In order to understand what type of information should be included in the DPP the overview in *section 2* of this deliverable was performed. It was clear, that the information included in ESPR proposal is the backbone of the DPPs to be created and that ESPR proposal should be used as core guideline in relation to both content and IT system architecture development. In terms of content, ESPR proposal outlines a number of elements that can be included in the DPPs. These elements can be found in *Annex III.* Based on the DPP data requirements defined in the ESPR proposal (Annex III and *Article 7*), four high level categories of data types were identified, namely:

- Identification related (e.g. unique identifiers of product, facility, manufacturer, economic operator; contact details)
- Circularity and sustainability related data (incl. information on substances of concern)
- Compliance documents (as defined by applicable laws)
- Other (e.g. user manuals, instructions)

Furthermore, an ongoing discourse revolves around the inclusion of data categories related to track and trace events in the DigInTraCE Digital Product Passport (DPP), contemplating whether such information will be incorporated directly into the DPP or made available through the platform.

The presented data groups serve as a starting point for discussion and will be further expanded to more detailed categories.

Identification data are strictly related to identifiers and other relevant information e.g., contact details. In the ESPR proposal, the following types of identifiers are stated: unique product identifier, unique operator identifier, unique facility identifier. Unique identification is a/the central aspect in terms of traceability and should follow standards defined in the ESPR proposal and delegated acts. Companies operating between sectors, should be able to operate based on one identifier only. The unique product identifier will be connected to the data carrier that will be physically present on the product as specified in *Article 9* of ESPR proposal. To ensure interoperability, data carrier and unique product identifier should be based on internationally recognised open standards, as well as be machine readable, structured and searchable. In DigInTraCE, the identification related data for the products are a derivative of the work performed in T2.1 *Methodologies for digital tracing across value chains*.

Circularity and sustainability related information are of special importance and form the core of the DPP concept. Therefore, one of the priorities in terms of DigInTraCE DPP design was to develop an approach on how to address this type of data. Due to lack of delegated acts, there was a need for proactiveness and therefore an approach based on LCA indicators and stemming from the sector's relevant Product Category Rules (PCRs) was developed for sustainability indicators, which has been presented in *Section3.1.* The initial set of sustainability and circularity metrics is presented in *Sections 3.4.1 and 3.4.2*. In the future, social and economic sustainability indicators could be considered to be added.

Compliance documents concern all types of data, records and reports that contain information required by obligatory or voluntarily compliance procedures. The exact content of this data category will be defined in cooperation with DigInTraCE demonstrators, and was already initiated through T2.1 *Methodologies for digital tracing across value chains* through the questionnaire on mapping the information flows across the values chains. A question on compliance documentation and information required under Union law applicable to the product was included, keeping in mind its usefulness for this data category.

On the other hand, the group "**other**" deserves more attention in the next stages of T2.2 as, many different types of information could potentially be included in this category, including product parameters not applicable to other data groups.

An attempt to define the Minimum Viable Information was made with an example provided in Table 3. It needs to be pointed out that, at this timepoint, it is challenging to define this type of information in more detail and prior to discussions with DigInTraCE demonstrators.

Table 3 Example of minimum viable information per data category and relevant ESPR quotation

Data type	Minimum viable information – an example of possible interpretation based on information from *Annex 3* ESPR	Relevant ESPR[1] quotation
Identification related	Unique product identifier	*"A product passport shall meet the following conditions: (a) it shall be connected through a data carrier to a unique product identifier…" (Article 9)*
Circularity &Sustainability	Existing labels	*"The delegated acts adopted pursuant to Article 4 shall identify information relevant to ecodesign requirements that manufacturers may include in the product passport in addition to the information required pursuant to Article 8(2), point (a), including information on specific voluntary labels applicable to the product. That shall include whether an EU Ecolabel has been awarded to the product in line with Regulation (EC) No 66/2010" (Annex 3)*
Compliance	Declaration of conformity	*"Before placing a product covered by a delegated act adopted pursuant to Article 4 on the market or putting it into service, manufacturers shall carry out the conformity assessment procedure specified in the delegated acts adopted pursuant to Article 4 and draw up the required technical documentation, or have it carried out on their behalf.* *Where compliance of a product covered by a delegated act adopted pursuant to Article 4 with the applicable requirements has been demonstrated by that procedure, manufacturers shall draw up an EU declaration of conformity in accordance with Article 37 and affix the CE marking in accordance with Article 39. However, where the Commission has specified alternative rules pursuant to Article 4, third subparagraph, point (f), the manufacturer shall draw up a conformity declaration and affix conformity marking in accordance with those rules." (Article 21)*

An important aspect of the DigInTraCE DPP is the dynamic update of information, which will be based on the data obtained from sensors, such as smart tags combining identification and monitoring, and live LCA. The LCA tool being developed in T3.5 considers a set of dynamic and static input data in the life cycle inventory, which will be assessed to obtain a set of sustainability indicators. The dynamic input data will cause a periodic update of the results which will mean that sustainability indicators will change depending on the dynamic update of inventory information. The target is to have at least 10 real time parameters integrated in the DPP.

3.4.1. Sustainability metrics

In the selection process of the sustainability indicators to be incorporated in the dynamic Digital Product Passports (DPPs) that will be developed in the DigInTraCE project, a rigorous approach has been followed based on the PCRs corresponding to each of the final products obtained in the four demonstrators located in Greece, Spain, Belgium, and Italy. These PCRs represent standardized guidelines that set out the essential criteria and parameters for assessing the environmental impact throughout the life cycle of a product, using the LCA methodology. In addition to providing instructions in terms of life cycle stages to be considered, calculation rules, functional unit and other relevant aspects, each PCR sets out the impact categories to be assessed in addition to the core environmental impact indicators. This approach ensures a consistent assessment of the environmental performance of products within the same category, thus facilitating the comparison of their environmental footprint.
The project implements specific value chains that align with the P4P strategy and focuses on key industrial sectors. These value chains allow testing circular supply chain solutions involving recycling, reuse and, upgrading of materials through optimized chemical processes. In this context, an overview of each of the demonstrators is provided below. Table 4 summarizes the environmental sustainability indicators to be assessed according to each sector/product specific PCR.

3.4.1.1. Selection of sustainability metrics for Greek demonstrator

Chemical industry, pulp & paper, and wood industry sectors are explored, focusing on value chains involving agricultural by-products from oilseed crops and wood by-products from a furniture manufacturer. The process includes protein extraction from oilseed crops, bio-based adhesive production, and the utilization of wood by-products for manufacturing wood-based composites and furniture, with research partners contributing to smart tag methodologies and wood sorter design.
Therefore, in the context of the Greek demonstrator, PCR 2019:14-c-PCR-021 Furniture (c-PCR to PCR 2019:14) (Adopted from EPD Norway)1 has been considered. All references to “NPCR part A” or “Part A” are replaced with references to PCR for construction products (PCR 2019:142). In this case, the indicators used to assess the environmental impact shall follow the guideline set by the PCR 2019:14, which specifies that the results of the indicators shall be reported according to EN 15804:2012+A2:2019/AC:2021, plus the supplementary indicator for climate impact: GWP-GHG. GWP-GHG is identical to GWP-total, except that the characterisation factor (CF) for biogenic CO2 is set to zero.
The environmental performance indicators to be declared are indicated in Table 4.

3.4.1.2. Selection of sustainability metrics for Spanish demonstrator

In the Pulp & paper and wood industry sectors, the demonstrator focuses on ASTI, a Spanish company encompassing the entire wood value chain. This includes processing tree trunks from

[1] PCR 2019:14-c-PCR-021 Furniture (c-PCR to PCR 2019:14) (Adopted from EPD Norway)
[2] PCR 2019:14 Construction products (EN 15804+A2) (1.3.1)

the forest, initial log transformation in the sawmill, and the production of solid wood furniture known for its durability and decorative appeal. For the Spanish demonstrator, it has been decided to consider two different PCRs depending on the products to be obtained:

- **PCR 2022:02 Pulps of wood or other fibrous cellulosic material[70]**

The products covered by this PCR include pulp made from lignocellulosic fibrous materials derived from both wood and non-wood sources, such as fibrous crops or recycled materials obtained through various processes, including chemical, mechanical, or semi-chemical processes.
This PCR defines a special calculation rule for the Global Warming Potential (GWP)-biogenic indicator so that when all LCA steps are summed, a net zero contribution to the GWP-biogenic results for the final product[71]: "*Based on the principle of mass balance, any transfer of biomass and biogenic carbon from previous product systems shall be characterized as -1 kg CO_2 equivalents per kilogram of biogenic carbon dioxide, and any transfer of biomass and biogenic carbon into subsequent product systems shall be characterized as +1 kg CO_2 equivalents per kilogram of biogenic carbon dioxide.*[72]
The environmental performance indicators to be declared are indicated in Table 4. In addition to environmental impact indicators, indicators of resource use and waste production and output flows shall be included as mandatory.

- **PCR 2019:14-c-PCR-006 Being updated - c-PCR-006 Wood and wood-based products for use in construction (EN 16485) (2019-12-20)[73]**

This PCR complements PCR 2019:14 Construction products, so both the guidelines set out in PCR 2019:14 and those specified in EN 15804:2012+A2:2019/AC:2021[74] shall be considered.

The products covered by this PCR include "*all wood and wood-based construction products as well as related construction services for buildings and other construction works*", as stated in EN16485:2014, limited to products that are used as construction products (products used in other applications are outside the scope).
The environmental performance indicators shown in Table 4 are defined according to PCR 2019:14 and EN 16485:2014[75]. As in the Greek demonstrator, indicator results shall be reported according to EN 15804:2012+A2:2019/AC:2021, plus the supplementary climate impact indicator: GWP-GHG. GWP-GHG is identical to GWP-total, except that the characterisation factor (CF) for biogenic CO_2 is set to zero.

3.4.1.3. Selection of sustainability metrics for Belgian demonstrator

The chemical process industry demonstrator targets the enhancement of polyester recycling, particularly for high-demand textile applications. CTB conducts lab-scale processing of end-of-life thermoplastic polyester, aiming to achieve decontamination and upcycling. The recycled polyester is subsequently utilized by SIOEN, a vertically integrated company, to produce PET textiles. CIRCE contributes through value chain mapping, while CTB coordinates the demo and oversees recycling processes. EREMA supports the project by supplying essential secondary raw

materials. The initiative represents a significant step toward expanding the use of recycled polyester in advanced textile applications.
Considering the intended end-product of the Belgian demonstrator, PCR 2013:12 Textile yarn and thread of natural fibres, man-made filaments or staple fibres (3.0)[76] has been considered. The products covered by this PCR include yarns and fibres, natural and man-made, intended for application in various sectors (apparel and household textile, floor covering, upholstery and automotive).
The environmental performance indicators to be declared are indicated in Table 4. In addition to environmental impact indicators, indicators of resource use and waste production and output flows shall be included as mandatory.

3.4.1.4. Selection of sustainability metrics for Italian demonstrator

The demonstrator in the process industry for plastic components in the automotive sector focuses on enhancing the circular economy flow of recycled polymeric materials for injection molding. The system processes heavy and contaminated plastics, handling up to 2000kg/h of flakes. The primary goals include improving the efficiency of polymer detection, enabling the identification and recycling of polymeric compounds, and reducing the incineration of materials. This initiative reflects a commitment to optimizing the utilization of recycled materials in injection molding processes within the automotive sector.
For the Italian demonstrator, **PCR 2018:10 Being updated - Boards, blocks, panels, sheets of plastics, or in composite system, for structural application (non-construction) (1.0.2)** has been considered. This PCR covers plastic core materials or formulated with polymeric binder. However, it is not applicable to strips, as well as films and sheets that do not have mechanical properties suitable for use in composite systems.
The environmental performance indicators to be declared are indicated in Table 4. In addition to environmental impact indicators, indicators of resource use and waste production and output flows shall be included as mandatory.

Table 4 List of potential sustainability indicators applicable to the DigInTraCE project according to the PCR considered for each demonstrator. "X" denotes indicators that are mandatory to be assessed according to their PCR, while "opt" denotes optional ones.

			Greek Demonstrator	Spanish Demonstrator		Belgian Demonstrator	Italian Demonstrator
Product Category Rules (PCR)		**Unit**	PCR 2019:14-c-PCR-021 Furniture (c-PCR to PCR 2019:14) (Adopted from EPD Norway)	PCR 2022:02 Pulps of wood or other fibrous cellulosic material	PCR 2019:14-c-PCR-006 Being updated - c-PCR-006 Wood and wood-based products for use in construction (EN 16485) (2019-12-20)	PCR 2013:12 Textile yarn and thread of natural fibres, man-made filaments or staple fibres (3.0)	PCR 2018:10 Being updated - Boards, blocks, panels, sheets of plastics, or in composite system, for structural application (non-construction) (1.0.2)
Indicators							
Environmental impact indicators	Global warming potential-greenhouse gases (GWP-GHG)	kg CO2 eq	X	-	X	-	-
	Global warming potential-total (GWP-total)	kg CO2 eq	X	X	X	X	X
	Global warming potential-fossil (GWP-fossil)	kg CO2 eq	X	X	X	X	X
	Global warming potential-biogenic (GWP-biogenic)	kg CO2 eq	X	X	X	X	X
	Global warming potential-land use and land use change (GWP-luluc)	kg CO2 eq	X	X	X	X	X
	Ozone depletion potential (ODP)	kg CFC 11 eq	X	X	X	X	X
	Acidification potential (AP)	mol H eq	X	X	X	X	X
	Eutrophication potential (EP-freshwater)	kg P eq	X	X	X	X	X
	Eutrophication potential (EP-marine)	kg N eq	X	X	X	X	X
	Eutrophication potential (EP-terrestrial)	mol N eq	X	X	X	X	X
	Photochemical ozone creation potential (POCP)	kg NMVOC eq	X	X	X	X	X
	Abiotic depletion potential (ADP) for minerals and metals	kg Sb eq	X	X	X	X	X
	Abiotic depletion potential (ADP) for fossil resources	MJ	X	X	X	X	X
	Water deprivation potential (WDP)	m3	X	X	X	X	X
	Emission of particulate matter	Disease incidence	X	opt	X	opt	opt
	Ecotoxicity (freshwater)	CTUe	X	opt	X	opt	opt

	Human toxicity, carcinogenic effects	CTUh	X	opt	X	opt	opt
	Human toxicity, non-carcinogenic effects	CTUh	X	opt	X	opt	opt
	Ionizing radiation, human health	kBq U235 eq.	X	opt	X	opt	opt
	Impacts of land use and land use change	Dimensionless	X	opt	X	opt	opt
Resource use indicators	Primary energy resources - Renewable	MJ	X	X	X	X	X
	Primary energy resources - Non-renewable	MJ	X	X	X	X	X
	Secondy material	kg	opt	opt	opt	opt	opt
	Renewable secondary fuels	MJ	opt	opt	opt	opt	opt
	Non-renewable secondary fuels	MJ	opt	opt	opt	opt	opt
	Net use of fresh water	m3	opt	opt	opt	opt	opt
Waste and output flows indicators	Hazardous waste disposed	kg	opt	X	opt	X	X
	Non-hazardous waste disposed	kg	opt	X	opt	X	X
	Radioactive waste disposed	kg	opt	X	opt	X	X
	Components for reuse	kg	opt	X	opt	X	X
	Materials for recycling	kg	opt	X	opt	X	X
	Materials for energy recovery	kg	opt	X	opt	X	X
	Exported energy, electricity	MJ	opt	X	opt	X	X
	Exported energy, thremal	MJ	opt	X	opt	X	X

3.4.2. Circularity Indicators

As introduced before, the use of LCA indicators is useful in measuring environmental sustainability because it assesses the impacts at a whole value chain level, avoiding the potential tradeoffs from those impacts amongst life cycle stages. However, using circularity indicators adds value to the decision-making process because they make up for those difficulties that LCA indicators might show in terms of measuring circularity.

Table 6 shows an overview of potential circularity indicators which can be useful for measuring the circularity of the products in the different value chains in DigInTraCE. Although they have been extracted from studies which have applied them to several value chains, they can all be applied to plastic and wood- based value chains.

Some observations can be made considering the information from the table, which shows an array of indicators used for measuring product level circularity. At a first glance, it should be highlighted that the MCI is one of the most used indicators to measure product-level circularity in terms of citations, eligibility, and completeness[77]. It can also be appreciated that some indicators consider an economic perspective, and others only consider a mass perspective which can require inputs from the PCR indicators regarding resource use. Furthermore, since some indicators require several inputs from different stages of the life cycle of a product, they will potentially require the inputs of a Bill of Materials (BOM), which potential availability should be discussed with DigInTraCE demonstrators. As a final remark, it should be highlighted that the availability of the data along with the developments of the project will allow for a further selection of the final indicators which will be used in the LCA tool that will be integrated into the DigInTraCE platform.

Table 5 List of potential circularity indicators applicable to DigInTraCE project.

Indicators' full name	Indicator	Description	Source
Material Circularity indicator	MCI	Provides an indication of the amount of a product's material which is circular. It builds on the combination of the raw virgin material used in the manufacturing stage, the mass of non-recoverable waste in the product, and the intensity and duration of the product's use phase.	Ellen MacArthur Foundation and Granta (2015)[78]
Material Reutilization Score	MRS	A ratio between the intrinsic recyclability of a product and its recycled content.	Moraga et al (2021) [79]
Circular economy performance indicator	CPI	The ratio between the actual obtained environmental benefit of the waste treatment option and the ideal environmental benefit according to quality. The environmental benefit is expressed in terms of the natural resource consumption, an indicator found in several impact assessment methods in LCA.	Huysman et al. (2017) [80]

Circular Economy Index	CEI	The ratio between the material value produced by the recycler (market value) and the material value entering the recycling facility. Indicates the effectiveness of recycling firms at extracting value from processed materials.	Di Maio and Rem (2015) [81]
Product-Level Circularity Metric	PLCM	This indicator uses economic value as the basic unit for aggregating product parts and it consists of the ratio between recirculated and total economic product value.	Linder and Sarasini (2017)[82]
Recycled content	RecC	The proportion of materials or components in a product that are made from previously recycled materials, typically expressed as a percentage mass.	Pauer et al (2019)[83]
Reuse rate	ReuR	The percentage of a material that is re-used for its original or similar purpose, without undergoing significant processing or alteration.	
Renewable content	RenC	The percentage of materials in a product that comes from sustainable, replenishable sources, such as plants or animals, and can be regenerated within a relatively short timeframe.	
Recyclability	R	The ability of a product or material to be recycled, typically measured as a property of the material itself.	
Recycling rate or recycling output rate	RR/RoR	The ratio between the useful amount of product that is recycled and the actual product that enters the recycling process.	
Downcycling factor	DF	A measure of how much the quality or value of a material or product decreases when it is recycled, typically expressed as a ratio or percentage, indicating the loss in quality during the recycling process	
Compostability	Com	The capability of a product or material to break down into natural, non-toxic substances when subjected to composting conditions, contributing to organic waste recycling.	

3.5. DPP users

According to ESPR the DPP aims to enable data sharing between supply chain companies, consumers and authorities. Additionally, the supply chain information can be produced by upstream data providers and downstream data providers[84]. In DigInTraCE demonstrations, the emphasis is given to the value chain actors operating upstream providing data related to cradle to gate. While the downstream users producing data related to usage history, EoL, etc.1,)[83] are not represented in DigInTraCE. Having in mind the possible future replication activities, both groups were addressed in an initial analysis in terms of viewing and editing data types defined earlier in this section (Table 6). ESPR[1]

proposal states, that the access to the information available in the DPP will be ruled by the rights depending on the role in the supply chain and shall be defined by the respective delegated acts. In the light of upcoming implementation of the DigInTraCE DPP, an attempt to define the major differences in the access to different groups of information (as described in *Section 3.1*) between different DPP user types has been made. The rights related to viewing and editing (including input of data, modifications and updates) of different groups of data have been considered. It can be noticed that, data provision is the domain of supply chain businesses, while consumers and authorities are expected to have access rights related mainly to viewing the data with different level of detail (authorities – detailed view, consumers – simplified). An exception to this would be compliance data, where authorities could be allowed to verify documents, if needed. The analysis provided in Table 6 (and 7) can be used as a starting point for the discussions in Task 2.4 *Specifications definition and architecture for DigInTraCE platform"* and T4.2 *Blockchain and Distributed ledger and secure systems development* and was performed at this point, as this type of information is needed by DigInTraCE prior to being available through relevant delegated acts, where it will be specified.

Table 6 Potential DPP Users and data

Data groups \ User groups			Supply chain actors			Authorities	
	Example	Rights	Downstream	Upstream	Consumers		ESPR Relevance
Identification related	Unique identifiers (product, manufacturer, facility), Global Trade Identification Number, Taric code	Editing	Yes: related to product & actor	Yes: related to actor only	No	To be defined	Annex III
		Viewing	Yes (selective, to be defined)		Yes, the level of detail to be defined	Yes, detailed view	
Circularity & sustainability related	Carbon and environmental footprint, Presence of substances of concern, information on disposal and EoL	Editing	Yes, related to design, environmental performance, etc.	Yes, data related to repair, EoL	No	No	Article 7
		Viewing	Yes, the level of detail to be defined		Yes, simplified view, tbd, Ecolabels	Yes	
Compliance data (obligatory & voluntary)	Compliance documents e.g. REACH	Editing	Yes, to be defined based on regulations		No	Yes, allowed to marked that document was verified and add comments	Annex III
		Viewing	Yes, to be defined		Yes, simplified view, e.g. "this product complies with obligatory regulations"	Yes, detailed view: including access to documents	
Other	manuals, instructions	Editing	yes	no	no	no	Annex III
		Viewing	Yes (selective, to be defined)				
Track & Trace	Location and time of events	Editing	Yes, in terms of actor relevant information		No	No	
		Viewing	Yes (detailed view with more info)		Yes (simplified view with less info)	Yes, detailed view: all tracing data visible	

In Table 7, an attempt was made to present how the general approach presented in Table 6 could be implemented in one of the DigInTraCe cases. A visual in Figure 7 with activities of Greek demonstrator corresponds with information in Table 7. In order to proceed with the design of the DigInTraCE DPPs it is crucial to define actors, that will be the actual economic operators placing products on the market, as those actors are responsible for making the relevant information available to stakeholders[1]. In case of the DigInTraCE Greek demonstrator, two potential actors with such role have been identified, namely CHIMAR that produces particleboards, plywood panels and bio-based adhesives and Menexes producing furniture and being the actual user of the Chimar products. The possible scenario, where both Menexes and CHIMAR are considered as economic operators placing products on the market, is presented in Table 7. It is visible, that those two actors have broader rights, especially in terms of editing data, than other actors involved in the value chain. Other actors of the value chain are: i) Agroinvest, the supplier of secondary resources, ii) NTUA, responsible for extraction of proteins that are used by CHIMAR, iii) ICCS, sorting technology developed and iv) VTT, Smart-tags technology provider.

Other possible scenario is that it is only Menexes, that is considered the economic operator placing product on the market, with CHIMAR having extended editing rights in the DPP related to their products. It should be pointed out, that after this initial analysis the partners will be contacted for consultation and final roles will be defined, including the decision on the DPP design proposed per case.

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Table 7 Data groups and users, Greek demo example.

Users / Data			Supply chain actors					
			Economic operators placing products on the market		Other actors involved in the value chain			
Data groups	Data type	Rights	CHIMAR	Menexes	Biomass supplier	NTUA	ICCS	VTT
			Economic operator placing i) particleboard and ii) plywood panels on the market	Economic operator placing furniture on the market	Supplier of secondary resources	extraction of proteins from the oilseed crops	Sorting mechanism provider	Smart-tags provider
Identification related	Static	Editing	Yes, advanced editing: company & product info		Yes, basic editing: company info only			
		Viewing	Yes, the level of detail to be defined					
Circularity & sustainability related	Dynamic & Static	Editing	Yes, the level of detail to be defined					No
		Viewing	Yes, the user can see the information provided by other actors of supply chain					
Compliance data (obligatory & voluntary)	Static	Editing	Yes, if needed they will be able to add information about compliance					No
		Viewing	Yes, general view: name of the document & verification information					
Other	Static (e.g. manuals) & possibly dynamic (related to parameters)	Editing	yes	yes	To be decided			
		Viewing	Yes (selective, to be defined)					
Track & Trace	Dynamic	Editing	yes					
		Viewing	Yes, selective to be defined					

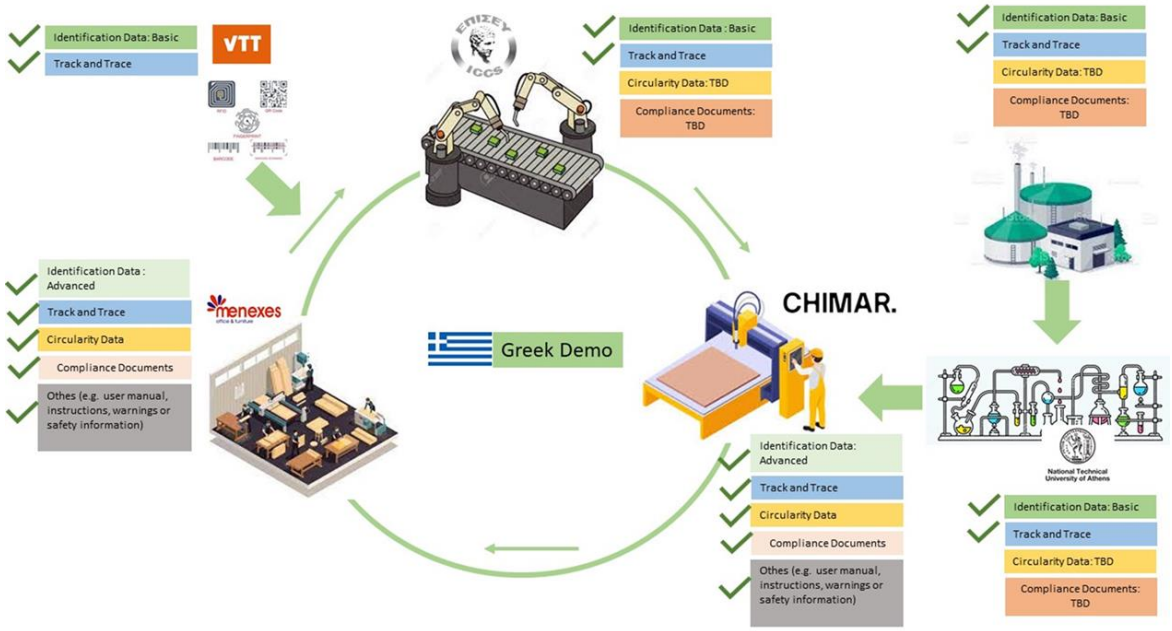

Figure 7 Stakeholders of the Greek demonstrator and corresponding data groups they will provide information for the DPP

3.6. Challenges and undertaken strategies

The content presented in this deliverable will be further enhanced with the approach presented here was aimed to be kept as general as possible at this early stage of the project, allowing for flexibility and further modifications in the future. In Table 8, main challenges encountered during this initial stage of DPP design preparation are presented and main strategies on how those challenges were addressed.

Table 8 Main identified challenges and strategies to be followed

Challenge	Strategies
The work on legislations is ongoing. Only general guidelines available	• Continuous monitoring of the current state of the relevant legislative acts • Development of flexible approach, that can account for future modifications/additions. • Participating in events on DPPs by the DPP development team • Cooperation with DigInTraCE sister projects
The delegated acts are not available at this stage	• Assuring flexibility in the approach • Emphasis on involvement of demonstrators, Industry - demo driven approach • The LCA and PCR based approach to the initial selection of sustainability metrics
A multitude of existing Digital Product Passport (DPP) initiatives and approaches lack homogeneity	• Focus on reviews of existing initiatives in terms of existing trends rather than on single projects, etc.

	• Relying on legislation as the primary source of guidance, with a specific emphasis on ESPR, rather than adhering to patterns introduced by other initiatives • Favor standards-based approaches
Complexity of the DigInTraCE flows	• Initial focus on flows rather than on the whole sector • Different options are presented, which will be further analyzed together with demonstrators
Difficulty to define Minimum Viable Information at this timepoint	• An attempt was made to provide preliminary MVI based on the information available in ESPR proposal • Consultation with demonstrators are expected to facilitate definition of the DPP content
The DPP should contain all the necessary data, but at the same time should not be overwhelming making it difficult for the partners to use it	• Consultations with demonstrators to assure the relevance of data included in the DPP • User rights will assure, that the actor sees only the relevant information
Number of standards, that are related to DPP exists, need for creation of new standards has been pointed out by European Commission	• DPP development team will keep updating themselves on the updates in the field • DPP development team will consult DS on the issue

The Commission also acknowledges themselves open aspects for ESPR and DPP related to e.g.

- product group prioritization,
- requirements for large enterprises vs. SMEs,
- item, batch or product level requirements,
- data storage managed by companies or the EU,
- selection of data carrier technology,
- management of data access per stakeholder group, and
- data requirements and governance.

3.7. Towards the final version of the DPP – next steps

Following, the next steps of the work to be performed within T2.2 leading to the final version of the DigInTraCE DPP concept have been distinguished:

- Examination of sector-specific legislation that has been recognized.
- Conducting a workshop with demonstrators to gather feedback.
- Dialogues with Danish Standards (DS) for coordinating actions concerning standards within the scope of T7.1 (Standardization and certification schemes).
- Exploring the potential integration of sorter-obtained data with the Digital Product Passport (DPP) to augment dynamic data exchange.

- Pending decisions regarding the incorporation of the tracing aspect, whether in the DPP or on the DigInTraCE platform.

3.8. DigInTraCE DPP design – summary

The most important conclusions for the DPP implementation in DigInTraCE context emerging from D2.4:

- ESPR proposal forms the backbone of the DigInTraCE approach.
- All of the DigInTraCE sectors fall under the ESPR proposal, meaning that it will be obligatory for them to implement DPP.
- The information to be included in the DPP will consist of the following layers: I) general – common for all the sectors II) sector/product specific. Some of the content will be obligatory, while other not.
- The DPP content has been divided into 4 main categories to be further analysed and expanded: i) identification related, ii) sustainability and circularity related, iii) compliance documentation and, iv) other. Additionally, the track and trace data (as possible 5th category) is pending the decision whether to be included in the DPP content or not.
- According to ESPR proposal, the requirements for specific product groups will be specified by delegated acts. The DPPs to be developed in DigInTraCE should apply the general suggestions on the content to the extent applicable per DigInTraCE case. This concerns a list of elements that shall or may be included in the DPPs, with some examples being: unique product identifier, Global Trade Identification Number, compliance codes, requirements concerning substances of concern, user manuals, warnings or safety information (full list is available in *Article 7* and *ANNEX III* of the ESPR proposal).The exact content of the DigInTraCE DPPs will follow a per case approach and will be defined in cooperation with the Demonstrators, to assure compliance with regulations that might be already in place and that DPP should complement.
- Need for DigInTraCE teams working on DPP to monitor the legislative landscape to stay updated on the regulations as well as developments related to standards.
- An attempt to present the minimum viable information using examples from ESPR proposal has been undertaken to be further revised in cooperation with other partners.
- An LCA and PCR based approach for sustainability indicators has been presented with sector-based PCRs implementing sector specific approach.
- Potential list of circularity indicators applicable to DigInTraCE project has been presented.
- Three main user groups of the DPP has been considered based on the ESPR: supply chain companies, consumers and authorities. Their access rights to specific content of the DPP and their obligations in terms of updating the tool with required data is discussed.
- Use cases of the DPP will be established at flow level with first attempt in terms of user groups and their possible access rights being presented for the Greek Demonstrator.
- A workshop with DigInTraCE project industries and other relevant stakeholders will be organized under the umbrella of T2.2. The initial DPP concept will be presented and feedback from stakeholders will be collected to assure that all the necessary aspects are properly addressed constituting stakeholder driven approach.
- Dynamic update of information in the DPP will be based on the data obtained from sensors and LCA tool. The target is to have Min. 10 real time parameters integrated in the DPP.

- The ESPR proposal defines also the technical aspects of the DPP: those should apply to all product groups.
- Data harmonization needs to be paid special attention to as the DPP will integrate data of different types and from diverse sources into one system having unified view.

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Conclusions

In summary, D2.4 “Digital Product Passport Concept v1”, sets the foundation for the strategic roadmap in crafting Digital Product Passports (DPPs) tailored to the DigInTraCE demonstrations. It offers a preliminary insight into the content and technical development approach of DPPs. Given the ongoing EU-level discussions on DPP development and concurrent legislative advancements, the approach taken is designed to adapt to emerging legal frameworks.

This document represents the first step in the development of DPPs within the DigInTraCE project, with further refinement and delivery anticipated in D2.5 Digital Product Passport Concept v2 at M24. The primary goal is to align DPPs with existing product information schemes and regulatory frameworks, ensuring seamless integration into the digital product management landscape.

Central to this conceptual phase is Task T2.2, a critical component in refining regulated or voluntary product information schemes, ensuring compliance, and addressing the complexities of contemporary product management. Diverse usage scenarios are explored to meet the needs of stakeholders, and this work continues into D2.5 and T4.1 implementation.

The DPPs described in this document are dynamic entities, capable of continual benchmarking against evolving standards and requirements. They incorporate sustainability and circularity metrics, reflecting the holistic approach expected by forthcoming European Commission regulations. Sustainability metrics are dynamically curated through a responsive Life Cycle Assessment (LCA) environmental tool.

The document highlights the role of the project demonstrators in shaping the DPP landscape and outlines the integration of sustainability and circularity metrics within DigInTraCE, providing a roadmap for similar initiatives. It delves into the metrics and indicators used to enhance circularity within the DPP framework, fostering a culture of sustainability in product lifecycles. Stakeholder identification and their roles are detailed, along with the challenges encountered during DPP formulation and the strategic measures employed to overcome them. This transparent approach adds authenticity and offers valuable insights for similar initiatives in digital product management.

In conclusion, this document serves as a comprehensive guide to DPP development within DigInTraCE, navigating the complexities and challenges of digital product information management, and setting the stage for a new paradigm in DPP implementation.

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References

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A0142%3AFIN
[2] https://eur-lex.europa.eu/eli/reg/2006/1907/2023-08-06
[3] https://eur-lex.europa.eu/eli/reg/2008/1272/2023-07-31
[4] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32001L0095
[5] https://echa.europa.eu/support/registration/your-registration-obligations/do-i-reach-the-one-tonne-a-year-threshold#:~:text=If%20you%20manufacture%20or%20import,you%20need%20for%20your%20registration.
[6] https://environment.ec.europa.eu/strategy/plastics-strategy_en
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN
[8] https://echa.europa.eu/regulations/clp/understanding-clp
[9] https://www.hse.gov.uk/chemical-classification/legal/background-directives-ghs.htm#:~:text=The%20GHS%20aims%20to%20ensure,transport%20and%20use%20of%20chemicals.
[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32010R0995
[11] https://single-market-economy.ec.europa.eu/single-market/european-standards/harmonised-standards_en
[12] Guillaume, E, de Feijter, R, van Gelderen, L. An overview and experimental analysis of furniture fire safety regulations in Europe. *Fire and Materials*. 2020; 44: 624–639. https://doi.org/10.1002/fam.2826
[13] https://single-market-economy.ec.europa.eu/sectors/raw-materials/related-industries/forest-based-industries/strategy-forest-based-industries_en#:~:text=Blueprint%20for%20the%20EU%20forest%2Dbased%20industries&text=One%20example%20is%20to%20further,%2Deconomy%20and%20bio%2Denergy.
[14] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:285:0010:0035:en:PDF
[15] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1369
[16] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:174:0088:0110:en:PDF
[17] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019#:~:text=This%20Directive%20lays%20down%20measures,of%20such%20use%20in%20accordance
[18] http://publications.europa.eu/resource/cellar/85f446fd-05a5-47d7-b0d3-96418710a1e0.0011.02/DOC_1#:~:text=Textile%20products%20shall%20be%20labelled,of%20a%20label%2C%20securely%20attached.
[19] https://ce-rise.eu/
[20] https://www.plooto-project.eu/
[21] https://cirpassproject.eu/
[22] CIRPASS Project FAQ Available online: https://cirpassproject.eu/faq/ (accessed on May 10, 2023)
[23] Colledani, M. A. (2023). D3.1 Benchmark of existing DPP-oriented reference architecture, CIRPASS project.
[24] University of Cambridge Institute for Sustainability Leadership (CISL) and the Wuppertal Institute. (2022). Digital Product Passport: the ticket to achieving a climate neutral and circular European economy? Cambridge,
UK: CLG Europe.

DigInTraCE

[25] https://unfccc.int/process-and-meetings/the-paris-agreement
[26] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32006L0066
[27] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52020PC0798
[28] https://www.consilium.europa.eu/en/press/press-releases/2023/07/10/council-adopts-new-regulation-on-batteries-and-waste-batteries/#:~:text=The%20new%20regulation%20aims%20to,batteries%20placed%20on%20the%20market.
[29] https://data.consilium.europa.eu/doc/document/PE-2-2023-INIT/en/pdf
[30] https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2312
[31] Blackstone, J., 2013. Apics dictionary. the essential supply chain reference.
[32] van Capelleveen, G., Vegter, D., Olthaar, M., & van Hillegersberg, J. (2023). The anatomy of a passport for the circular economy: a conceptual definition, vision and structured literature review. Resources, Conservation & Recycling Advances, 17, 200131. https://doi.org/10.1016/j.rcradv.2023.200131
[33] https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en
[34] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0125
[35] https://circthread.com/
[36] https://catena-x.net/
[37] https://www.youtube.com/watch?v=6WhogezxioI
[38] Circular economy - Product Circularity Data Sheet - Methodology and requirements, ISO/DIS 59040. https://www.iso.org/standard/82339.html
[39] Batch control - Part 1: Models and terminology, EN 61512-1. Brussels: CENELEC
[40] Information and documentation - Digital object identifier system, ISO 26324:2012. https://www.iso.org/standard/43506.html
[41] Information technology - Database languages - SQL, ISO/IEC 9075-1:2023. https://www.iso.org/standard/76583.html
[42] Information technology - Metadata registries (MDR) - Part 1: Framework, ISO/IEC 11179-1:2023. https://www.iso.org/standard/78914.html
[43] Information technology - Radio frequency identification (RFID) for item management - Data protocol: Data encoding rules and logical memory functions, ISO/IEC 15961:2004. https://www.iso.org/standard/30528.html
[44] Information technology - JAB code symbology specification, ISO/IEC 23634:2022. https://www.iso.org/standard/76478.html
[45] Information technology - Unique identification - Part 1: Unique identifiers and their assignment, ISO/IEC 15459-1:2014. https://www.iso.org/standard/54779.html
[46] Information technology - Unique identification - Part 2: Registration procedures, ISO/IEC 15459-2:2015. https://www.iso.org/standard/54780.html
[47] Information technology - Unique identification - Part 3: Common rules for unique identifiers, ISO/IEC 15459-3:2014. https://www.iso.org/standard/54781.html
[48] Information technology - Unique identification - Part 4: Individual items, ISO/IEC 15459-4:2014. https://www.iso.org/standard/54782.html
[49] Information technology - Unique identification - Part 5: Returnable transport items (RTIs), ISO/IEC 15459-5:2014. https://www.iso.org/standard/54785.html
[50] Information technology - Unique identification - Part 6: Groupings, ISO/IEC 15459-6:2014. https://www.iso.org/standard/54786.html

DigInTraCE

[51] Information technology - Product information representation, ISO/IEC 22603-2:2022. https://www.iso.org/standard/82070.html

[52] Information technology - EAN/UCC Application Identifiers and Fact Data Identifiers and Maintenance, ISO/IEC 15418:2016. https://www.iso.org/standard/67405.html

[53] Information technology - Security techniques - Information security management systems - Requirements, ISO/IEC 27001. https://www.iso.org/standard/27001

[54] ISO 14040:2006, Environmental management — Life cycle assessment — Principles and framework, https://www.iso.org/standard/37456.html

[55] ISO 14044:2006, Environmental management — Life cycle assessment — Requirements and guidelines, https://www.iso.org/standard/38498.html

[56] ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification, https://www.iso.org/standard/71206.html

[57] ISO 14025:2006 Environmental labels and declarations — Type III environmental declarations — Principles and procedures, https://www.iso.org/standard/38131.html

[58] ISO/TS 14027:2017, Environmental labels and declarations — Development of product category rules, https://www.iso.org/standard/66123.html

[59] https://www.gs1.org/standards/gs1-digital-link

[60] Linder M., Sarasini S., van Loon P., (2017) ''A Metric for Quantifying Product-Level Circularity.'' J Ind Ecol

[61] Bracquené E., Dewulf W., Duflou J. R., (2020),'' Measuring the performance of more circular complex product supply chains.'' Resources, Conservation & Recycling 154.

[62] Peña C, Civit B, Gallego-Schmid A, Druckman A, Caldeira- Pires A, Weidema B, Mieras E, Wang F, Fava J, Milà i Canals L, Cordella M, Arbuckle P, Valdivia S, Fallaha S, Motta W (2021) Using life cycle assessment to achieve a circular economy. Int J Life Cycle.

[63] Melanie Haupt M., Zschokke, M., (2016) How can LCA support the circular economy? —63rd discussion forum on life cycle assessment, Zurich, Switzerland. International Journal of Life Cycle Assessment

[64] European Commission, 2022. ''Proposal for a regulation of the European Parliament and of the Council establishing a framework for setting eco design requirements for sustainable products and repealing Directive 2009/125/EC.

[65] Official Journal of the European Union. 2022. ''Ecodesign and Energy Labelling Working Plan 2022-2024''

[66] European Committee for Standardisation, 2006. Environmental management. Life cycle assessment. Principles and framework. Requirements and guidelines

[67] European Committee for Standardisation, 2018. Greenhouse gases. Carbon footprint of products. Requirements and guidelines for quantification

[68] European Committee for Standardisation, 2020. Environmental labels and declarations — Type III environmental declarations — Principles and procedures — Development of product category rules

[69] Environdec- EPR International, 2023: https://www.environdec.com/faq#epdfaq

[70] PCR 2022:02 Pulps of wood or other fibrous cellulosic material

[71] Except for any biogenic carbon share that is converted to methane, CO or N2O.

[72] 4.7.4 SPECIAL CALCULATION RULES: GLOBAL WARMING POTENTIAL (GWP) – BIOGENIC

[73] PCR 2019:14 Construction products (EN 15804+A2) (1.3.1)

[74] EN 15804:2012+A2:2019/AC:2021, Sustainability of construction works — Environmental product declarations – Core rules for the product category of construction products.

DigInTraCE

[75] EN 16485:2014 Round and sawn timber – Environmental Product Declarations – Product category rules for wood and wood-based products for use in construction.
[76] PCR 2013:12 Textile yarn and thread of natural fibres, man-made filaments or staple fibres (3.0)
[77] Bracquené E., Dewulf W., Duflou J. R., (2020),'' Measuring the performance of more circular complex product supply chains.'' Resources, Conservation & Recycling 154.
[78] Ellen MacArthur Foundation and Granta, (2015), ''Circular Indicators: An approach to measuring circularity.'' Methodology. vol. 23
[79] Di Maio, Rem F., (2015) ''A Robust Indicator for Promoting Circular Economy through Recycling.'' J Environ Prot.
[80] Huysman S., De Schaepmeester J., Ragaert K., Dewulf J., De Meester S. (2017). ''Performance indicators for a circular economy: A case study on post-industrial plastic waste''. Resour Conserv Recycl.
[81] Di Maio and Rem (2015)
[82] Linder M., Sarasini S., van Loon P., (2017) ''A Metric for Quantifying Product-Level Circularity.'' J Ind Ecol
[83] Pauer, E., Krauter, V., Wohner B., Tacker M. (2019) ''Assessing the Environmental Sustainability of Food Packaging: An Extended Life Cycle Assessment including Packaging-Related Food Losses and Waste and Circularity Assessment'' Sustainability
[84] Eduard Wagner, Boriana Rukanova, Carolynn Bernier, Thibaud Wautelet, Anne-Christine Ayed, Marvin Böll, Jens Gayko, Andreas Schneider, Konrad Bendzuck, Ilka von Dalwigk, "D2.1 Mapping of legal and voluntary requirements and screening of emerging DPP-related pilots", (07/2023) CIRPASS project.