CIRPASS
Digital Product Passport

Cross-sector and sector-specific DPP roadmaps

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21	BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG	BAM	DE
22	SyncForce BV	SyncForce	NL
23	ASOCIACION DE EMPRESAS TECNOLOGICAS ES INNOVALIA	INNOVALIA	ES
24	Textile Exchange	TextileExchange	US
25	Responsible Business Alliance	RBA	US
26	WORLDLINE FRANCE	WORLDLINE	FR
27	RISE RESEARCH INSTITUTES OF SWEDEN AB	RISE	SE
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Preparing the ground for the gradual piloting and deployment of the DPPs from 2023 onwards, focusing on developing a roadmap for prototypes in three value chains: electronics, batteries, and textiles.

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API	Application Programming Interface
CEAP	Circular Economy Action Plan
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CEOP	Circular Economy Operator
CSDDD	Corporate Sustainability Due Diligence Directive
DA	Delegated Act
DPP	Digital Product Passport
EBSI	European Blockchain Services Infrastructure
EC	European Commission
EEE	Electrical and Electronic Equipment
EIB	European Investment Bank
ELI	European Legislation Identifier
EPREL	European Product Registry for Energy Labelling

ERP	Enterprise Resource Planning
ESPR	Ecodesign for Sustainable Products Regulation
EV	Electric Vehicle
IA	Implementation Act
IMDS	International Material Data System
IP	Intellectual Property
JRC	Joint Research Centre of the European Commission
LMT	Light Means of Transport
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
PIM	Product Information Management
PLM	Product Lifecycle Management
POS	Point of Sale
REACH	Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals
REO	Responsible Economic Operator (legally responsible for issuing DPPs)
SoH	State of Health (of a battery)
SReq	Standardisation Request
UPI	Unique Product Identifier
WEEE	Waste Electrical and Electronic Equipment

1 Executive summary

This report aims to provide both a cross-sector system roadmap, as well as sector-specific roadmaps, for the development and large-scale implementation of a functioning Digital Product Passport (DPP) that effectively supports the circular economy in the EU. The sector-specific DPP roadmaps in this report relate to the batteries, electronics, and textiles sectors and cover the period 2024 to 2027.

Cross-sector DPP system roadmap

The main **driver** of the cross-sector DPP system is the upcoming Ecodesign for Sustainable Products Regulation (ESPR), which is closely linked to the EU's Circular Economy Action Plan (CEAP). Beyond 2027, we expect economic factors, like increasing costs for critical raw materials (CRMs), to gain importance in driving industry across sectors to embrace the opportunities of data-driven circularity enabled by the DPP.

Based on the ESPR requirements, the **DPP system architecture** will be decentralized, enabling a high degree of interoperability and the ability for economic operators to connect their existing IT systems.

Concerning **technologies**, since the DPP system will rely heavily on the use of existing and widely deployed Web and Semantic Web technologies and associated standards, the DPP system architecture will cater to both the need for mandatory DPPs in 2027 and the need to enable progressive integration of advanced digital technologies further in the future. In relation to this, open questions remain concerning the choice and evolution of data carriers for different uses in different sectors.

With regards to **standardisation gaps**, a standardisation request by the EC to CEN/CENELEC is ongoing, with the aim to review and develop a set of harmonised standards that will enable an interoperable, fully operational DPP-system. The deadline for delivering the requested standards is 31 December 2025.

DPPs are created, enabled, and used by various actors, which we call **DPP system actors**. These include responsible economic operators (REOs), which are defined in this report as economic actors who will have the regulatory obligation to issue DPPs and populate these with data; and data users, such as circular economy operators (CEOPs), public authorities and consumers. The DPP-readiness of data providers will have a large impact on the effectiveness of the DPP system in generating the envisaged circularity impacts. For this reason, DPP-as-a-Service (DPPaaS) providers are considered to have an important enabling role in supporting REOs, CEOPs and other value chain actors with DPP deployment and compliance, and the reaping of economic benefits from the DPP.

Resources, including data ecosystems, pilot projects, and mechanisms for knowledge transfer and financial support, will play an important role in the deployment of the DPP system. In view of the complexity of the DPP endeavour, these resources will be critical to avoid the emergence among stakeholders of feelings of confusion, scepticism and, finally, rejection, which may lead to delays in implementation and in reaping associated benefits. Such resources will be particularly important for accelerating the DPP-readiness of SMEs.

Sector-specific DPP roadmap for batteries

The DPP for batteries will enter into force in February 2027. The roadmap explores what needs to happen by then and how the DPP could drive circularity in the sector. The surge in EV battery demand,

and the limited supply of CRMs required to produce them, add urgency to the need to get the battery passport up to speed. To this purpose, we recommend adapting and expanding existing data ecosystems as well as other measures.

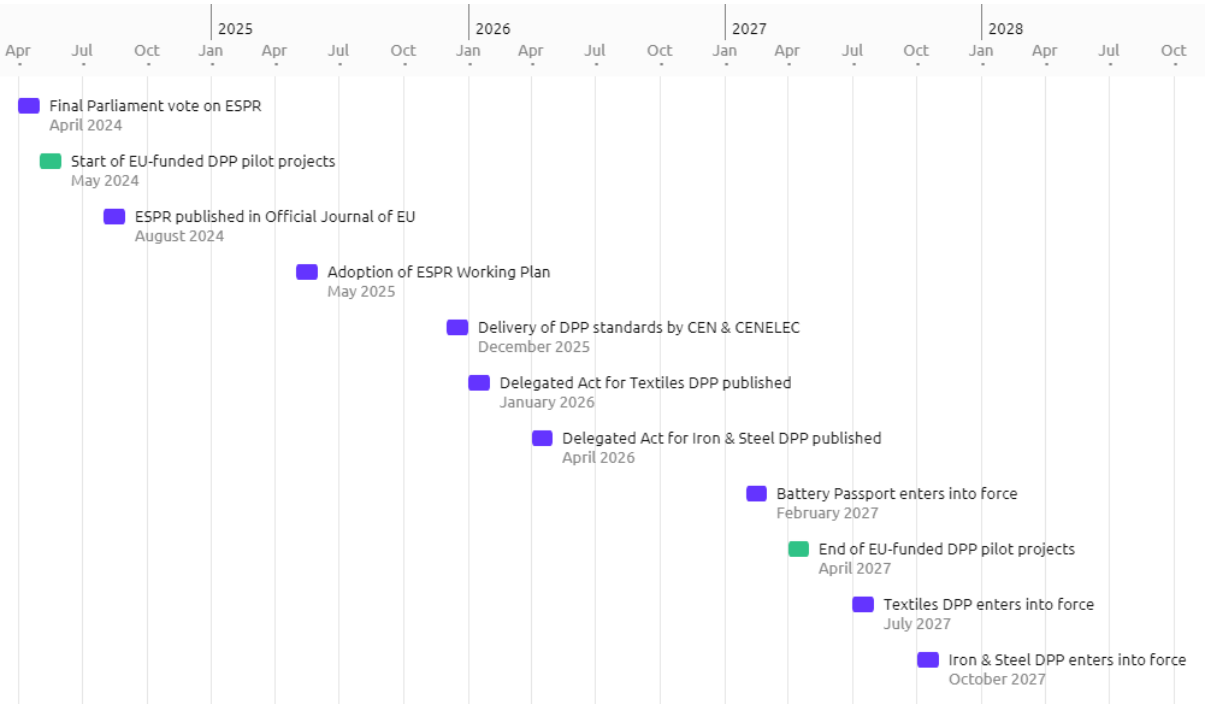
Sector-specific DPP roadmap for electronics

The roadmap for electronics entails the highest degree of uncertainty, as there is no set planned date for introducing a mandatory DPP in this sector. Electronics is a very heterogeneous sector in terms of its various product groups, which makes the establishment of a mandatory DPP for all electronics challenging. At the same time, the electronics sector offers high potential for data-driven circularity, which could be unlocked through a DPP. Thus, we propose the introduction of a DPP in this sector by 2030.

Sector-specific DPP roadmap for textiles

The textiles sector will be the first sector to be regulated under the ESPR, and the second in line (after batteries) scheduled to have a mandatory DPP entering into force. This is planned for the second half of 2027, a few months after the DPP for batteries. There are some special challenges to be addressed in textiles and apparel that are different from other sectors. On a technological level, the wear and tear to which data carriers on apparel are exposed make the choice and improvement of the right data carrier a tricky trade-off. Even more serious is the estimated low DPP-readiness of many REOs in textiles and apparel, most of which are micro-enterprises. Providing the necessary resources to increase the DPP-readiness of REOs in textiles and apparel appears to be an important precondition for ensuring successful DPP deployment in this sector.

Cross-sector DPP system roadmap timeline 2024-2027



2 Introduction

The EU plans to transition towards a circular economy, as defined in the circular economy action plan (CEAP).[1] The EU's circular economy vision includes multiple societal benefits: reducing pressure on natural resources, creating sustainable growth and jobs as well as contributing to the EU's goal of becoming climate neutral by 2050.

On the way towards realising the vision of a circular economy in Europe and beyond, the Digital Product Passports (DPP) plays an important role. It enables sharing of key product-related information that is essential for a product's sustainability and circularity. The DPP, as defined by the European Commission, is a structured collection of product-related data, which is accessible via electronic means through a data carrier. It has a pre-defined scope, agreed data management and access rights conveyed through a unique identifier.

The CIRPASS project aims to prepare the ground for a gradual deployment of an interoperable DPP system that is compliant with European regulations and international standards. To understand and address sector-specific challenges, the project focuses on three sectors: batteries, electronics, and textiles.

Implementing an EU-wide DPP system is a complex endeavour that involves many different public and private stakeholders as well as numerous technological, legal, and economic challenges. While some elements for implementing a functioning DPP system in the EU are already available, others are still emerging.

This report aims to provide both a cross-sector system roadmap as well as sector-specific roadmaps for the development and large-scale implementation of a functioning DPP that effectively supports the circular economy in the EU. The sector-specific roadmaps covered in this report include batteries, electronics, and textiles.

Targeted readers of this report are all current and future stakeholders who are shaping and will be using the DPP, particularly regulators, standards organizations, trade associations, and particularly companies in their roles as providers, enablers, and users of product data to be shared in a DPP system.

Due to the dynamic nature of the emerging European DPP landscape, all statements, assessments, and recommendations made in this document should be regarded as temporary and open for scrutiny and thorough revision. At the same time, we hope that the roadmaps suggested in this document provide orientation and a framework for productive exchanges that contribute to shaping a European DPP system that benefits society, economy, and environment within and beyond the EU.

Based on the insights gained from stakeholder feedback on the previous version of this report, we updated and consolidated it into this final version, which is part of the CIRPASS deliverable D5.2 "DPP roadmaps & recommendations".

3 Methodology

The methodology employed by the CIRPASS project for developing the roadmap for the generic DPP system and the three sector-specific DPP roadmaps is based on established methodological approaches for the development of technology roadmaps, which have been adapted to the purposes of DPP roadmaps.

3.1 Roadmap definition and purpose

For the purpose of the roadmaps to be presented in this document, we follow the technology roadmap definition of De Weck (2022)[2]: "A technology roadmap is a plan that shows which technologies will be used by which current or future product (or service or mission) and by when these technologies have to be ready and at what level of performance."

The purpose of a technology roadmap, according to De Weck, is to show "the relationships across technologies, capabilities, products/services, and needs." The mapping of these relationships is combined with the definition of a timeline which visualizes the progress towards maturity and adoption.

In accordance with this general definition, we create one roadmap for a cross-sector, interoperable DPP system, which transcends the boundaries of specific sectors and value chains, to support the purpose of novel circular value chains.

Our goal is to make this cross-sector DPP system roadmap sufficiently comprehensive while keeping it succinct. CIRPASS is developing more detailed roadmaps on architecture and technology (CIRPASS Deliverable D3.4 "Roadmap & implementation guidelines") and standardisation (CIRPASS Deliverable D4.2), which will complement the broader, less detailed system roadmap in this report.

In addition to the cross-sector roadmap, we need to consider that sector-specific differences may lead to varying conditions in terms of technical implementation and adoption of DPPs. There are, for example, differing sector-specific regulations and varying degrees of digitalization between economic operators in different sectors. Thus, we complement the generic roadmap with three sector-specific roadmaps for batteries, electronics, and textiles.

3.2 Roadmap development process

The methodology used for the process of developing the roadmaps is based on an adapted version of the Advanced Technology Roadmap Architecture (ATRA) by De Weck 2022.[3] The core process consists of four steps, which are followed taking into account relevant information from other CIRPASS work packages. In these four steps we filter and assess the available information from different perspectives based on guiding questions and criteria sets.

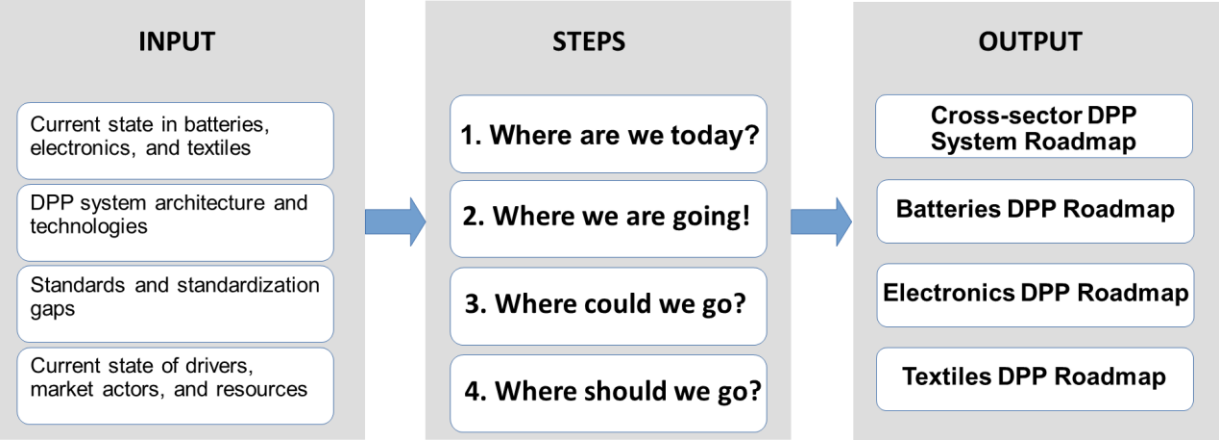


Figure 1: Roadmap methodology overview

Step 1: Where are we today?

In this step, we explore the current state of the art in cross-sector DPP systems and sectoral DPP solutions for batteries, electronics, textiles.

Step 2: Where we are going!

Some key elements of a DPP system in the EU appear already to be predetermined with a high degree of certainty. This includes especially the DPP-related EU regulation. The same applies to public-private investments in EU-level pilot projects, which cover key product groups that have been or soon will be regulated. In this step, we will summarize these mostly predetermined pathways and evaluate, which options they leave for stakeholders in the emerging European DPP ecosystem.

Step 3: Where could we go?

The regulation mandating the introduction of DPPs for different product groups leaves plenty of scope for different technological and organisational approaches to implement functioning DPPs in a compliant way. To highlight what is possible, we explore a small selection of different scenarios based on potential options and timelines for development and implementation of a generic DPP system.

Step 4: Where should we go?

Based on the exploratory work performed by CIRPASS regarding the DPP system architecture and the standardisation requirements, we will describe some recommended pathways, which we aim to evaluate against envisioned key results of effective DPP systems.

Stakeholder validation of proposed roadmaps

From December 2023 to February 2024, we elaborated, checked, and validated the sector-specific roadmaps through project-internal online workshops and interviews with sector experts. Version 1.0 of the document was shared with the Battery Pass project for comments on the batteries DPP roadmap. Based on the comments received from Battery Pass, the batteries DPP roadmap was updated in version 1.1.

In addition, we conducted an online stakeholder consultation on version 1.1 of this report on 5-18 March 2024, to give all interested stakeholders the opportunity to comment. We received feedback from 33 public and private stakeholders that was used to reevaluate and refine the roadmaps and consolidate these insights into version 1.2, which is a part of CIRPASS deliverable D5.2.

3.3 Roadmap boundaries for timeline and scope

3.3.1 Timeline

The roadmaps will cover the seven-year period from **2024 to 2030**. For practical purposes, we have further divided this timeframe into two sub-periods, which will be covered in differing levels of detail:

- **2024-2027:** This could be called the '**DPP preparatory phase**', as in this period the DPP will be introduced for the first product group, i.e., batteries, and possibly also textiles. The roadmap will be more fact-based in this period, as many developments are already happening.
- **2028-2030**: This could be called the '**DPP diffusion phase**', as in this phase, the DPP is expected to be introduced for further product groups. For this three-year sub-period, we will explore alternative pathways, based on the development of different factors in the DPP system.

This mid-term time horizon of seven years ensures that the roadmaps can be well balanced between short-term plans and long-term visions, thus enabling guidance on the direction and required actions towards DPP system implementation.

3.3.2 Scope

DPP development and implementation will be directly and indirectly influenced by a plethora of interdependent factors. As it is hardly possible nor practical to analyse all factors and their interdependencies within the project, we focus on a set of factors we consider most relevant for the DPP roadmaps:

- **Drivers**
  - Regulation (ESPR, Batteries Regulation, etc.)
  - Political factors (CEAP, etc.)
  - Economic factors (e.g. availability of critical raw materials, capital, will to invest, etc.)
- **System architecture and enabling technologies**
  - DPP system architecture
  - Data storage and management (data spaces, etc.)
  - Internet technologies
  - Semantic technologies, mainly regarding their use in the area of automated instead of manual data generation and exchange
  - Data carrier technologies (QR code, Barcode, RFID, Watermark, NFC, Bluetooth tags)
  - Data access (access rights management, security, etc.)
- **Standards** (related to enabling technologies and regulatory requirements)
  - Data storage and management (data spaces, etc.)
  - Semantic technologies
  - Data carrier technologies (QR code, Barcode, RFID, Watermark, NFC, Bluetooth tags)
  - Data access (access rights management, security, etc.)
- **System actors**
  - Economic operators (manufacturers, importers, distributors, etc., including both large companies and SMEs)
  - DPP as-a-service providers (DPP generation, data management, data backup)
  - DPP users (Circular Economy Operators and companies, public authorities, consumers)

- **DPP support resources**
  - Data ecosystems
  - Support projects and pilot projects
  - Information and knowledge support mechanisms (for all but especially for SMEs)
  - Financial support mechanisms (public loans and grants, venture capital for startups providing DPP-related services, etc.)

3.4 Definition of key terms used in the DPP context

The following definitions are mainly based on the current draft of the EC's new ESPR[4], if not indicated otherwise.

Product passport (or digital product passport, DPP)

A *product passport* is a set of data specific to a product. This dataset includes the information specified in the EC 's applicable delegated act. The dataset is accessible via electronic means through a *data carrier*. The *product passport* is applied on item, batch, or product model level.

Data carrier

A *data carrier* can be a linear bar code symbol, a two-dimensional symbol or any other medium for automatic identification and capturing of *product passport* data that can be read by a device.

Unique product identifier (UPI)

A *unique product identifier* is a unique string of characters designed for the identification of products. It also enables a web link to the *product passport*.

Responsible Economic Operator (REO)

A R*esponsible Economic Operator* (REO) is any natural or legal person who places a product on the EU market or puts a product into service on the EU market. The REO can be a manufacturer, an importer, or an authorised representative of a manufacturer or importer. The term used in the ESPR is 'economic operator'. To communicate that we are not referring to economic operators in general, but specifically to economic operators responsible for providing a DPP for their product, we add ''responsible' to the term.

Circular economy operator (CEOP)

A Circular Economy Operator (CEOP) in this context includes all economic stakeholders involved in a Circular Economy as a data user. REOs are not included under this definition. CEOPs of particular interest for DPP data use case are downstream operators, particularly sorters, recyclers, remanufacturers, and repairers. CEOPs are not defined in the ESPR. In CIRPASS deliverable D3.2 "DPP system architecture" they are described as an actor in the DPP system.

Product passport registry

As defined in the draft of the new ESPR, the European Commission plans to set up and maintain a *product passport registry.* It is meant to store a record of all the unique identifiers linked to products placed on the market or put in service. If needed, the Commission may specify further *product passport* information to be stored in the *registry*. The main purpose of the registry is to improve enforcement of ESPR requirements. Access to the registry is expected to be provided through dedicated APIs. The registry will be interconnected to the EU Customs Single Window Certificates Exchange System (EU CSW-CERTEX).

Ontology

We define an *ontology* as a model for representing the properties of a subject area and how these properties are related, defined through a set of concepts and categories that represent the subject. An *ontology* in the DPP context provides the vocabulary and structure for the classification of products and their components, materials, and other relevant product attributes. In this way, an *ontology* is essential for achieving semantic interoperability within a DPP system within and across sectors.

Interoperability

We define interoperability in the context of the DPP as semantic interoperability. It allows the exchange of product data across heterogeneous information systems with unambiguous and shared meaning, as well as cross-domain interoperability, which enables seamless data exchange in a multi-stakeholder ecosystem based on common standards and protocols.

DPP system

We define a DPP system as a socio-technical system[5] for enabling the generation and use of a digital *product passport* (DPP). The system consists of a social subsystem and a technical subsystem. The social subsystem includes, for example, regulation and governance of the DPP as well as IP ownership and management aspects involved in the role of the *REO*. The technical subsystem includes all elements for the technical operation of the DPP system, like system architecture, technologies, standards, and protocols. By including existing systems, the DPP system can also be characterised as a system of systems.

Data space

A data space is a "federated, open infrastructure for sovereign data sharing based on common policies, rules, and standards", according to a definition by the Gaia-X Hub Germany.[6]

Web Portal

According to the ESPR, the Commission will set up and manage a public Web Portal allowing stakeholders to search and compare information included in product passports.

4 Cross-sector DPP system roadmap

Based on the view that the DPP system is a socio-technical system of systems, the roadmap presented in this section explores more than just technologies and standards. Beyond the purely functional aspects it looks also at the drivers which generate and accelerate its emergence as well as the various kinds of actors in this system. Finally, the resources that could or should facilitate the deployment of a cross-sector DPP system are considered.

The DPP system roadmap is meant to cover the most relevant aspects without going into detail. In this way, it aims to provide some orientation and support to stakeholders in their decisions regarding their involvement in the DPP system.

This cross-sector DPP system roadmap is closely connected to CIRPASS deliverables D3.4 “Roadmap & implementation guidelines”, which covers the architecture and technologies roadmap in more detail, and D4.2, which provides details on the standardisation roadmap for the DPP system.

4.1 Drivers

4.1.1 Where are we today?

Some of the questions addressed in this sub-section: Which drivers already have an immediate impact on pushing and shaping the DPP? What is their current influence?

4.1.1.1 Regulation

The central direct driver for the creation of a cross-sectoral DPP system in the EU is regulation.

The new Batteries Regulation, which entered into force on 17 August 2023, marks the official starting point for the first EU-wide Digital Product Passport in a product category.[7] It covers LMT (Light Means of Transport) batteries, industrial batteries with a capacity above 2kWh, and electric vehicles batteries. From 18 February 2027 on, a DPP will be mandatory for these battery types.

Details about the DPP and key elements of the DPP system are specified in the Proposal for Ecodesign for Sustainable Products Regulation (ESPR)[8], which is the basis for the DPP system architecture proposed by CIRPASS.

According to information shared by the Commission with CIRPASS in January 2024, the Commission is expected to adopt an ESPR working plan around Q1-Q2 2025, 9 months after the entry into force of ESPR.

The EU co-legislators have pre-identified several product groups, which the Commission should prioritise in its ESPR working plan. This list includes:

- Iron & steel
- Aluminium
- Textile, notably garments and footwear
- Furniture, including mattresses
- Tyres
- Detergents
- Paints
- Lubricants
- Chemicals
- Energy-related products
- ICT products and other electronics

The list is not final, as the Commission retains the right to add or remove product groups from the working plan, if it is justified.

Besides the ESPR and the Batteries Regulation, there are further evolving EU policies, which will rely on the DPP, or elements of it, to make product-related information digitally available. These policies include the toys regulation, detergents regulation, Construction Products Regulation, and the Critical Raw Materials Act. A list of the relevant EU policies and regulations is available on the CIRPASS website.[9]

4.1.1.2 Political factors

Behind this EU-level regulation are political factors driving the introduction of the DPP. The regulatory push towards a cross-sector DPP is driven by the political intention of the EC and the EU Member

States to increase sustainability and economic sovereignty through the transition towards a circular economy. On EU level, this political intent is expressed in the EU's Circular Economy Action Plan.[10]

Several EU Member States have developed circular economy strategies that aim to accelerate the transition from today's predominantly unsustainable linear economy to a sustainable circular economy. Frontrunners are Finland and the Netherlands, who launched their respective circular economy strategies as early as 2016. The second version of the "Finnish road map to a circular economy 2016-2025" puts high emphasis on using innovative digital technologies for achieving circularity.[11] The second version of the Dutch circular economy strategy specifically refers to the EC's draft for a new Ecodesign regulation. For a specific aspect, the extension of the product lifetime, the Dutch strategy seems to be going even beyond the new Ecodesign directive:

"Moreover, the ESPR discourages the destruction of unsold goods: businesses have to report on this. The Netherlands is aiming for a tightening here, where the destruction of unsold goods will be prohibited unless it is the most sustainable solution."[12]

In regard to digital data in the context of the digital product passport, the Dutch government considers strengthening data sharing and data quality: "The Ministry of Infrastructure and Water Management is examining whether there is financial room for a cross-sector data and digitisation strategy, the development and introduction of product and/or material passports, a data sharing platform, and a research agenda for data & digitisation to fill the gaps in the available data and improve their quality."[13]

4.1.1.3 Economic factors

Economic factors alone have so far not been strong enough to overcome the substantial barriers hampering the introduction of a cross-sector interoperable DPP system.

There are already numerous data sharing schemes in different industries, e.g. tracing and tracking systems for metals and the global IMDS database for the automotive industry. However, all existing data sharing schemes are fragmented and not interoperable.

Thus, despite the economic benefits of an interoperable cross-sector DPP system, there has been no collaborative industry-driven initiative towards a cross-sectoral DPP at EU level yet. There are three explanations for this:

1. there is insufficient motivation for one sector alone, to take the initiative in tackling the huge challenge of addressing multiple sectors at the same time
2. the substantial cost and coordination effort required for such a collaborative industry initiative, and
3. the remaining high economic and financial barriers to a circular transition from a company perspective.

It seems that for now these three factors still outweigh an economic factor whose geo-strategic implications have moved it to the centre of political discussions – the accessibility and pricing of virgin raw materials, especially critical raw materials and rare earth minerals required for EV batteries and ICT equipment. On EU and ember State levels, this has already led to the formulation of raw material strategies and policies.

In March 2023, the EC finalised its proposal of a framework for ensuring a secure and sustainable supply of critical raw materials, better known under its short title Critical Raw Materials Act.[14] Annex I of the proposal lists the following 16 raw materials as strategic for the EU: (a) Bismuth, (b) Boron -

metallurgy grade, (c) Cobalt, (d) Copper, (e) Gallium, (f) Germanium, (g) Lithium - battery grade, (h) Magnesium metal, (i) Manganese - battery grade, (j) Natural Graphite - battery grade, (k) Nickel - battery grade, (l) Platinum Group Metals, (m) Rare Earth Elements for magnets (Nd, Pr, Tb, Dy, Gd, Sm, and Ce), (n) Silicon metal, (o) Titanium metal, and (p) Tungsten.

The strategic risk for the EU's industry and economy is that the supply of many critical raw materials is highly concentrated in a few countries, like, e.g. China (heavy rare earth elements), Turkey (boron), and South Africa (platinum), which leads to critical dependencies. In many cases this risk is compounded by low substitution and low recycling rates of CRMs.[15]

Already in 2020, the European Raw Materials Alliance (ERMA) was launched as part of an EU Action Plan on Critical Raw Materials.[16]

Despite all the political action and the latent strategic risks, CRMs cannot yet be considered a strong driver for a DPP and the Circular Economy in general, if measured against industry efforts across sectors towards increasing circularity and recycling rates for CRMs.

4.1.2 Where we are going!

Some of the questions addressed in this sub-section: Is there already a high level of certainty for some drivers to have a strong impact on the direction of the DPP in the next 7 years? Are those the same drivers as today? What will change in the relative strength of drivers?

4.1.2.1 Regulation

To prepare for the rollout of the DPP system, the European Commission is, at the time of writing, actively preparing for the adoption of Delegated Acts setting out the rules and requirements to be followed by DPP service providers, including a conformity assessment scheme to verify compliance with such requirements. This will be supported by an impact assessment study. Similarly, it is preparing the adoption of implementing acts setting out procedures to issue and verify the digital credentials of economic operators and other relevant actors that shall have access rights to information included in the product passport. Finally, it is preparing the adoption of delegated acts to establish rules and procedures related to unique identifiers and data carriers' lifecycle management.

Thus, there is a high certainty that the regulatory push for an interoperable DPP system on EU level will continue over the next seven years. This includes firstly the final adoption of the ESPR, which appears certain after the agreement reached in the trilogue in December 2023.[17] Publication in the Official Journal of the EU is expected in summer 2024.

Beyond that it appears quite certain that after the Batteries Regulation, which came into force in August 2023, the EC will propose Delegated Acts under the ESPR mandating DPPs for textiles as well as iron & steel in the very near future, possibly before the end of 2024. Preparatory studies by the JRC are ongoing at the time of writing.

In the period up to 2027, it seems likely that the main driver for the DPP system implementation will remain the EU-level regulation in combination with EU-level resources like EC-funded pilot projects and targeted funded mechanisms for implementing a DPP system at scale.

4.1.2.2 Political factors

EU-level policies under the Green Deal, including the Circular Economy Action Plan, are expected with high certainty to remain a strong driver of further regulations supporting the emergence of a circular economy in the EU and the achievement of the Fitfor55 carbon emission reduction goals.

4.1.2.3 Economic factors

Economic factors driving the development of a DPP system are very different across sectors, which makes it hard to assume that any specific economic factors will drive a DPP with high certainty. If there is any economic factor that would be a good candidate, it would be the long-term increase of prices for crucial materials which would drive the need for circular business models and, hence, the need for a cross-sector DPP system. In the exploration of economic factors for DPPs in batteries, electronics, and textiles in this document, we will provide a more detailed and differentiated assessment on this point. Another factor with a high degree of certainty is the increasing consumer demand for more transparency about the ecological and social impacts of the products they buy, for example in the textiles sector.

4.1.3 Where could we go?

Some of the questions addressed in this sub-section: What are realistic alternative scenarios related to different drivers dominating the DPP development up to 2030? How could regulation develop? How will raw material markets and prices for critical raw materials develop and impact the need for DPPs in more sectors?

In regard to drivers of the EU DPP system, there are two main alternative scenarios possible for the seven-year period up to 2030.

4.1.3.1 Scenario 1 – Regulation stays in the driver seat

The first scenario is that the main push will continue to come from the regulatory side. After batteries, textiles, and iron & steel, the EC is likely to make DPPs mandatory in more sectors, which will be defined in the ESPR work plan (see list of pre-identified product groups in section 4.1.1.1). In this scenario, the industry's role will be mainly limited to influencing the rules for new sectoral DPPs and complying with the new rules, when they come into effect. As the EC will not be able to introduce mandatory DPPs in many more sectors up to 2030, there will still be many sectors left that will not have a DPP despite high circularity potential for their products.

4.1.3.2 Scenario 2 – More proactive role of industry

The second scenario is characterised by a more proactive role of industry in introducing voluntary DPPs on a European/global scale in sectors without mandatory DPP. This scenario would be based on an increasing shift of economic factors towards circularity and transparency of supply chains enabled by a DPP. More prosaically, it could be promoted by the industry realizing the economic value of common data sharing standards and voluntarily wishing to adopt them.

In this context, there could be positive knock-on effects between sectors with a regulated DPP and those without. For example, if sector A is required to have a DPP, suppliers from other sectors will have to contribute and be part of the DPP. Hence, cross-sector data exchange would have to be implemented early on.

4.1.4 Where should we go?

Some of the questions addressed in this sub-section: What are the most likely and most beneficial pathways regarding DPP drivers for the next 7 years? Which of those drivers can be influenced and to what extent by actors in the EU?

Economic factors should become the dominant driver of further DPP development beyond 2027.

The policy-making process on EU level is by nature complex and relatively slow. While regulation has been the main driver in the initial phase of a cross-sector DPP in the EU and should probably remain so for the period including 2027, there are good reasons why this needs to change for the period from 2028 to 2030:

- The EC has scheduled working on regulations for introducing mandatory DPPs in other sectors than batteries, starting with textiles and iron & steel. However, even if the EC manages to publish Delegated Acts for two sectors per year, this would not be enough to introduce a DPP in all sectors currently envisaged for the ESPR work plan (see 4.1.1.1). In short, while regulation for further sectors is planned beyond 2027, it is doubtful whether this would be fast enough in view of Europe's societal and economic need for an accelerated transition towards a circular economy, as envisaged in the CEAP.
- For the period 2028 to 2030 economic factors should become relatively stronger drivers of DPPs in sectors without regulated DPPs than the, depending on the sector, uncertain prospect of further Delegated Acts. There will be a significant number of sectors that could potentially benefit from a voluntary industry-driven DPP, which are unlikely to have a regulated DPP at the end of 2030. Potential knock-on effect from sectors with a regulated DPP could increase the economic pressure towards a DPP in other sectors.
- The two major economic factors to be considered are efficiency gains through data-driven automation and the supply cost of critical raw materials (CRMs). While every sector is different in this respect, especially in regard to further automation potential, we would expect a general trend towards higher supply chain costs for CRMs to be highly relevant across sectors. Rising CRM costs are expected to make circular uses of products already on the market economically more attractive than today, driving the need for a DPP in sectors affected by such market developments.
- Based on the experiences gained with the cross-sector DPP system in batteries and textiles, the implementation cost for DPPs in other sectors would probably decrease, making the voluntary adoption of DPPs in unregulated sectors economically more attractive.

4.2 System architecture and enabling technologies

The DPP system architecture is the technological skeleton that will enable the exchange of Digital Product Passport and additional non-mandatory product information. This system's information flow will start from a unique product identifier embedded into a data carrier physically attached to a product and which can be scanned to reach a stakeholder's information system on the Web. The stakeholder's information system contains the DPP data that can be accessed by a DPP system user (consumer, recycler, and others).

The diagram below provides a structural view of the DPP system architecture, reproduced from CIRPASS Deliverable D3.2 "DPP system architecture". Note that the "Decentralized DPP Data Repositories" component represents the very large number of storage locations for DPP data.

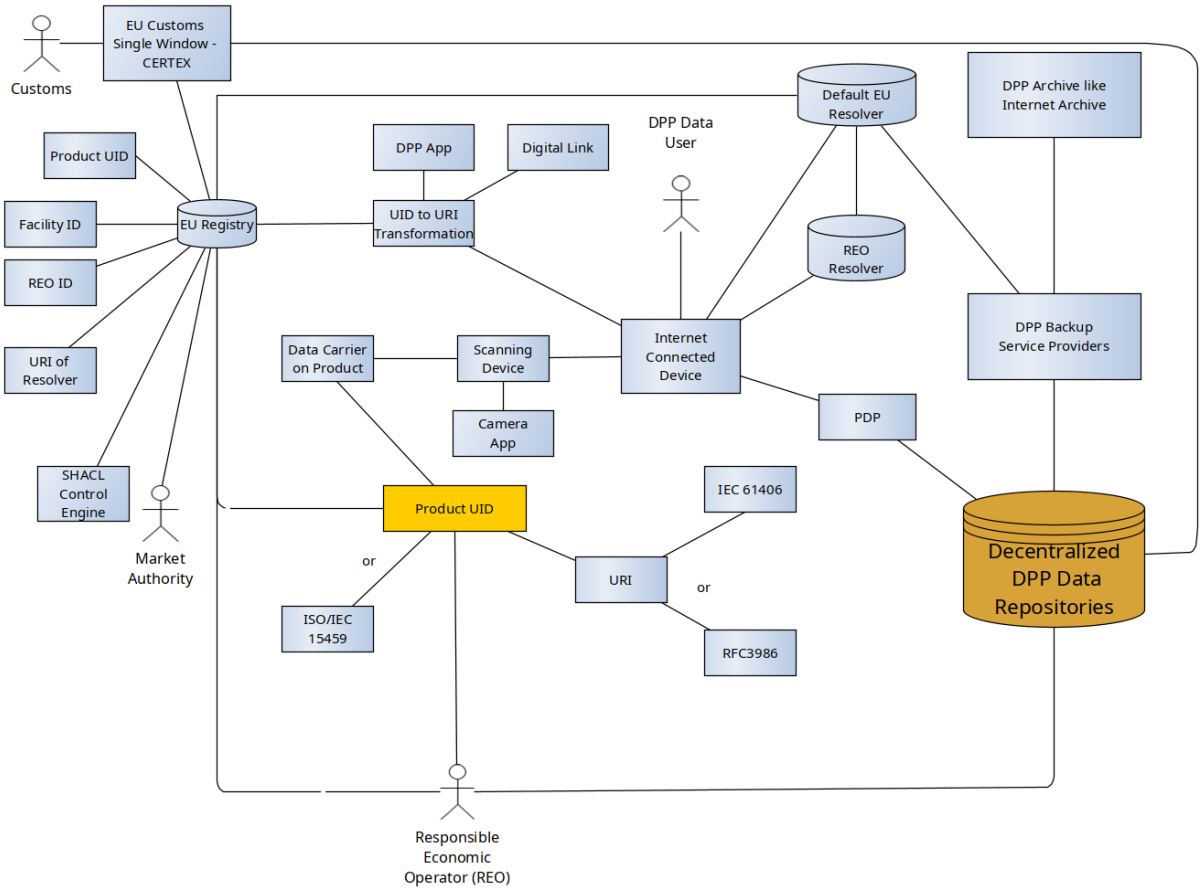


Figure 2: Structural view of the CIRPASS DPP system architecture[18]

In order to build a roadmap for the future deployment of the DPP system and enabling technologies, the CIRPASS project studied the DPP system from different perspectives.

- First, a review of the architecture of a large number of existing DPP-related initiatives was undertaken, facilitated by the use of a common comparison framework.
- The next step was to extract the DPP system's high-level technical requirements while assessing if the essential requirements defined in the ESPR and DPP standardisation request are sufficient to define a working DPP system.
- Because of the importance of the unique product identifier as the foundation of the DPP system, a specific focus was placed on the criteria for assessing the suitability of an identification scheme with respect to the essential requirements.
- A vision of the DPP system architecture including its necessary components and associated data flows was proposed and validated with respect to the high-level technical requirements. The vision both explains why some connections are necessary between different components of the DPP system and provides concrete examples of alternatives for DPP system implementation.

Based on these results, CIRPASS has identified gaps in the availability of necessary system elements, developments already on the way towards closing these gaps, as well as options and suggestions for the way ahead in the period 2024-2030. Each of these points will be detailed in the sub-sections below. CIRPASS is also developing more detailed roadmaps on architecture and technology for the DPP system. For more details see the forthcoming CIRPASS deliverable D3.4 "Roadmap & implementation guidelines".

4.2.1 Where are we today?

Some of the questions addressed in this sub-section: To what extent have viable DPP system architectures already been conceptualised? Where are gaps in terms of technical specification?

4.2.1.1 DPP-related initiatives and architectures

The current DPP-related solutions landscape comprises hundreds of initiatives. By studying these initiatives, we identified general trends. The initial 80 responses (collected through an online questionnaire) gave us useful insights on currently available approaches. From this benchmark, one of the lessons learnt is that 57% of the solutions already adopt decentralised data storage systems, similarly to the DPP system.

Regarding the data carrier used by these initiatives, QR codes are not only the predominant one, but associated with other data carriers, QR codes are supported by 95% of the surveyed initiatives. Regarding other architectural choices, the study showed that a wide variety of implementations exist. This suggests that the DPP system should focus almost exclusively on providing a semantic interoperability layer and means to connect to a heterogeneous set of solutions.

More details can be found in CIRPASS D3.1 “Benchmark of existing DPP-oriented reference architectures” available at https://cirpassproject.eu/project-results/.

4.2.1.2 System requirements

From the requirements perspective, the draft ESPR and the DPP standardisation request give essential requirements that the DPP system will have to fulfil. However, the level of detail with which these requirements are expressed varies from one to another. In addition, some of these essential requirements are not specific enough to be directly usable to design a working technical architecture that will support the DPP system.

For these reasons, the CIRPASS consortium developed a set of “DPP user stories” in an attempt to bridge the gap between the intentions of the European regulators, as expressed in the above-cited regulatory acts, and the technical implementation and standardisation activities. Their purpose is to support reasoning on how the future DPP system needs to function, thanks to a functional reformulation of the essential requirements of the DPP system. They aim to support exchanges and foster a common understanding of these functionalities, in discussions with the European Commission and with stakeholders both within and outside of the consortium. The “DPP user stories” report is therefore a living document meant to evolve as understanding improves.

The user stories further allowed for a more detailed description of the technical requirements of the DPP system, along with their respective areas of standardisation.

More details can be found in the forthcoming CIRPASS report “DPP User Stories”, which will be available on the CIRPASS website at https://cirpassproject.eu/project-results/.

4.2.1.3 Identification schemes

Due to the importance of the unique product identifier as the foundation of the DPP system, specific focus was placed on the criteria for assessing the suitability of product (and also operator and facility) identification schemes with respect to the essential requirements. To this end, an assessment framework was designed to evaluate a number of identification schemes according to the different criteria. The selected criteria are the following:

- Uniqueness
- Interoperability
- Granularity (Product)
- Representation in Data Carriers
- Linking Physical to Digital
- Current Scope of Use/Pervasiveness
- Online Selling (Product)
- Persistence
- Offline data encoded in AIDC Data Carrier
- Delegated Act or Regulatory Direction (on Choice of Identification Schemes)

In particular, this report proposes an inclusive definition of the concept of product identifier interoperability, allowing for the parallel use of a wide range of product identification schemes.

The above criteria were used to assess up to 6 identifications schemes for the identification of products, economic operators, and facilities.

More details can be found in CIRPASS Deliverable D3.3 “Identification Schemes” available at https://cirpassproject.eu/project-results/.

4.2.1.4 DPP system architecture and components

A number of essential requirements for the DPP system are already known and mentioned in the ESPR:

- Decentralised storage of DPP data,
- Need for a unique and persistent product identifier embedded into a scannable data carrier placed on the product or its packaging,
- Use of open standards and interoperable formats,
- Semantic interoperability (including syntactical interoperability) to ensure that the meaning of the information in the DPP can be recorded and transmitted efficiently between economic operators,
- Confidentiality of specific data, that will only be accessible to specific users of the DPP system based on proper authentication of said users,
- Dynamicity of DPP data, to reflect the state of the product (update of battery state of health ...) and possibly lifecycle events (repair...),
- Existence of an EU operated, centralized registry for DPP registration, interconnected to the EU Customs Single Window Certificates Exchange System (EU CSW-CERTEX),
- Existence of a standardized API to access DPP data which will enable the development of other services such as a web portal for different types of actors
- Existence of DPP backup mechanisms.

Inspired by, but not limited to the above requirements, a vision of a working DPP system architecture including its necessary components, interconnections and associated data flows was proposed by CIRPASS. Concrete examples of alternatives, although far from exhaustive, for the implementation of the different components and associated data flows were provided.

This vision includes two technologies for connecting product identifiers to the data sources where associated product data is hosted. In the first of these, the unique product identifiers are embedded into HTTP URIs. The second technology scenario relies on the use of Decentralised Identifiers (DIDs) as product identifiers. I both cases product identifiers can be linked to one or more sources of data

associated with the product identifiers. The main difference lies in the governance of the identifiers, in which the HTTP based scenario relies of the use of identification schemes either managed by Issuing Agencies or using self-minting approaches, while DIDs can be generated without any governance structure.

The vision proposed does not deeply detail the connectors needed to interface the DPP system with existing software in the economic operators' IT systems, nor does it discuss how the data is sourced over the supply-chain. However, the vision does show how the DPP system can be designed for maximum flexibility, in order that it can function seamlessly in a variety of situations (different product identification schemes, data hosted at numerous locations, changing data storage location, etc.). The architecture proposed is validated with respect to the DPP user stories set out in the CIRPASS report "DPP User stories".

More details can be found in the forthcoming CIRPASS deliverable D3.2 "DPP system architecture", which will be available on the CIRPASS website.[19]

4.2.2 Where we are going!

Some of the questions addressed in this sub-section: Which parts of system architecture still need to be defined and how will this likely be achieved?

4.2.2.1 System requirements

Although many points concerning the DPP system are already certain, the functional requirements for certain components of the architecture are still under consideration, including for the EU registry, the needed backup mechanisms, and the API. In addition to this, many other aspects of the DPP system are often not yet fully defined, including concepts such as DPP deactivation, DPP authentication mechanisms, DPP transfer of responsibility, the "linking of DPPs", etc. The use of digital credentials for economic operators and other relevant actors that shall have access rights to information included in the product passport must also be elucidated with regards to their use in the architecture. The European Commission is currently preparing an ESPR implementing act focusing on the issuing and verification of these credentials.

The European Commission will likely continue to progress on all of these topics until the end of 2024, supported by the ongoing preparatory studies for the DPP registry and web portal, the ongoing standardisation activities for the DPP system and upcoming piloting activities.

Once the functional requirements are defined, each individual component of the DPP system will require a detailed technical specification to enable its implementation. These detailed technical specifications will undoubtedly be defined over the period of 2024-2025 for implementation in 2025-2026.

4.2.2.2 DPP system components – Implementation

The European Commission is currently preparing the adoption of delegated acts to establish rules and procedures related to unique identifiers and data carriers' lifecycle management. It is also actively working towards the design and set-up of the DPP registry and web portal. This may include the setting-up of automatic DPP validation tools. This could be achieved through the use of a SHACL control engine as described in CIRPASS Deliverable D3.2 "DPP System Architecture". Similarly, the design of solutions for the archiving of DPPs for economic operators who have gone out of business is currently under consideration.

For economic operators, including DPP-as-a-service operators, since the technologies that will be used to build the DPP system architecture are already relatively well-known and deployed, the development of DPP resolvers and associated DPP data repositories should be straight-forward. Experience shows that this can be implemented in a matter of hours. Slightly more complex may be the design of repositories that are directly linked to internal ERP, PLM, or PIM systems. For access to restricted DPP information, access control mechanisms need to be implemented and those require identity management.

The identity management requires additional administrative overhead in order to identify the privileged actors. For example, a recycling facility needs to be identified as such. To do so, a company can use their normal enrolling procedures. Deploying access control technology itself is not expensive, it is the identity management inherently needed that is expensive. Alternatively, access control credentials can be issued by trustworthy public organisations. Finally, the economic operators responsible for the DPP (REO) will also have to choose among the options of managing DPP compliance tasks themselves, including the operation of the DPP data repository, or using alternative DPP data repositories such as those that might be provided by industry associations or by DPP-as-a-service providers taking care of this on behalf of the economic operators.

More complexity for manufacturers will undoubtedly arise from the embedding of DPP-compliant data carriers into manufacturing processes. If the European Commission decides to adopt the views proposed by CIRPASS on product identifier interoperability, the possibility to adopt a wide range of identification schemes should facilitate adoption.

While the CIRPASS system architecture described in D3.2 “DPP system architecture” outlines a general technical direction, many details still remain underspecified. It is expected that the CEN/CENELEC standardisation mandate will fill in those technical details. The detailed technical specifications for the implementation of the DPP system, that will result from the ongoing CEN/CENELEC standardisation work, will create further interoperability.

A key component of the DPP system that is currently underspecified is the DPP system ontology which might contain the minimum necessary vocabularies and semantics applicable across sectors. The architecture presented in D3.2 assumes the presence of a graph but does not specify that graph and its constraints expressed in an ontology. The design of such an ontology may be a useful tool to facilitate the later development of the sector-specific ontologies.

4.2.2.3 Data carriers

Automatic Identification and Data Capture (AIDC) systems for products are currently evolving, with major actors such as the GS1 user community currently migrating from 1D data carriers to 2D data carriers. The generalization of these data carriers will enable new interactions with product-related information, either by the consumer or by commercial DPP data users.

To favour openness and ease of integration of all actors, the DPP system also works with other types of data carrier and identification schemes. Any data carrier that can be resolved to a usable URI can be used in the DPP system.

4.2.3 Where could we go?

Some of the questions addressed in this sub-section are: What are realistic alternative scenarios for large-scale DPP deployment of different system architecture and technology options? What are the pros and cons of different technology options? What are the trade-offs in terms of functionality, cost-effectiveness, accessibility, and speed of implementation?

4.2.3.1 System requirements

The DPP system could be extended to ensure full alignment with the UN Transparency Protocol promoted in UN/CEFACT Recommendation No. 49, to facilitate the inclusion of non-mandatory data about verified traceability events and credentials from international supply chains into the DPP.

4.2.3.2 Data carriers

Taking into account that sector-specific needs will also play an important role in the acceptance of the DPP system, the choice of data carrier type and placement has an important impact on usability of the DPP for a wide range of circular economy activities, particularly for any activity requiring high-speed sorting. In addition, consumers must be able to easily scan a data carrier, which should remain possible with any QR-code reading camera application in a smartphone. Smartphones able to read NFC (i.e. short-range RFID) tags are common today and will certainly become more so in the future. While NFC-enabled smartphones typically use the NFC embedded chip in a 'bank card emulation' profile, the default driver installed in most smartphone operating systems is also capable of executing the 'tag reader' profile that is capable of extracting an URL from a passive NFC tag. This means that most smartphones could already read DPP-related URLs today[20], without the need to install any additional applications.

It is foreseeable that the use of longer-range RFID technology will be necessary in some domains to identify the product at the end of the life cycle (e.g. fashion and footwear). Future cell phones will likely be able to read not only NFC chips, but also UHF Gen 2 chips, making both short- and long-range RFID possible candidates as consumer-ready DPP data carriers. This would automatically lead to a broad application of UHF Gen 2 chips, simultaneously allowing for "theft protection ready" products (which use UHF RFID technology). In such a case the cost of RFID tagging may be lower than that of the financial damage associated with stolen goods.

If the European Commission decides to embed additional information in a QR code used as a DPP data carrier, in addition to the URI related to the unique identifier, specific smartphone DPP applications will be needed to read the DPP system components, symbol size will increase, and reading performance will decrease. More information can be found in CIRPASS Deliverable D3.3 "Identification schemes", Annex D.

4.2.3.3 DPP system components – Possible implementation options

The vision for the DPP system architecture proposed by CIRPASS includes two interoperable options:

1. A DPP system based on HTTP URIs,
2. A DPP system based on DIDs.

Since the HTTP based approach is more mature and currently being implemented globally for most retail products, it will likely be adopted first. Indeed, DID technologies are not as known to IT service providers compared to HTTP technologies. Therefore, the adoption of a parallel, yet interoperable, DPP system based on DIDs will depend on the future readiness of a DID based DPP system and if and

when economic operators see an advantage to using DIDs as a product identification scheme over other schemes.

To provide useful services to actors, ideally beyond that of a mere regulatory obligation, the DPP system must be able to connect easily to economic operators' different IT systems while also ensuring data sovereignty. This could be achieved via using data-space connectors and widely promoting the use of semantic adaptors and ontology alignment tools.

4.2.3.4 The DPP as an enabler

Because of its use and promotion of machine-readable semantically interoperable data, it is likely that the DPP will encourage European industry to further adopt such standards and thus increase data exchanges generally. This could potentially be done using the DPP itself. Indeed, the DPP could grow beyond a mere regulatory tool to become a vehicle for exchanging additional product data that is useful for enabling further circular use cases, supply chain use cases and use case cases that cannot be foreseen, such as new business model based on product data The DPP itself integrates perfectly into Industry 4.0, the Internet of Things, the paradigm of the European data economy and can play a role in their adoption.

4.2.4 Where should we go?

Some of the questions addressed in this sub-section are: What is the most promising and most beneficial pathway regarding DPP system architecture and enabling technology options within this architecture for the next 7 years? Which concrete steps should be taken?

Due to a constrained implementation timeframe (first DPPs must be issued in 2027), the preferred route will likely follow the implementation of an HTTP URI-based DPP architecture. The technologies for this architecture all exist and are mature enough to be employed in such a large-scale system.

Implementing DPP pilots targeting SMEs and showcasing success stories can demonstrate how the DPP benefits companies, especially aiding SMEs that might lack experience or knowledge in implementation. Pilots showcasing the economic and sustainability benefits of the DPP should be put forward, even if these pilots go beyond the data sharing requirements of regulation. Use cases in need of more advanced features of the DPP system e.g., distributed ledgers, AI, reasoners, etc. should also be explored.

Similarly, the development of new technologies for the embedding of persistent data carrier technologies onto products should be seen as an opportunity for innovation.

Solution providers of enterprise IT systems e.g. PLM, ERP, PIM need to be stimulated and supported to integrate DPP solutions into their systems as soon as possible.

To support economic operators in DPP compliance tasks, the EC should make a specific request to member states for generalized deployment support and industry should be involved in the design of these mechanisms. However, to ensure alignment between the support activities proposed by all member states, the EC should further deploy a "DPP implementation support centre" which would simultaneously:

- Serve as neutral expertise "bureau" providing contacts and financing expertise,
- Run training and information events,
- Collect success stories, best practices and share them for inspiration,
- Design and provide open-source training material for all.

4.3 Standards

This chapter is an extract of the result of the gap analysis and roadmap for the DPP system standards.

More details can be found in the forthcoming CIRPASS Deliverable D4.2.[21]

4.3.1 Where are we today?

Some of the questions addressed in this sub-section are: What standards are already available that are required for a viable DPP system and its enabling technologies? Which required standards are under preparation?

The CIRPASS standardisation roadmap focuses on the implementation timeline of the ESPR. According to the timeline, the final vote on the current ESPR is due in April 2024, with the adoption of ESPR expected in Summer 2024 and the first products with mandatory DPPs in 2027. For the EU's DPP to comply with European technical standards, the CEN/CENELEC joint technical committee 24 (JTC24) has been formed. Preceding the JTC24, the DPP Standardisation Request AdHoc group supported the Commission in the definition of the 8 areas of standardisation which were taken up in the standardisation request (version 2, 2023-10-4) submitted to the European Standardisation Organisations (ESOs). Surveys conducted both by the AdHoc group and by CIRPASS showed that for each of these areas, there already exist several standards from officially recognized international and national standardisation organizations (IEC/ISO, CEN/CENELEC, DIN/DKE etc.) as well as standards from Fora and Consortia, and those developed by industry and service providers.

Although there is disagreement on the relevance of specific standards, the availability of in-use standards for each of the eight categories is sufficient. While this would seem to indicate that there is no gap identified at this very high level, this does not mean that any combination of standards results in a working system, thus potentially hiding a number of gaps.

Despite the fact that a number of architectural design choices, which affect also the choice of standards, have already been made in D3.2 "DPP System Architecture", certain areas remain underspecified. Those underspecified areas represent standardisation gaps. Generally, the flexibility of the architecture proposed by CIRPASS is such that it can digest diversity in implementation choices and standards used. But this only works within certain boundaries as the combination of specific standards can be difficult (e.g., using an HTTP resolver with a DID as product identifier).

The work on the standards landscape also highlighted the need for further specification of the DPP system's functional requirements to the component interfaces to enable the data flow, which are inspired by, but not limited to:

1. The essential requirements from the ESPR and the Battery Regulations. This includes requirements from use cases and user stories briefly hinted at in these texts.
2. The mandate to develop an EU technical standard that has been given to CEN/CENELEC to develop technical DPP standards.

As most of these essential requirements are not specific enough to fully capture all of the needed functionalities of the system, and as explained above in section 4.2.1.2, the CIRPASS consortium developed a set of "DPP user stories" describing the data flow steps in an attempt to bridge the gap between the intentions of the European regulators, as expressed in the above-cited regulatory acts, and technical implementation and standardisation activities. Through a functional reformulation of the essential requirements, the purpose of the user stories is to support exchanges and foster a

common understanding of these functionalities, in discussions with the European Commission and with stakeholders both within and outside of the consortium. The "DPP user stories" report is therefore a living document meant to evolve as understanding improves.

The user stories further allowed for a more detailed description of the technical requirements of the DPP system, along with their respective areas of standardisation.

More details can be found in the forthcoming CIRPASS report on "DPP user stories", which will be available on the CIRPASS website.[22]

4.3.2 Where we are going!

Some of the questions addressed in this sub-section are: For which parts of the standards development for a DPP system architecture and enabling technologies is there already a high level of certainty that they are on their way? Which new DPP-related standards are relatively certain to be available by when?

As of the time of writing, the development of the EU DPP standards has started.

A Standardisation Request by the EC to CEN/CENELEC is currently being finalised (status: March 2024). The scope of the standardisation request is to review and develop a set of harmonised standards to enable an interoperable, fully operational DPP-system. The deadline for delivering the requested standards is 31 December 2025.

Furthermore, the work on product- and sector-specific delegated acts will come, and independent of the finalization of European standards for the DPP architecture, the implementation of the DPP as per the requirements of the ESPR will begin. Simultaneously to the activities of CEN/CENELEC JTC 24, formally recognized international standardisation organizations (e.g. ISO/IEC) and various consortia are also continuing their working on DPP relevant standards and specifications.

According to the Commission, the implementation of the DPP shall proceed as planned even in the absence of harmonised EU standards. If delays or other issues occur related to the content of these standards developed by CEN/CENELEC, existing standards, standards in development and common specifications (ESPR article 42) can be utilized.

While the CIRPASS system architecture described in D3.2 "DPP system architecture" provides a general technical direction, many details still remain underspecified. It is expected that the standardisation mandate will fill in those technical details. The detailed technical specifications of implementation that will be the result of the ongoing CEN/CENELEC standardisation work will create further interoperability between existing systems.

As the DPP gains in maturity and additional user stories are defined, the further existence of standardisation gaps may emerge. This difficulty is related to the current gaps in the definition of functional requirements for the DPP system, the closing of which should be seen as an absolute priority.

4.3.3 Where could we go?

Some of the questions addressed in this sub-section are: Which realistic alternative standards development scenarios are available, based on different system architecture and technology options for large-scale DPP deployment? What are different possible timeframes for the development of standards? Which standards may be essential and which may be secondary?

Since the CEN/CENELEC JTC24 has less than two years to develop standards, there are a few scenarios that may lead to different possible directions. We present here two of the possible scenarios and the consequence of each one:

Scenario A: CEN/CENELEC JTC24 can finish the development on time

CEN/CENELEC JTC24 delivers all standards on time. In this case, adopters of the DPP will have sufficient time for implementation and the basis for the delegated acts is given.

Scenario B: CEN/CENELEC JTC24 cannot finish the development on time or the proposal is rejected

There is the possibility that the work of JTC24 cannot be completed on time or the proposal is rejected by the EC. In this case the Commission will adopt Common Specifications.

In addition, two further scenarios are possible: scenario C - JTC24 only delivers part of the requested standards; and scenario D – JTC24 delivers standards not fully in line with the standardisation request. They appear to be similar to scenario B in that the Commission may be required to make a decision on the full or partial adoption of Common Specifications.

Due to the short timeline to DPP adoption, standardisation activities for the DPP system will likely take place in parallel to the implementation of DPP system components based on existing specifications. This may apply, for example, to the DPP system ontology, which may be needed to describe the minimum necessary vocabularies and semantics applicable across sectors. Also, if deemed useful by implementors and standardisation bodies, the registration of specific resolver link types with the Internet Assigned Numbers Authority (IANA) may be necessary. Finally, the standardisation of component interfaces related to a DID-based DPP system will likely be necessary.

4.3.4 Where should we go?

Some of the questions addressed in this sub-section are: What is the most promising and most beneficial pathway regarding standards development and use of standards for a viable DPP system architecture and its enabling technologies for the next 7 years.? Which concrete next steps should be taken?

At the moment there are several IT-system architectures proposed as candidates for the DPP system, which are based on existing standards and common specs, while new standards are in development and close to release. In order for the DPP system to integrate the widest possible number of them, as proposed in the vision of the DPP-system architecture presented by CIRPASS these systems should keep requirements and criteria to component interfaces in mind enable interoperability in the future.

In parallel the findings from CIRPASS should support the work of CEN/CENELEC JTC24 in to formulate the requirements which enable the integration of existing systems into the DPP ecosystem. This support would increase the chance of CEN/CENELEC delivering on time, and of industry implementing according to the Commission's roll-out plan.

In particular, it would be useful to further expand and review the functional requirements assessment and component descriptions of the standards and specifications identified by CIRPASS. As stated above, the functional requirements for certain component interfaces to enable a data flow are still under consideration including for the EU registry, the needed backup mechanisms, and the web portal. In addition to this, many other aspects of the DPP system are still not fully defined, including concepts such as DPP deactivation, DPP authentication mechanisms, DPP transfer of responsibility, the “linking of DPPs”, etc. The use of digital credentials for economic operators and other relevant actors that shall

have access rights to information included in the product passport must also be elucidated with regards to their use in the architecture. The existing standards landscape should be evaluated if they address the requirements and criteria to the component interfaces.

The essential requirements from the regulation can be formulated into technical requirements of sufficient detail to match existing standards, when available. These requirements should be identified by testing and practicing the data flow of existing systems, based on different standards. Then, based on the interfaces of DPP-system components, the compatibility of standards must be assessed due to the likelihood of partial overlaps or technical incompatibilities, hindering interoperability.

The work done by CIRPASS in defining and identifying technical requirements based on the DPP user stories has only scratched the surface of this necessary work. It can serve as a starting point for selecting components which need further investigation. For example, the standardisation gaps identified by following the vision from CIRPASS deliverable D3.2 “DPP system architecture” should be addressed as a starting point. In particular, for the variant of the DPP system architecture based on DIDs, currently the W3C standards do not foresee any default DID method. For DPPs, it could be considered for example that the standardisation efforts also include a DID method that fulfils all criteria from EBSI (European Blockchain Services Infrastructure).

4.4 System actors

DPPs are created, enabled, and used by a wide range of stakeholders, whom we call DPP system actors. They differ significantly in their nature, motivation, and involvement in DPP development and usage. Thus, given its scope, this section will not attempt to discuss extensively all aspects of all DPP system actors. Instead, it provides a broad overview of main DPP system actor categories, their current status, and potential challenges as well as opportunities in related to DPP implementation.

The aim is to generate further dialogues both in the regulatory context and industry implications. DPP system actors are particularly important, if DPP implementation is to be viewed as a business opportunity instead of an extra compliance requirement, where industries are motivated to go above and beyond and/or ahead of their sector’s delegated acts. Consideration of DPP system actors in DPP implementation also helps to foster DPP enabling businesses, and data-driven economy.

DPP system actors can be categorized in three main groups:

1. **DPP data providers**, referring to actors that are: directly or indirectly providing data relevant to DPPs; responsible for issuing, maintaining, and updating DPPs; as well as ensuring DPPs are available and accessible according to the ESPR and applicable regulations. Examples of DPP providers include:
    - Responsible Economic Operators (REOs) are economic operators placing the product on the market or putting it into service. These are the manufacturers, importers, or their authorized representative. REOs are expected to create DPPs when placing products on the market, as well as to provide DPP data access, maintain, update, and remove DPPs when applicable.
    - Circular Economic Operators (CEOPs), including repairers, recyclers, and remanufacturers, or any other actors who may be required to provide data for the purpose of updating DPPs or to update DPPs themselves or create a new DPP when applicable.

- Suppliers who may be requested, directly or indirectly, to provide data relevant to the task of creating DPPs by REOs. While they are not mentioned in current DPP-related regulations, they are an integral part of ensuring DPP data is available and reliable.

2. **DPP data users**: referring to a broad range of actors that access DPP data for various reasons such as being informed of product information, making purchasing decision, using it for business and processing purposes, and enforcing regulations. They include, in accordance with ESPR, Article 8: 2(f):
   - Consumers, B2B end users, and public purchasers
   - Circular Economic Operators (CEOPs), such as repairers, refurbishes, remanufacturers, waste management operators, second hand market operators
   - Customs and market surveillance authorities
   - Civil society organisation, researchers, trade unions, and the Commission, and any organisation acting on their behalf
   - Other companies in the market or data enabling businesses.

While a DPP should be free of charge and easily accessible, according to the ESPR, it is essential to note that DPP data users will have different access rights set out in applicable Delegated Acts. Finally, an actor can be both DPP data provider and DPP data user for the same or different products. For example, a repairer can use DPP data to repair a product and provide repair information to update DPP data, if applicable.

3. **Other DPP actors that support the DPP ecosystem** in terms of providing a wide range of services and setting standards. They neither provide nor use DPP, yet they play an essential role in scaling up DPP implementation and fostering a DPP-enabling economy. They include:
   - Digital Product Passport service providers, defined as *"a natural or legal person who, authorised by the economic operator placing the product on the market or putting it into service, processes the digital product passport data for that product for the purpose of making such data available to economic operators and other relevant actors with a right to access those data under this Regulation or other Union laws"* (ESPR, 32(a)).
   - Other DPP-as-a-Service providers (DPPaaS providers), which provide services beyond DPP data processing such as consulting, DPP solution development, DPP component suppliers (e.g. data carrier technologies), cloud service companies, DPP backup service providers
   - Regulators and policy makers at the national and EU levels
   - Standardisation and certification bodies
   - Industry associations.
   - Financial organisations like, e g., the EIB

The following sub-sections explore these actors' current status regarding their roles in the upcoming DPP system, as well as the directions, options, and recommended pathways for each category of actor and their interdependent actions. This analysis is drawn from:

- Analysis of regulations and standardisation implications at the national, EU, and international levels
- Expert opinions within and outside of CIRPASS
- Surveys and interviews of businesses with different sizes and product or service offerings, of DPPaaS providers, of customs and market surveillance authorities, and of policy makers,

- Research and policy impact assessments
- Industry reports and publicly funded project results.

4.4.1 Where are we today?

Some of the questions addressed in this sub-section are: What motivates system actors to embrace the opportunities of the DPP? What capabilities do they have for performing their tasks in the system?

This sub-section focuses on observations, incentives, and the readiness of DPP actors for the introduction of a mandatory DPP. Special attention is paid to SMEs, as new regulatory requirements can have disproportional impact on them. DPP actors are best described as extremely diverse in terms of their characteristics, incentives to implement DPP or DPP-like systems, and DPP readiness.

4.4.1.1 Characteristics of DPP system actors

Characteristics of DPP system actors include:

- Industry, size (revenue and employee number), product and service offerings
- Business and production processes, as well as product technologies
- Geographic location and regions of operations
- Business models and strategic directions
- Role in their value chain and supply chain structure
- IT capabilities
- Data management strategy and practices, including data collected and processed
- Intangible hard to quantify characteristics: innovation culture, organization structure, supplier relationships, risk tolerance, change management capability, and cross-sector relationships.

This diversity will result in significant differences in DPP readiness and implementation needs, as well as the ability to leverage DPP data across different organizations and potentially sectors. Furthermore, given the early phase of DPP policies and experience, it is unclear what characteristics would precisely predict DPP success. Early DPP experiments and similar digital initiatives in recent years allow us to speculate on which actors are in a more advantageous position to implement and utilize DPPs, yet this is not a guaranty for successful or easy DPP implementation.

For instance, it is intuitive to presume that it is easier to collect DPP data for simpler products (i.e. lower technology or fewer components) such as apparel or shoes, when compared with high-tech complex products such as mobile phones or cars. However, many textile companies, which tend to be smaller in size and scattered across the world, can easily face the same level of difficulty in collecting and standardizing product information as a mobile phone or automobile manufacturer, which tends to be much larger and better organized and coordinated.

This will make it challenging to generalize some meaningful and concrete DPP implementation guidelines, support actions and coordination initiatives. It will also likely make the task of assessing and validating DPP impacts much more complicated, particularly at scale. These challenges highlight the need for an interoperable, flexible, yet clear DPP system, data requirements and supporting set of standards.

4.4.1.2 Incentives for fully embracing the DPP opportunities

Incentives for fully implementing and utilizing DPP data and systems for DPP actors, even those within the same DPP actor category, are also vastly different.

For **DPP data providers and users**, the incentives for fully utilizing DPPs, even beyond regulatory demands, may include:

- Anticipation of regulations. This is likely to be the main incentive. In the case of batteries, Battery Directive 2023/1542 makes it clear which businesses are subjected to mandatory DPPs. A few other product categories such as toys, detergents as well as apparel and shoes are likely to be directly mandated to issue DPPs in the next few years. However, even for product categories without their Delegated Acts in sights, some businesses still proceed with DPP initiatives to ensure a smooth DPP implementation transition.
- Public and consumer demands for more and better product information aid their purchasing decisions and avoid greenwashing.
- Pressure from competitors who have embarked or plan to take on DPP-like initiatives in anticipation of their sector's possible mandatory DPP or perceived benefits of DPPs.
- Pressure from one's own value chain network, including suppliers, buyers, partners, expecting cooperation for their own DPP initiatives.
- Specific use cases. Some DPP actors, such as luxury goods brands or manufacturers relying on scarce resources, believe that DPPs can be part of the solution to their problems of anti-counterfeiting or reliable supplies.
- Competitive advantage. Recyclers, repairers, or second-hand market platforms, consider that DPPs, once implemented at scale, as a competitive advantage to improve their process efficiency, productivity, and customer services in the form of information transparency.
- Enabling circular business models and ecosystems. This is particularly true for companies actively exploring circular business models, or embracing their sustainability programs, or founded entirely based on sustainable or circularity principes. These actors consider digital solutions, including DPP or DPP-like systems, to be a key to their success.
- Natural fit to the business' strategy or other initiatives such as Digital Twin or Track and Trace.

For **DPPaaS providers and supporting organizations**, the incentives, and therefore business models, also vary widely:

- Identifying a DPP-related market need and purposefully developing solutions or services to fill such a need.
- Requests from existing customers to develop and / or share DPP solutions and services to bring down implementation costs and increase the user base
- Strengthening of sector bargaining power or standardisation of sector practices to reduce complexity and inconsistency

Together, these factors could result in a vibrant and growing DPPaaS community, which fosters competition and innovation. At the same time, this could potentially pose challenges to govern and ensure that the DPP system, data and data space stay in line with the vision of being a useful circularity tool, instead of becoming a barrier to competition or an extra burden to SMEs.

4.4.1.3 DPP readiness of system actors

DPP **readiness** can be assessed in a number of dimensions:

- DPP policy and implication awareness
- Knowledge to implement and leverage DPPs

- IT capabilities (technologies and skills)
- Data availability and accessibility
- Resources (financial and human, including change management).
- Less direct readiness facets: infrastructure (e.g. internet connection), production technologies and processes, supply chain relationships, value chain complexity, industry maturity and best practices, and access to support systems if DPP actors are to minimize risks in implementing DPP and maximize DPP benefits beyond meeting mandatory DPP requirements.

DPP actors vary greatly in their DPP readiness. This correlates with the prioritisation of DPP within each organisation, ranging from those that are completely unaware of DPP regulation and its implications to their businesses, to those making DPP an integral part of their digital strategies. While it is difficult to generalize DPP readiness for a particular group of DPP actors, it is safe to say SMEs, as data providers and data users, are, on average, likely to have a lower level of DPP readiness than their larger business counterparts, mostly due to the lack of resources and limited capabilities.

This complexity leads to great difficulty in generalising the estimated cost and time frame needed to become DPP ready for a specific actor. It is even more challenging to have a complete picture of the readiness level of suppliers to support DPP implementation, where their cooperation is needed due to the complexity of modern supply chains. In circumstances where a large number of suppliers are located outside of the EU, they may have no awareness of upcoming mandatory DPPs or the resources to meet requirements from REOs based in the EU. This factor should not be ignored if the DPP is to be implemented smoothly and provide reliable data. REOs should be prepared to support their buyers, suppliers, or other partners in their DPP implementation in the form of providing required data or cooperating in data collection and system integration.

Ideally, assessing an actor's DPP readiness should be done on a case-by-case basis, which represents a business opportunity for DPPaaS providers to fulfil this market need. Third-party solutions in DPP data collection, integration, and storing, and/or DPP issuing, are also viable options to rapidly scale up DPP implementation while lowering costs. To further explore this issue, it would be useful to examine different pillars of the DPP – e.g., data requirements, system requirements, standards, business, and policy context – from the perspectives of different DPP actors, to determine common elements that could help them get ready for DPP implementation.

4.4.2 Where we are going!

Some of the questions addressed in this sub-section are: Which market trends and development pathways in regard to system actors appear already to be highly certain for the coming years? Is the development of a growing DPPaaS market already a given?

This sub-section aims to determine observable trends and identifiable development pathways for different DPP actors as a result of regulation, or industry and market developments within the next 3 to 5 years. The **regulations and standardisations** that have the most impact on shaping DPP directions include the draft ESPR, the Batteries Regulation 2023/1542, and the EC Standardisation Request for the Digital Product Passport[23]. Other relevant regulations can be found in the forthcoming CIRPASS deliverables, which will be available via the project website. Expert opinions and workshops, as well as industry surveys and interviews have contributed to identifying these trends.

It should be noted that, given the constantly evolving DPP landscape and early phase of DPP regulations and implementation, there are many topics (e.g. standardized circularity or sustainability

indicators, data models) still open to interpretation, and market trends (e.g. drastic decrease in IT solution development costs due to innovative technologies and business models) can quickly take a sharp turn. Thus, it is sensible to stay informed of regulation developments and implementation guidelines, as well as frequently re-examine industry trends and movements to make adjustments if needed.

Projects such as CIRPASS have contributed to clarifying DPP system requirements and standardisation which we expect to be used as input for DPP implementation, regardless of sectors and organization typologies. Data requirements, on the other hand, tend to be much more sector-specific, though several attributes (ESPR, Annex III) are mandatory regardless of product category. Note that even these generic data requirements still need to be further clarified in Delegated Acts.

Specifically, in the **DPP data providers** group, a few key observations include:

- **Responsible Economic Operators (REOs)** of products such as batteries and most likely apparel and shoes, toys, and detergents should be ready to issue a DPP (or authorize DPP service providers) by the deadlines stated in their applicable regulations.
- However, even when a product-specific regulation such as the Battery Regulation is available, there are many details in the regulation that need to be verified and interpreted before the battery DPP can be implemented. In addition, there are REOs that are unaware of the upcoming introduction of mandatory DPPs for their products or unclear on the DPP regulation implications for their businesses or where to start with DPP implementation.
- For other **DPP data providers**, Delegated Acts for specific products will also lay out the actors that are to update information in the DPP as well as what information to be updated (ESPR, Article 8: 2(g)).
- It is highly likely and also desirable that economic actors continue or start their own DPP initiatives in anticipation of their own product category's mandatory DPP, or to explore specific DPP use cases.

Among **DPP data users**, the identifiable trends are quite specific to each sub-group:

- **Consumers** are increasingly interested in getting informed about their product and/or including sustainability indicators (e.g. water consumption, carbon footprint, repairability index) in their purchasing decisions. However, multiple companies have indicated that even for sustainability conscious customers, being sustainable alone is not enough to sell a product. Thus, DPP availability, free of charge and user-friendly per ESPR, in isolation may not be persuasive enough to change consumer behaviour.
- **Public sustainable procurement or green public procurement** is becoming more popular. DPPs, as envisioned and mandated in the ESPR, are expected to become a useful tool in the decision-making process.
- For **Circular Economy Operators**, such as repairers, refurbishers, remanufacturers, and recyclers, DPPs as described are welcomed in general and considered to be useful for their business practices. The forthcoming CIRPASS deliverable D2.2 "List of use cases related to the DPP and the related benefits for key actors in the three sectors" provides detailed insights into use cases of DPP data in a number of circular business activities.
- Finally, the use of DPP by **customs and market surveillance authorities** is explicitly stated in the ESPR. Customs authorities should have direct access to the Passport Registry via the EU Single Window Environment for Customs provided that a product passport exist for a product to be imported (ESPR (36)). The ESPR also describes the use of DPP data for customs and

market surveillance authorities *"The information included in the product passport can allow customs authorities to enrich and facilitate risk management and enable the better targeting of controls at the border. Therefore, customs authorities should be able to retrieve and use the information included in the product passport and the related registry for carrying out their tasks in accordance with Union legislation including for risk management in accordance with Regulation (EU) No 952/2013 of the European Parliament and of the Council18*" (ESPR (38)). Article 13 in the ESPR has more details on Customs controls relating to the product passport.

- What has not been specified, is what DPP information would be relevant for improving the efficiency and effectiveness of market surveillance checks and customs controls while avoid disproportionate administrative burden for economic operators and customs authorities. It is expected that Delegated Acts will provide these missing details.

In the last group of DPP system actors, a few things can be stated with a high degree of certainty.

- **DPPaaS providers** appear to embrace the opportunity for DPP consultancy and solution development.
- It also appears that DPPaaS providers do tend to stick to commonly accepted standards and viable technologies in developing their DPP solutions. WP3 provides details on DPP or the DPP-like technology landscape.
- In addition, it is highly likely DPP solutions will have to be customized for specific product groups and/or companies.
- The ESPR also indicates that **certified independent third-party product passport service providers** authorised to act on the behalf of economic operators shall not be allowed to sell, re-use or process DPP data, as a whole or in part, beyond what is necessary, unless specifically agreed with the economic operator placing the product on the market or putting it into service(ESPR, Article 10).
- However, the ESPR does not seem to refer to what constitutes a "certified independent third-party" product passport service provider. Instead, it states: "The Commission is empowered to adopt delegated acts in accordance with Article 66 to supplement this article by setting out the rules and requirements to be followed by product passport service providers, including a certification scheme to verify such requirements, if appropriate." (ESPR, Art. 10).
- Other actors such as **standardisation bodies** (e.g. ISO, CEN/CENELEC) are active in developing standards for DPP, circularity indicators and data models and semantics. These will be essential building blocks to implement DPP at scale that is still interoperable and long-lasting.

4.4.3 Where could we go?

Some of the questions addressed in this sub-section are: What could be realistic alternative scenarios, e.g. on the development of the DPPaaS market? Or on the DPP-readiness of economic operators or DPP users like recyclers and others?

4.4.3.1 How system actors could contribute to achieving the DPP objectives

To discuss where we could go in terms of DPP system actors, it is crucial to understand what DPP objectives are and what DPP system actors need to accomplish to achieve these DPP objectives. Then a gap analysis between their current status and desirable status is performed.

Objectives of the DPP are, according to the European Commission[24]:

- Sustainable choices by consumers: support consumers in making sustainable choices by allowing them to have access to relevant and verified information on products they own or are considering to buy/rent
- New or expanded business opportunities for economic actors through circular value retention and optimization: provide new business opportunities and improve current business practices to economic actors through circular value retention and optimization based on improved access to data (e.g. repair, servicing, remanufacturing, recycling, extended producer responsibility and product-as-a-service activities)
- Verification of product compliance with legal obligations: support market surveillance and customs authorities in necessary checks and controls, as well as streamline the monitoring and enforcement of the regulation carried out by the EU and Member State authorities. This includes the controlling of the upcoming definition of quality-relevant parameters in the Delegated Acts
- Sustainable products and production: support sustainable products and production boosting material and energy efficiency, extending product lifetimes and optimizing product design, use and end of life handling.

In the following we discuss, in which ways DPP system actors could deliver on these objectives.

4.4.3.1.1 Sustainable choices by consumers

To achieve the goal of facilitating sustainable choices by consumers, the DPP needs to be easily accessible and free of charge as well as understood by consumers DPP data provided to customers should be relevant to their purchasing decisions and product usage.

DPP data providers

- Collect and integrate data, that is reliable and up-to-date, for their DPP
- Issue DPPs that, at the minimum, meet DPP data and system requirements
- Maintain and update DPP data as required or needed, pursuant to the delegated acts
- Beyond what is mandated by regulations, REOs should understand their consumers to decide if DPP mandated data is sufficient to support their consumers to make sustainable choices
- Support / educate consumers on the benefits of considering DPP data in their decision-making process
- Consider measures to support customers to maintain product circularity such as repair services and end-of-life collection. While this is not directly related to DPP implementation, it has become apparent that DPP data availability does not automatically translate into

sustainable consumption or circularity without support actions such as new services and business processes.

DPP data users

- Become aware of the DPP and its use
- Have the ability to read DPP data: technologies (e.g. smart phones) and skills (e.g. where to find DPP if hidden in clothing seams, for example)
- Can interpret DPP data to aid their decision-making process or extend the life of their products (e.g. understand data attributes included without feeling overwhelmed, comparing alternative choices based on their selection criteria)
- Support to maintain DPP availability by avoiding damaging or removing tags unnecessary.

Other DPP system actors

- Develop and/or provide DPP solutions (e.g. issuing, maintaining, hosting, and performing access control) at scale to bring down costs. This is particularly relevant to SMEs
- Provide DPP-related technologies and products (e.g. NFC tags, RFIDs)
- Consulting and data integration services
- Standardisation works to ensure interoperability and indicator consistency (e.g. LCA indicators and interpretation consistency)
- Industry associations: support DPP implementation, particularly for SMEs.

Gaps or unknowns

- DPP (and DPP like systems) is not implemented on a large enough number of products, hence it is difficult to determine if it affects consumers' sustainable choices.
- Similarly, it is difficult to determine if DPP provide the right data attributes, mandated and voluntary data, that consumers need to make purchasing decisions, or how consumers use this data to make their decision.
- It is unclear, how big a DPP market has to become for DPPaaS providers to be able to bring down costs to reduce the cost burden for REOs, especially SMEs.

Scenarios and follow-ups

Scenario 1: DPP is used widely and helps consumers make sustainable choices, at least in a few specific product categories.

In this case, industries, and regulators, if possible, should accelerate DPP implementation across product categories to replicate the success. It would be helpful to study the mechanism of impact DPP has on consumer behaviour (e.g. timing and frequency of DPP data access, most relevant data attributes, ease of access of DPP data)

Scenario 2: DPP is not widely used. In this case, underlying causes (e.g. difficult to access DPP carrier and / or DPP data, data are too difficult / confusing to understand) should be determined. Ideally, this difficulty should already be minimized during the DPP pilot phase to ensure ease of access. However, if a problem is identified, alternative solutions should be applied.

Scenario 3: The DPP is available and accessed but makes no difference in consumer purchasing behaviour. In this case, reasons should be determined. For example, data attributes may be irrelevant or too difficult to interpret for decision making, or added data fundamentally do not change behaviour unless costs and functionalities of sustainable products are the same or better than non-sustainable

ones. Again, the concern of irrelevant data should already be avoided in the early phases through consultation with industry experts with sector specific knowledge and consumer behaviour experts.

4.4.3.1.2 New business opportunities for economic actors through circular value retention and optimization

To achieve this goal, DPP needs to be available, DPP data is likely to be more extensive and restricted than that available to the public, DPP is accessible to CEOP with the right access, and data is circularity enabling.

DPP data providers

- Collect and integrate data, that is reliable and up-to-date, for their DPP
- Issue DPP that at the minimum, meet DPP data and system requirements
- Determine who should have access to what data (i.e. unpublic data)
- Manage access control to provide restricted data to actors with the right credentials
- Determine DPP data that enable circularity. It is challenging as technologies, processes and business models that can enable circularity are continuously evolving. CEOPs are also constantly exploring data potentials. However, this consideration should be a part of DPP implementation if DPP are to deliver on these objectives.
- Provide support that enables DPP data leverage such as spare parts. While this is not directly related to DPP implementation, this is crucial from conversations with multiple CEOPs. Data alone without the ability to leverage it for their means is useless data.

DPP data users

- Are aware of DPP and its content
- Gain right level of access to relevant DPPs
- Have technologies and processes in place to read and make use of DPP data
- Support maintaining DPPs by providing data to REOs if mandated (e.g. repairers) or take over or create a new DPP if required (e.g. remanufacturers).

Other DPP system actors

- Develop and / or provide DPP solutions (e.g. issuing, maintaining, hosting, and performing access control) at scale to bring down costs. This is particularly relevant to SMEs
- Provide DPP-related technologies and products (e.g. NFC tags, RFIDs)
- Consulting and data integration services
- Standardisation works to ensure interoperability and indicator consistency (e.g. LCA indicators and interpretation consistency)
- Industry associations: support DPP implementation particularly for SMEs

Gaps and unknowns

The DPP has not been implemented yet to demonstrate its capacity for creating new business opportunities. However, interviews with a number of CEOPs show that the DPP has the potential to increase efficiency or improve their businesses. However, more studies are needed to clearly explain its impact mechanism and quantify impacts.

Multiple interviews with CEOPs also show DPP data alone without changes in business practices (e.g. restriction of selling spare parts, product designs with low repairability) may not make any significant impact.

Many CEOPs are still at the early or exploratory business phase to discover themselves all data attributes needed or how to leverage data to best maximize circularity.

Scenarios

Scenario 1: DPP, in at least one product category, is adopted and shows evidence of creating new business opportunities through circular value retention and optimization. In that case, DPP implementation should accelerate. In addition, it would be helpful to conduct more detailed studies on the impact mechanisms of DPPs to support DPP implementation in other sectors and on large scale.

Scenario 2: The DPP is implemented but not used. In that case, potential causes should be determined (e.g. difficult to access DPP data, data carriers are destroyed or too damaged, business processes do not allow for reading DPP data) and correction courses should be identified.

Scenario 3: DPP is implemented and accessed, but shows no evidence of increasing circularity through new business models. This should be examined to identify causes (e.g. irrelevant data attributes, no enabling support needed to leverage DPP data) and find solutions.

Verification of product compliance with legal obligations

To achieve this goal, DPP needs to be available, and in compliance with regulations, DPP is accessible to public authorities. Keep in mind particular public authorities may require specific interfaces.

DPP data providers

- Collect and integrate data, that is reliable and up-to-date, for their DPP
- Issue DPP that at the minimum, meet DPP data and system requirements
- Provide UID for their products to add to the DPP registry, as required
- Ensure that DPP is accessible to public authorities
- Allow queries of multiple IDs
- While it is not strictly the task of DPP data providers, helping to ensure ease of use of DPP interfaces will support DPP usage adoption.

DPP data users

- Being trained on how to access DPPs and check / use DPP data for their works
- Ensure the use of DPP incorporated into their work flow
- Smooth transition, if required, from old systems and processes to new systems and processes that include using DPPs.

Other DPP system actors

- Develop and / or provide DPP solutions (e.g. issuing, maintaining, hosting, and performing access control) at scale to bring down costs. This is particularly relevant to SMEs
- Provide DPP related and technologies and products (e.g. NFC tags, RFIDss)
- Consulting and data integration services
- Standardisation works to ensure interoperability and indicator consistency (e.g. LCA indicators and interpretation consistency)
- Industry associations: support DPP implementation particularly for SMEs

Gaps and unknowns

- It is unclear what the DPP registry will look like, or which type of DPP interfaces are required for each type of public authorities. Thus, it is difficult to say if they will service the purposes that DPPs are intended for.
- In addition, it may be still too early in the DPP regulation and implementation process to understand how further public authorities, apart from customs and market surveillance, could benefit from using DPP data for performing their work.
- It is important to ensure that DPP regulations and DPP data are not a duplication or contradiction of other existing regulations and databases.

Scenarios

Scenario 1: DPP is implemented and serves its role to public authorities.

Scenario 2 DPP does not only achieve its stated compliance-enforcing role, but also shows possibility to replace other central databases to streamline compliance works for both authorities and economic actors.

Scenario 3: DPP is implemented but public authorities have a difficult time checking it or using it for intended purposes. In that case, it would be helpful to examine what the underlying causes (e.g. system designs, badly designed interface, does not fit into existing processes) could be and how to correct problems identified.

4.4.3.1.3 Sustainable products and production

To achieve this goal, DPPs needs to be available, likely restricted DPP data is included and accessible to authorized users.

DPP data providers

- Collect and integrate data, that is reliable and up-to-date, for their DPP
- Issue DPP that at the minimum, meet DPP data and system requirements
- Determine authorized users and ensure restricted data is available to them
- Similarly to objective 2: new circularity business opportunities. It is difficult to determine what data attributes would support sustainable products and production objectives. In addition, DPP data providers themselves may need to consider business processes such as end-of-life product collection to fully capture and leverage DPP data and / or support sustainable products and production.

DPP data users

- Have the ability to access DPP data (e.g. technologies, procedures)
- Have the resources, technologies, and strategies to leverage DPP data such as product and / or process redesign or collecting used products

Other DPP system actors

- Develop and/or provide DPP solutions (e.g. issuing, maintaining, hosting, and performing access control) at scale to bring down costs. This is particularly relevant to SMEs
- Provide DPP-related technologies and products (e.g. NFC tags, RFIDs)
- Consulting and data integration services

- Standardisation works to ensure interoperability and indicator consistency (e.g. LCA indicators and interpretation consistency)
- Industry associations: support DPP implementation particularly for SMEs

Gaps or unknowns

- As too few DPP or DPP-like initiatives have been implemented, yet, and hardly data on their impact captured, it is difficult to determine, to what extent the DPP could affect sustainable products and production in a measurable way.
- Increasing sustainable products and production may require significant investment and/or significant innovation in business practices and processes. Thus, DPP data availability alone may be insufficient.

Scenarios:

Scenario 1: DPP is implemented and used, and there is evidence of improving product and production sustainability. In this case, DPP implementation should be accelerated. Further studies are needed to determine how the DPP achieves that objective.

Scenario 2: DPP is implemented, with little or no evidence of increasing sustainable products and production. Further studies are needed to determine if DPP data is unhelpful or there is a lack of enabling factors (e.g. resources, infrastructure, technologies, innovation strategies)

Development of DPPaaS providers

DPPaaS providers need to be discussed separately regarding their potential future paths, because they have a special enabling role in the system.

Each component of the DPP system architecture presents an opportunity for product and service offerings. DPPaaS providers could build multiple APIs to this purpose. Furthermore, DPPaaS providers could be enablers of DPP systems and data which may contribute to fostering the data economy that the EU is pursuing as one of their future development strategies.

However, DPP implementation is in a very early phase, and so is the DPPaaS provider community. It is expected that this community will grow and become more diverse in its offerings and characteristics. Yet, it is entirely possible that its future can divert into many different paths. There are several scenarios to consider:

Scenario 1: The DPPaaS community grows strong with a diverse base of company sizes, types, product and service offerings, and technologies, yet follows common DPP standards to remain interoperable. Open source is preferred, and interoperability is achieved. This is an ideal scenario.

Scenario 2: The DPPaaS community **evolves** into a few strata that focus on specific products or services, and may have different standards and technologies, which make interoperability a challenge. This is a likely scenario where many players want to enter the field quickly and try to go to market as early as possible. This is intensified by industries trying to have their own DPP ahead of the regulations. To avoid the ramifications of this possibility, it is important to ensure DPP system requirements and standardisation progress quickly and produce actionable results. Promoting interoperability across systems and sectors is also essential. In addition, supporting organizations and their works on topics such as semantics or data models will play an important role.

Scenario 3: DPPaaS community will eventually become a very small group of large players that act as an oligopoly, and in a winner-takes all-scenario may even be borderline to a monopoly. This is, of

course, the worst-case scenario, which should be avoidable given DPP regulation and standardisation work, supporting DPP projects, and other EU data / IT regulations in place.

4.4.4 Where should we go?

Based on the discussions above, selecting a pathway for each DPP system actor category should take into consideration the DPP objectives, the various characteristics of DPP system actors, technological feasibility, DPP regulations, DPP system requirements, and applicable standards.

While there are multiple options, and the results cannot achieve absolute certainty, given how novel DPP implementation is, the following suggested pathways appear to us to be the most promising and beneficial. They also aim to balance regulation and innovation, to ensure interoperability while leaving room for the flexibility needed. In addition, they view DPP implementation for all actors from a holistic point of view where actors are interdependent and policies are intertwined.

In the following we outline some proposed pathways for selected DPP system actor groups:

REOs

- Whether they choose to issue (and maintain, update) DPP in-house or use third party solutions, they should stick closely to DPP requirements and standards
- Ensure DPP include data that meet DPP data requirements, particularly those that come from their sector Delegated Acts if available. They as well as strive to provide data that is relevant to their customers and data users to achieve the DPP sustainability objectives stated above
- Consider support actions to realize DPP data benefits

End users

- Are informed of DPP existence and its content
- Educate themselves in interpreting DPP data and take that into consideration in decision making
- Support DPP persistence by not damaging data carriers

CEOPs

- Are prepared to access DPP data when available (e.g. technologies to read data carriers, processes / procedures needed to read DPP data)
- Understand DPP data attributes and potential benefits in their works
- Are ready to make changes needed, in terms of organization, business practices, technology and process, to fully leverage DPP data
- Support DPP updating or create new DPPs if required

Public authorities

- Get trained on how to check or use DPPs in their work per regulatory mandate
- Ensure DPP inclusion is compatible with their workflows and processes / procedures

DPPaaS providers

- Stick with DPP regulation, system requirements and standards developed
- Develop products and services with interoperability in mind
- Seek opportunities by having an overview of the entire DPP system architecture and market needs

Supporting organizations

- Get informed on DPP developments to provide implementation support, particularly to SMEs
- Continue working on setting standards and certification schemes

What these general suggested pathways mean specifically and how they could be broken down into action items needs to be elaborated in each sector, as the constellations and conditions for system actors differ significantly across industry sectors.

4.5 DPP support resources

4.5.1 Where are we today?

Some of the questions addressed in this sub-section are: What are the resources already available today? How do or could they facilitate the deployment of a cross-sector DPP system?

4.5.1.1 Data ecosystems

There are already several data ecosystems, most of them sector-specific, that already exist (GDSO, IMDS) that can be leveraged to deploy DPPs relatively quickly. The creation of the DPP system will therefore be in many cases a brown field-effort.

IMDS

The International Material Data System (IMDS)[25] is a centrally managed global data repository for components and materials in the automotive industry. The vast majority of global OEMs and automotive suppliers use the IMDS, which started in 2000. The system is well-established and, through its centralised management mechanisms, ensures consistent data quality. IMDS is of high relevance for the battery passport, which regulates particularly batteries for electric vehicles (EVs). In a decentralised DPP system, IMDS could become a sector-specific data hub for the automotive industry that could support Economic Operators in fulfilling their obligations related to the DPP, first in the batteries sector, and later in other sectors with an expected DPP.

GDSO

GDSO is the Global Data Service Organisation for Tyres and Automotive Components[26], which was established in 2022. GDSO is standardizing data related to tyres and defining solutions to access and exchange data. In this way, it complements the IMDS for the automotive sector and could be seen as well as a supporting resource for facilitating the adoption of DPPs in the automotive sector.

These are just two prominent examples from the global automotive sector, which is quite advanced in regard to data ecosystems. That said, national and international data ecosystems also exist in many other sectors.

European data space ecosystems

For at least the last ten years, Europe has been actively investing in the development of wide-scale data sharing initiatives and related infrastructure through initiatives such as Gaia-X, IDSA, and FIWARE who have all published data space reference architectures.[27] In addition, the European Commission has funded many Digital Europe Programme and Horizon Europe Programme calls for projects related to the deployment of data spaces in many sectors, including manufacturing and Green Deal related topics. A recent initiative is the Simpl middleware[28] that will enable cloud-to-edge federations and

support all major data initiatives funded by the European Commission, such as common European data spaces.

Catena-X

The Catena-X association was formed to promote the digitalization of the automotive industry with the aim of improving the sustainability, transparency, and efficiency of manufacturing processes. It is active in the development of a cloud-based data ecosystem as well as supplier and technologically open standards to facilitate reliable and secure data sharing over value chains. This will be supported by the recently founded Cofinity-X network of partners in the automotive ecosystem that will operate an open dataspace of distributed, sovereign data sources.[29]

4.5.1.2 DPP-related initiatives

Since the launch of the CIRPASS project, 226 DPP-related initiatives have registered with CIRPASS. This number gives an idea on the size of the emerging DPP ecosystem. 83 of these initiatives are described in the CIRPASS deliverable D3.1 Annex "DPP Related Initiatives". As shown in the table below, half of the registered initiatives are cross-sector, and most of the remaining half are sector-specific.

Table 1: DPP-related initiatives by sector

DPP-related initiatives	Number
Cross-sector	123
Textile	56
Batteries	11
Electronics	11
Construction	1
Furniture	1
Chemical	1
Aviation	1
Food	5
3D printing	1
Automotive	1
Other / Not specified	14
Total	**226**

4.5.1.3 Support projects and pilot projects

Besides CIRPASS there are a few other projects that have been preparing the ground for the introduction of regulated DPPs. Most notable among them is BatteryPass[30], a German publicly-funded project dedicated to the exploration and preparation of the battery passport.

In September 2023, an EC-funded study project led by KPMG began to explore how the planned EU registry and DPP web portal should be designed.

4.5.1.4 Knowledge and information support mechanisms

Existing institutions and initiatives have been already, to some extent, sharing information on the upcoming DPP. These include national chambers of commerce, sectoral industry associations, and standardisation bodies. They have been informing their members and interested stakeholders about the purpose, opportunities, and progress of the DPP.

4.5.1.5 Financial support mechanisms

Beyond projects on EU level and national level, we are not aware of any specific financial support mechanisms aimed at facilitating the adoption of DPPs, yet.

4.5.2 Where we are going!

Some of the questions addressed in this sub-section are: What resources are relatively certain to be available in the 2024-2027 timeframe? How will they facilitate the deployment of the DPP system?

4.5.2.1 Data ecosystems

It can be safely assumed that existing data ecosystems, like, e.g., IMDS and Catena-X, will play a role in the deployment of regulated DPPs, starting with the battery passport. The GDSO will likely support preliminary studies with regards to a DPP for tyres.

4.5.2.2 Support projects and pilot projects

The most relevant projects certain to come on EU level is the DPP pilot project under the Digital Europe programme, which is at the time of writing (February 2024) in the grant preparation phase, with an assumed launch date in the second quarter of 2024.

Dozens of other ongoing or upcoming projects on EU level, e.g., through the Horizon Europe Programme, and national level are mostly either sector-specific or focused on other aspects of the circular economy, which may be DPP-related.

4.5.2.3 Knowledge and information support mechanisms

It can be taken for granted that existing institutions and initiatives that have been already sharing information on the upcoming DPP, will continue to do so, the closer the launch dates of the first DPPs in batteries and probably textiles will come.

4.5.2.4 Financial support mechanisms

Beyond projects, we are not aware of any planned financial support mechanisms aimed at facilitating the adoption of DPPs on EU level and national level.

4.5.3 Where could we go?

Some of the questions addressed in this sub-section are: Which options appear possible for the development of data ecosystems and other resources? Which options can realistically be expected?

4.5.3.1 Data ecosystems

The basic choice is between creating new data ecosystems and using existing data ecosystems for establishing sector-specific and cross-sector ecosystems for DPP-related data. Between these two fundamental options, a wide range of combinations is possible between old and new data ecosystems. It could be quite likely that existing data ecosystems become a hub for emerging data ecosystems around the DPP. Existing data ecosystems are predominantly sector-specific, which may create the

need for establishing cross-sector data ecosystems for DPP purposes, possibly driven by DPPaaS providers providing DPP services across sectors or creation of interoperability in a form “translation” can become a service of its own.

4.5.3.2 Support projects and pilot projects

DPP pilot projects under the Digital Europe programme with sector-specific DPP system deployments on scale are expected to run from Q2/2024 to 2027. Furthermore, there are already DPP-related projects on national level ongoing, specifically in the Netherlands and Finland. More project on EU level and on national level are expected to follow, which will support REOs and CEOPs in getting ready for the DPP in batteries and textiles as well as further sectors to be expected introducing mandatory DPPs.

4.5.3.3 Knowledge and information support mechanisms

Knowledge and information on how to create and use a DPP could be spread through existing institutions and channels to REOs, CEOPs, and DPP service providers. This may be sufficient for standard information on the DPP.

However, especially in the initial rollout phase of DPPs after the deployment of the DPP system between 2027 and 2030 we foresee a potential need by stakeholders for a central information point that could answer even detailed and special questions with a high level of competence and reliability. This could be an EU-wide DPP Implementation Support Centre that provides the required expertise at least until the end of the DPP deployment phase per sector. Considering that the planned DPP regulations for several sectors may just start to be drafted before 2030, this may require such a centre to be operational beyond 2030 for as long as it is needed.

The alternative could be to leave this support service to certified DPP service providers in the EU Member States. The drawback of this solution could be that different providers in different countries might give different advice, which could either become a compliance risk for Economic Operators or an efficiency risk on system level when it comes to topics like data quality and DPP data storage and backup requirements.

4.5.3.4 Financial support mechanisms

Especially SMEs could be in need of financial support via public loans and grants for setting up DPP-compliant data management. Current instruments like national support programmes for digitalization of SMEs could possible integrate this. However, there could also be a need for setting up DPP-specific support programmes on European and/or Member State level.

4.5.4 Where should we go?

Some of the questions addressed in this sub-section are: Which of the possible for the development of data ecosystems and other resources should be chosen? Which impacts could be expected from these choices?

4.5.4.1 Data ecosystems

Within the context of European data spaces, we consider a pathway advisable, in which at least one cross-sector data ecosystem for DPP data is created. That said, existing data ecosystems, which are typically sector-specific and centralised, could and should play an important role in the data ecosystem landscape, as they have valuable experience from years of practice in ensuring good data governance

and high data quality, which are essential requirements for the effectiveness of a cross-sector DPP system.

4.5.4.2 Support projects and pilot projects

The results of the Digital Europe DPP pilot projects and other efforts will ideally include the proven feasibility of large-scale DPP system deployment as well as beneficial impact for system actors and the circular economy. It appears quite certain that the insights from these projects and other related projects will highlight further challenges and opportunities. As planning cycles for innovation programmes are quite long, it is thus essential, to already earmark budgets on European and national level for projects that develop innovative solutions for the identified challenges, to better exploit the DPP opportunities and ensure a seamless, highly effective functioning of the cross-sector DPP system.

4.5.4.3 Knowledge and information support mechanisms

Due to the expected need by stakeholders for a central information point on all DPP-related questions, there should be an EU-wide DPP Implementation Support Centre, which provides the required expertise at least until 2030, and if needed even longer, depending on the schedule of DPP launches under the ESPR work plan.

In addition, it would be advisable to create specific training and information offers especially for SMEs in the role of REO, who may be overwhelmed with the DPP-related requirements. Such offers in the respective national languages of SMEs could ensure that SMEs can make the most out of the DPP while keeping cost and effort for complying with DPP requirements low. It would also contribute to higher data quality in the overall DPP system.

These SME-specific local language offers could be provided by existing institutions, mostly on national level, which are already well-known to SMEs, like, e.g., chambers of commerce and existing SME support initiatives.

4.5.4.4 Financial support mechanisms

For many SMEs, the only viable option to comply with DPP requirements may often be using a DPPaaS provider. To cope with the additional cost for these services, it should be evaluated on national level, if loans or grants could be provided in a way compliant with EU competition laws that would support SMEs in building up their data management capabilities in general and their DPP readiness in particular.

4.6 Timeline

The timeline proposed in the figure below is mainly based on our interpretation of information received from the EC about the regulatory process for the ESPR and the Delegated Acts (DAs) for textiles and iron & steel. The timeline is limited to regulation and standardisation in the period 2024 to 2027. In addition, it includes the assumed average start and end dates of the DPP pilot projects under the EC's Digital Europe programme, as they are considered an important resource in support of the DPP deployment. This limit in time and scope was done, because including further categories of factors as well as the period from 2028 to 2030 would have involved a very high level of uncertainty up to the point of making this part of the timeline too arbitrary to be useful.

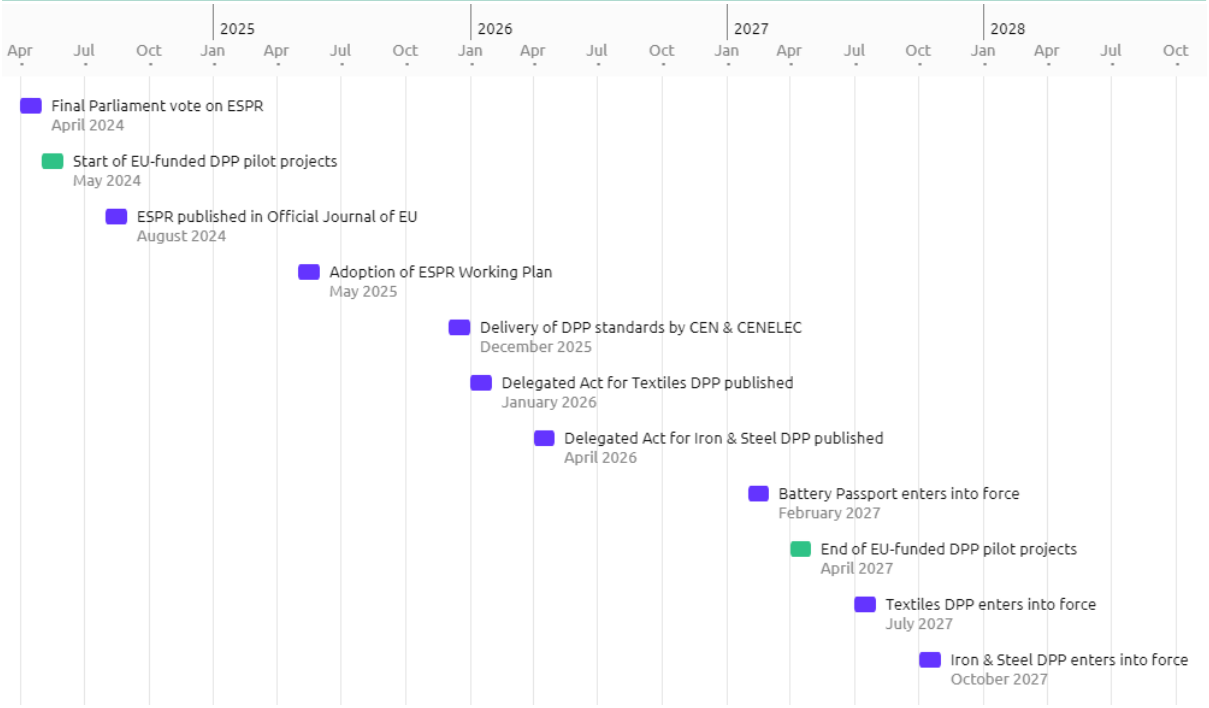


Figure 3: Cross-sector DPP system roadmap – Proposed timeline 2024-2027

As far as regulation is concerned, the further development of the timeline beyond 2027 depends on the next product groups to be scheduled by the EC for a mandatory DPP via Delegated Acts. The following nine pre-selected product groups have been listed in the ESPR as candidates for further mandatory DPPs in the timeframe 2028-2030 and beyond: a) Aluminium, b) Furniture, (including mattresses), c) Tyres, d) Detergents, e) Paints, f) Lubricants, g) Chemicals, h) Energy related products, i) ICT products and other electronics. The order does not indicate ranking in terms of priority, and the Commission may alter the list in their ESPR work plan, if justified. Based on current drafts, further regulations expected to include DPPs are inter alia toys, cars and construction-related products.

5 Sector-specific DPP roadmaps

While the DPP system is meant to be interoperable, functioning as a system of systems across sectors, each sector has its specific conditions across all roadmap categories. Thus, sector-specific roadmaps that take the sector-specific conditions into account are required to complement the cross-sector roadmap.

The following three sector-specific roadmaps for batteries, electronics, and textiles are focusing on these sector-specific conditions without duplicating what is already covered in the section on the cross-sector DPP system.

5.1 Batteries

5.1.1 Where are we today?

Some of the questions addressed in this sub-section are: What are the specific drivers for a DPP in the batteries sector? Which technologies and standards are particularly relevant to the batteries sector in regard to the DPP? What sector-specific features characterize market actors? Which sector-specific resources are available?

5.1.1.1 Drivers

5.1.1.1.1 Regulation

The main driver of a DPP in the batteries sector is regulation on EU level. Besides the ESPR, which drives the interoperable, cross-sector DPP, the regulatory push for a batteries DPP particularly includes the EU's Battery Regulation.[31] It entered into force in August 2023, replacing the EU Battery Directive. The Battery Regulation complements the EU's Strategic Action Plan for Batteries[32], which aims at developing a sustainable and competitive battery value chain in the EU, with the goal of ensuring a reliable and sustainable supply of batteries, particularly for the growing EV market.

The Battery Regulation has set a clear start date for the introduction of the DPP for batteries: "From 18 February 2027 each LMT battery, each industrial battery with a capacity greater than 2 kWh and each electric vehicle battery placed on the market or put into service shall have an electronic record ('battery passport')." The Regulation defines the mandatory information, which the battery passport shall contain, some general design criteria, including interoperability, security and more, and how it shall be accessible, i.e. through a QR code.

For further details on the new Batteries Regulation see the Battery Passport Content Guidance by the Battery Pass project.[33]

5.1.1.1.2 Economic factors

In addition to regulation, there are some economic factors that may already today drive producers, remanufacturers, and recyclers towards a battery passport:

- **Cost-effective validation of remaining value in used batteries:** EV batteries are being taken out of use at roughly 80 % remaining performance. However, at that stage some batteries could still be suitable for second-life applications. A DPP could validate this and thus reduce the need for expensive testing of modules, which today is only done selectively.
- **Rapidly increasing demand for EV batteries:** According to IEA's Global EV Outlook 2023, demand for automotive lithium-ion batteries increased from 2021 to 2022 by about 65% to 550 GWh. The increase in battery demand has driven the demand for critical materials. In 2021 and 2022, lithium demand exceeded supply, despite a 180% increase in production since 2017.[34] Increasing demand drives prices and potentially limits availability of critical materials. This provides a strong economic incentive for increasing circularity in EV batteries.
- **Retrieval of critical raw materials:** Batteries contain a huge amount of very valuable and in part critical raw materials with insecure supply sources (general scarcity, geopolitical unrest, disturbance of supply routes, etc.). Being able to retrieve these materials (e.g. by dismantling and disassembly information from a DPP) is a major incentive.

5.1.1.2 Technologies

5.1.1.2.1 Sector-specific product dictionaries/ classification systems

Sector-specific product dictionaries/ classification systems play an important role for the consistent identification of products and components in a DPP. In the batteries sector there is only one specific dictionary we know of:

BattINFO

BattINFO[35] is the battery interface ontology developed in BIG-MAP. BIG-MAP, the Battery Interface Genome – Materials Acceleration Platform, is a Horizon 2020 project running from 1st September 2020 to 29th February 2024. It is part of the EU research initiative BATTERY 2030+[36], which aims to support the transition towards sustainable batteries.

BattINFO has defined a common battery language to help support interoperability of data in battery research. The initial version of the ontology from February 2021[37] has been mainly developed by academic organisations. Thus, it cannot be assumed that BattINFO has been already in widespread use across the battery sector.

In this context, it may be relevant to mention that Catena-X has developed a detailed data model, which is currently being updated together with the Battery Pass project.[38]

The Catena-X model is expected to become very relevant in the automotive industry. However, as of today, it is not yet ready to be used.

5.1.1.2.2 Adoption level of data carriers

QR codes are already extensively used in the industry. QR codes are on batteries and on modules inside the batteries.

There are also directly printed unique IDs in use. Since 2018, unique IDs are mandatory in China, the country producing by far most batteries globally. Thus, we estimate that unique IDs are provided on more than 90 % of batteries in the DPP-relevant segment worldwide.

5.1.1.2.3 Available systems and platforms that could facilitate DPP adoption

Especially for batteries to be used in EVs, there are already data management systems and collaboration platforms in place that has the potential to facilitate DPP adoption in the automotive sector.

International Material Data System (IMDS)

The IMDS[39] is the automobile industry's material data system. It was launched by a group of car manufacturers in 2000 in parallel to the evolution of the EU End-of-Life Vehicle (ELV) directive, in order to ensure ELV compliance of OEMs and their suppliers.[40] Since then, IMDS has become the central material data system for almost all global OEMs and their suppliers. IMDS collects data on all materials in the automotive production supply chain. Thus, it enables the participating companies to comply with worldwide ELV directives, REACH SVHC, Relative Risk Reduction (RRR), and similar regulations.

Unlike the envisaged decentralized DPP system, IMDS is a centrally managed system. Despite this, the data quality standard achieved in IMDS could facilitate compliance with DPP data requirements by REOs in the EV battery sector.

Catena-X

Catena-X[41] is part of Gaia-X[42], a European initiative that aims to establish an ecosystem in which data is shared in a trustworthy environment. Catena-X is Gaia-X's first implementation project. The goal of Catena-X is to provide an open data ecosystem for the automotive industry designed to create data chains that will enhance its members' value chains.

As mentioned above, Catena-X had published in 2023 a draft Standard (CX – 0034) for a data model of a battery passport. In this way, Catena-X is part of the ecosystem facilitating the development and implementation of the battery passport.

5.1.1.3 Standards

5.1.1.3.1 Existing standards for identification, capture and exchange of mandatory/non-mandatory product information

There are already several standards in place that are related to data relevant for a battery passport. The Battery Pass project has mapped standards relevant for the end of life and the carbon footprint of batteries; in the project's Battery Passport Content Guidance all relevant data attributes are described in detail referring to available standards.[43]

In addition, there are several standards relevant for electric vehicle batteries:

- UL 2580: The Standard for Batteries for Use in Electric Vehicles
- UL 1973: The Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications
- UL 2271: The Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications

These standards are used to test and certify electric vehicle batteries for safety, performance, and reliability.

5.1.1.3.2 Standards under development

There are international traceability standards for batteries under development by SAE, a US-based standardisation organisation. The SAE Battery Global Traceability Committee is developing standards for common battery data and security to be shared with various global stakeholder groups enabling sustainability and compliance for the global battery supply and value chain.[44]

In January 2024, a battery passport content standardisation effort under DIN DKE SPEC 99100 was launched. This is a standardisation effort based on results from the Battery Pass project. As of February 2024, it is unclear, if the Implementing Acts for the Battery Regulation will refer to this standard or if they will require a parallel additional standardisation effort.

There is the plan to introduce the DIN DKE SPEC 99100 to CEN and/or CENELEC with the aim to develop a European standard (EN) which could be listed under the expected standardisation request on batteries.

There is also a working group at ISO working on the standardisation of battery passport data: ISO/AWI 18006-1 – Electrically propelled road vehicles — Battery information — Part 1: Labelling and QR/bar code for specification, safety, and sustainability. This working group is organizationally managed by the VDA, the German Association of the Automotive Industry, and technically managed by a large German OEM, Volkswagen, which is also a member of the battery passport project via Audi, a subsidiary of the Volkswagen Group.

5.1.1.4 Market actors

5.1.1.4.1 Responsible Economic Operators

Openness to adopting new technologies

We assume a high level of openness to new technologies by Responsible Economic Operators (REOs) in the EU, including OEMs in the automotive sector as well as producers, importers, and distributors of batteries in the scope of the Battery Regulation. This assumption is based on interviews conducted by CIRPASS with battery producers and OEMs between November 2023 and January 2024. The DPP would streamline their due diligence in certifications and provide clarity in requirements. Additionally, the hurdle towards implementations is not very high, since the large OEMs and battery producers already have a well-functioning internal information systemin place, i.e. IMDS.

CATL, the world's largest producer of lithium-ion batteries for electric vehicles and energy storage systems from China, seems to be keen to adopt the DPP, in order to better trace their batteries, which would help CATL in facilitating the compliance process with OEMs and would use life cycle data collected from DPP for further improving their batteries for different usage scenarios.

Digital maturity of most companies regarding product data management and related technologies

As already hinted above, the digital maturity of most companies in the batteries sector and related sectors can be assumed to be high regarding product data management and related technologies. This applies particularly to the large EV battery producers, many of them in China, and the OEMs in the automotive sector.

Legal responsibility for putting the product and the DPP on the market

Today, OEMs often buy batteries from battery producers and build them into their EVs. If OEMs put their brand name on the battery and subsequently place them on the market, they take over ownership of the battery passport and the product responsibility, which can be delegated back to the battery manufacturer by agreement. As per article 2.19 of the Batteries Regulation, the economic operator can also be a ‘fulfilment service provider’. This can be, upon agreement, the initial battery producer. The term ‘fulfilment service provider’ is defined in Regulation (EU) 2019/1020.[45]

DPP service providers could offer the service for smaller battery producers/sellers to comply with their economic operator obligations.

IP protection

Battery cell manufacturers are concerned about IP protection in regard to the forthcoming battery passport in case they are not the REO. If, for example, the battery passport will be issued either by the pack manufacturer or the OEM, it may contain confidential information from the cell producer, like, e. g., the detailed chemical composition of the battery cell, which is protected knowledge.

5.1.1.4.2 Circular Economy Operators (CEOPs)

Openness to adopting new technologies

We assume a high level of openness to new technologies by Circular Economy Operators (CEOPs) in the EU, including recyclers and remanufacturers. This assumption is based on interviews conducted by CIRPASS with recyclers and second life operators between November 2023 and January 2024.

Recyclers need specific information, including the composition of batteries, for their proper pre-treatment of the batteries, meaning their sorting, discharging and dismantling. For the time until the

wide-spread adoption of a battery DPP, the recyclers are using internal databases with information they gathered through desk research or directly from the producers. This is not always possible, therefore a complete data set for each battery would ensure better safety and a higher recycling yield.

Second life operators, such as providers of stationary batteries for grid stability from second life automotive batteries, have to assess the usability of said batteries based on limited data and thus cannot use them to their full potential, e.g. take them out of commission earlier than needed. A DPP that has stored lifetime information on the battery would help to properly assess and use them.

Recyclers need new DPP-based solutions to automatically identify and sort the batteries they receive. Up to now, recyclers have to check every battery they receive manually, at worst look up their composition on the Internet or open them to find. Thus, recyclers have a clear economic incentive to be innovative and open to new technologies in this area.

5.1.1.4.3 Service providers

Use of service providers for product-related data management solutions

As an example of the successful use of a service provider in the automotive sector, IMDS could be mentioned. In the automotive industry, the use of sector-wide service providers for data management and sharing has been a proven practice since the early 2000s, when IMDS was created. IMDS is operated by an external service provider, DXC. The IMDS database is relevant for the batteries sector, as it contains information on EV batteries.

There are already a few initial DPP-like solutions by service providers on the market. Most emerging DPPaaS providers cover several sectors, including batteries.

5.1.1.5 Resources

Projects related to DPPs or track & trace solutions in this sector

There have been several projects in Europe that have been doing preparatory research and development work for the introduction of a battery pass.

The German Battery Pass project[46] is among the major projects preparing the implementation of the battery pass, with a focus on the automotive industry. Several large industry players are involved in the project, and Battery Pass results are contributing significantly to the development of the battery passport in Germany and the EU.

Catena-X has developed a battery passport consumer app, which is meant to serve as a frontend interface for end users.[47] As a platform for the automotive sector, Catena-X can be considered an important resource for supporting the development of the DPP for EV batteries.

The Global Battery Alliance (GBA) has launched three battery passport proof-of-concept pilots.[48] Furthermore, the GBA Battery Passport Steering Committee includes several major international battery value chain stakeholders.[49] Thus, the GBA efforts can be considered very important for the implementation of the battery passport.

Publicly funded support mechanisms for DPP adoption in this sector

Beyond publicly funded R&D projects, there are no other support mechanisms for DPP adoption in the battery sector known.

5.1.2 Where we are going!

Some of the questions addressed in this sub-section are: Which market trends and development pathways in regard to sector-specific factors appear already to be highly certain for the coming years? What does this mean for the development of the DPP in this sector?

5.1.2.1 Drivers

The main driver, for which there is a high certainty on where the sector is going to regarding the DPP evolution, is regulation. For economic drivers, there is a high degree of certainty that scarcity of CRMs will play an increasing role. However, due to a variety of factors (new mining projects, geopolitical situation, innovative technologies reducing the need for some CRMs, etc.) it is rather unclear, how fast CRM scarcity will become a forceful driver of circularity.

5.1.2.1.1 Regulation

Delegated Acts and Implementing Acts for the Battery Regulation

Related to the Battery Regulation, Delegated Acts (DA) and Implementing Acts (IA) are planned in order to complement it. The timeline for these has not been determined yet, as of January 2024. The publishing of these DA/IA is expected to happen between 2024 and 2031. Preparatory studies on different product groups are currently in the launch phase (January 2024).

According to a publication by the Battery Pass project from December 2023[50], the "EU Battery Regulation provides the legal basis for 32 Delegated (DA) and 15 Implementing Acts (IA). Of these, 29 DAs/IAs may be adopted by the Commission as needed to ensure uniform conditions or amend the Regulation based on market developments as well as technical and scientific progress. 18 DA/IA will be adopted to complete the Regulation in detail, according to the schedule defined in the Regulation".

The envisaged DA/IA are expected to cover the topics of carbon footprint (methodology, performance classes, thresholds, formats), circularity (recycling efficiency, material recovery), performance and durability (minimum values for electrochemical performance), battery passport access (access rights), and reporting to the Commission (harmonization of data and information formats for reporting).

EU End-of-life Vehicles Regulation

The currently revised EU End-of-life Vehicles Regulation will bring new rules for the design and end-of-life management of vehicles. This aims to protect the environment, decarbonise production and reduce raw material dependencies.[51] The current proposal from July 2023[52] could have an impact on the battery pass and vice versa once it is implemented.

EC plans for battery-specific carbon footprint calculation

There is an ongoing JRC activity preparing a battery-specific carbon footprint calculation which will contribute to the implementation of the battery passport. In 2023, the JRC published a final draft of a report for the calculation of the carbon footprint of EV batteries.[53] It is supposed to provide the basis for implementing the requirements of Article 7 of the Battery Regulation, supplementing the Regulation by establishing the methodology for calculation and verification of the carbon footprint of EV batteries.

5.1.2.2 Market actors

Share of SMEs

The share of SMEs who will be in the role of economic operator under the Batteries Regulation is expected to be relatively small, as large players dominate the market. However, among suppliers in the battery value chain, there are a larger number of SMEs.

5.1.3 Where could we go?

Some of the questions addressed in this sub-section are: What major realistic options for DPP development are available in this sector? How do these options differ and how should they be evaluated?

5.1.3.1 Drivers

5.1.3.1.1 Regulation

Up to 2027, regulation is expected to remain the main driver for the battery passport in the EU. There are still a few open questions in regard to regulation, for example: How will access rights be distributed? How are composition data specified? What are data security requirements per access group? It is not clear, to what extent these and other open questions will be addressed in the DAs and IAs following and complementing the battery regulation. Basically, the choice is between putting more strict or less strict data requirements on REOs and CEOPs. And then there are yet unclear issues to be addressed.

It is, for example, not clear yet how regulation will handle a scenario where a consumer buys an electric car, including the EV battery as a central component, and the car dealer and/or consumer needs to access the battery passport before the product even exists, as it only gets produced/assembled, when ordered. There are different options how to regulate this: a) the economic operator could issue the product passport once the buying order is in the production system; or b) the economic operator is only permitted to issue the product passport once the product has been manufactured. In addition, A "standard" DPP could be provided to the customer showing average numbers for orientation.

5.1.3.1.2 Economic factors

Beyond 2027, there is a considerable chance that the relative weight of economic factors versus regulatory requirements will increase, although it is anything but certain. This could lead to a scenario, where REOs and CEOPs not just comply with regulatory requirements but exceed them, when necessary, to further increase transparency in their value chains. Factors contributing to such a scenario could be increasing prices, respectively high price volatility, for production-critical battery materials and components, issues related to accessibility and availability of such critical materials and components as well as economic benefits for the battery producers that exceed the implementation effort of the battery passport.

5.1.3.2 Technologies

Pathways for technological progress in the batteries sector related to the battery pass could involve technological innovations for more efficient automated sorting, remanufacturing, and dismantling of batteries towards the end of their first lifecycle. The DPP could provide an additional push to ongoing developments in this direction, making novel or existing circular business models especially for EV batteries, such as stationary energy storage from second-life EV batteries, more feasible.

The DPP could help improve the operations of stationary energy storage from second-life EV batteries through more data about the old batteries. Extended lifetime information about the batteries would allow providers to find a lower bottom State of Health (SoH) cut-off than they are using right now. Currently, most providers use batteries down to around 60% SoH; with more information, they could use batteries with a lower SoH.

5.1.3.3 Standards

For battery passport content standardisation, there are at least two different options. The first option would be to adopt the DIN SPEC 99100 standard, which is currently being developed, as a reference for the Implementing Acts of the EC Battery Regulation. The second option is that the EC would request an additional standardisation effort that would run in parallel to DIN SPEC 99100. Noteworthy is also the formation of a committee on global battery traceability standards for common battery data formed by SAE[54].

5.1.3.4 Market actors

5.1.3.4.1 Responsible Economic Operators (REOs)

By the time the Battery Passport will come into effect in February 2027, the battery market, especially for EV batteries, could have substantially changed compared to 2024. Due to the increase of battery production in the EU and other regions, a large increase in global battery production and a moderate decrease of the market domination by Chinese battery manufacturers can be expected. For Economic Operators bringing batteries into the EU market, this could mean that more of them will be producing the batteries within the EU.

There are good economic reasons for Economic Operators to fully embrace the circular opportunities of the DPP, as extending the lifecycle of batteries, especially EV batteries, will likely reduce price risks for raw materials and would allow to reduce prices for EVs, which is one of the barriers limiting sales of EVs in Europe. At the same time, battery manufacturers are wary of disclosing their intellectual property, like, e.g., the exact material composition of their batteries, to competitors.

Generally, we see two major options for Economic Operators regarding the Battery Passport: 1. DPP compliance only, i.e. the mandatory regulatory requirements will be fulfilled, but nothing more; 2. full embracement of circular DPP opportunities, i.e. the mandatory information will be complemented as needed to facilitate more efficient circular processes for batteries along their lifecycle.

5.1.3.4.2 Circular Economy Operators (CEOPs)

For Circular Economy Operators (CEOPs), especially remanufacturers of EV batteries, the battery passport could open up potentially lucrative mid-term business opportunities. However, this involves a certain degree of risk, as the business case for refurbishing DPP-regulated batteries needs to take into account their average lifetimes, which for EV batteries is between 10 and 15 years. Thus, it is rather a longer-term investment horizon for remanufacturers and recyclers, which involves the risk of under-utilization of modernised, DPP-ready remanufacturing and recycling plants.

This risk could be mitigated through close collaboration and even vertical integration with OEMs in the automotive sector, which seems to be already happening and might be intensified once the battery pass is being deployed from 2027 onwards.

In view of the investment opportunities, it appears likely that a growing number of non-EU batteries manufacturers will expand their already ongoing investments in battery plants in the EU.

5.1.3.5 Resources

In addition to ongoing and emerging pilot projects for supporting the battery passport, it is also expected that a number of data ecosystems around batteries will emerge. They could either evolve from existing data ecosystems like IMDS, or they could be new data ecosystems initiated by DPPaaS providers supporting REOs and CEOPs in coping with regulatory DPP requirements.

5.1.3.6 Outline of scenarios based on dominant factors for batteries

Based on the exploration of factors influencing the available DPP pathways in batteries, we suggest to sort them into two dominant factors: 1. maturity level of the DPP system in batteries, and 2. DPP readiness of batteries market actors. The matrix below accordingly provides four alternative scenarios to be considered for the timeframe 2027-2030, which would be the period after the battery passport has come into effect.

Note that these are simplified scenarios whose sole purpose is to achieve more clarity on decision-making options for optimizing factors improving the circularity impact of a DPP in batteries. Possible scenarios are not limited to the four scenarios presented, but could be any variation of combinations between different system maturity and market actor readiness levels.

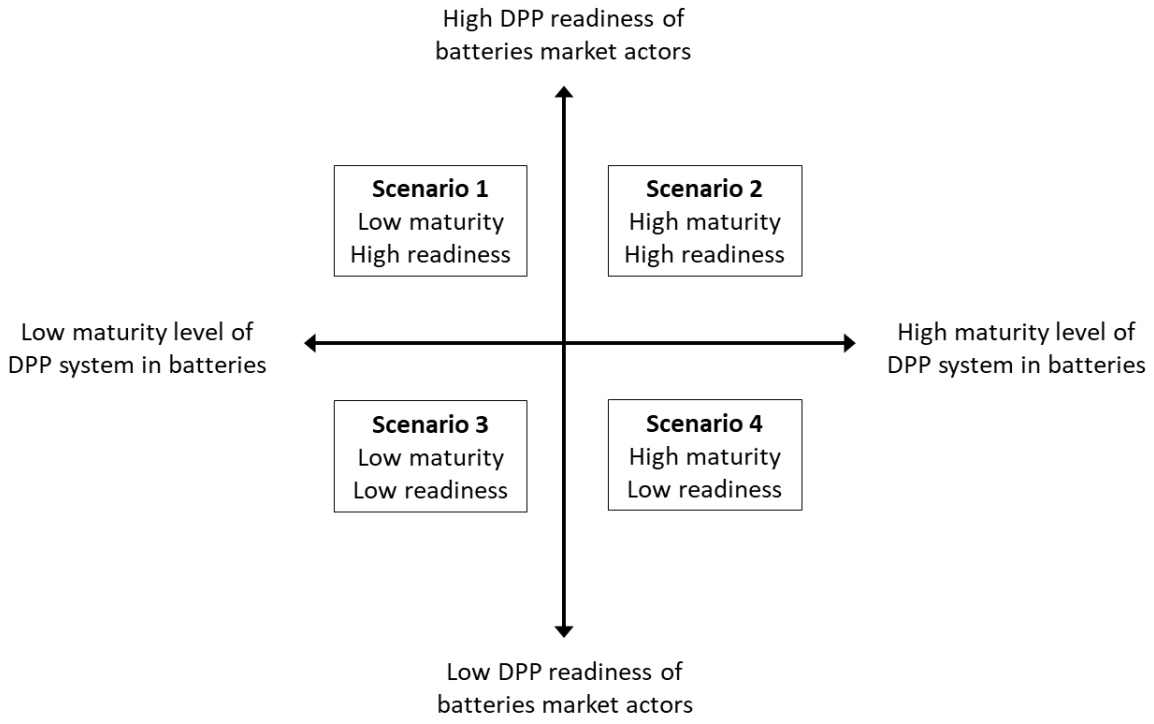


Figure 4: Scenario matrix of dominant factors influencing a DPP in batteries

Scenario 1 – low maturity & high readiness

This scenario could be the most probable out of the four.

A high readiness of the majority of REOs, which appear to be mostly large enterprises, appears to be likely. That may also apply to IT providers and special DPPaaS providers in the sector.

The batteries sector is the first sector, in which a DPP will be introduced. Thus, we consider a low maturity of the generic architectural and technological elements of the DPP system to be a realistic possibility, at least for the period 2027-2028. In addition to general architectural or technological still requiring optimization, there may also be sector-specific challenges to be addressed, which may only

find mature solutions in the years after DPP introduction. In addition, also regulation may still need further adaptation.

Scenario 2 – high maturity & high readiness

The DPP in the batteries sector comes into effect February 2027, according to the battery regulation. This scenario assumes a high maturity of the DPP system, which would mean all standards are in place and the implementation of the DPP architecture works flawlessly. However, a high maturity of the DPP system in this sense appears unlikely, for the reasons mentioned above. At the same time, the maturity will probably not be low either, due to the three-year lead time.

For the reasons mentioned under scenario 1, a high readiness level of all market actor, particularly the majority of REOs, appears possible, if not likely within the given period.

Scenario 3 – low maturity & low readiness

This scenario assumes a low maturity, which would imply that standards are not in place, respectively not harmonised, and the implementation of the DPP architecture and its elements reveals serious issues that need to be fixed.

A major concern for the maturity of the DPP system relates to the timeline. Delivery on the Standardisation Request to CEN/CENELEC is expected by the end of 2025, which leaves around 14 months for the implementation of the DPP system. Even if it is done in time, the market actors will only have a relatively short time to implement the DPP.

Due to the reasons mentioned above, a low maturity of the DPP system is possible, while a medium maturity of the DPP system at the time a DPP is coming into force in the batteries sector could be slightly more likely, if regulation, standardisation, and deployment run on schedule.

We would not expect a low readiness level of a majority of market actors, both REOs as well as CEOPs, as they have the foundation of existing data management systems, like IMDS, and the experience and capacity of large or medium-sized companies with a relatively high degree of digitalization and data management.

Scenario 4 – high maturity & low readiness

Out of the four basic scenarios, this could be the least likely. A high maturity of the cross-sector DPP system does not appear highly probably for the reasons discussed above.

At the same time, we expect a high level of market-actor readiness. Most large REOs will already have data management structures and procedures in place that will facilitate introducing a DPP in 2027. Due to the expected high regulatory and economic pressure for extending the lifetime of batteries and better recycling them at their end of life, we also expect most CEOPs to have achieved a relatively high maturity level by the time the battery passport comes into effect.

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The presented scenarios require further exploration. However, even in their current shape, they may be useful for evaluating the available options and their impacts as well as triggering necessary discussions on the required innovations for optimizing the circularity potential of an upcoming DPP in the batteries sector.

5.1.4 Where should we go?

Some of the questions addressed in this sub-section are: What would be the most effective way to implement the DPP in this sector? How would the suggested DPP pathway help in advancing the circular economy in this sector?

5.1.4.1 Drivers

Beyond 2027, economic factors, like raw material prices and availability, should become the main drivers for DPP deployment in the batteries sector. Instead of the regulator pushing industry, it would then be rather industry, primarily the global automotive industry, driving the DPP system beyond regulatory requirements, to achieve full circularity for batteries as a pre-condition for satisfying the increasing demand for EVs worldwide.

5.1.4.2 Technologies

The EC and industry should increase their investments in data-driven DPP-enabled technological solutions which accelerate efficiency increases in the automation of battery remanufacturing and dismantling processes.

5.1.4.3 Standards

Standards need to evolve in parallel to the technological advances described above. Such standards could ensure consistent and comparable data that can be used throughout the battery processing stages. Furthermore, aligned standards could help to avoid longer periods of competition between large industry players for de-facto standards in the battery sector, which could lead to macroeconomic costs which could rather slow down than accelerate the emergence of a circular economy in the EU.

5.1.4.4 Market actors

REOs in the battery sector should not just comply with regulatory requirements but go beyond to fully embrace the circular business opportunities enabled by the battery passport. More specifically this could mean to include further, non-mandatory data points in the DPP, to facilitate reuse, remanufacturing, and recycling of batteries, particularly for EVs, where a steep increase of demand is expected closer to 2030, when the exit from new fossil-fuel driven vehicles in 2035 will only be five more years away.

CEOPs, especially remanufacturers and recyclers of EV batteries, should expand the data-driven automation of remanufacturing and recycling processes in existing and planned plants. The associated long-term investments could have a 5-10-year horizon, entailing a significant degree of uncertainty and risk regarding demand. However, the potential economic rewards appear equally significant and could justify such long-term investments after a thorough analysis of specific business cases. In this effort, CEOPs should collaborate more closely with battery manufacturers and OEMs in the automotive sector.

DPPaaS providers should join forces with REOs and CEOPs for adapting and expanding existing data ecosystems, like, e.g., IMDS, in a way that facilitates the flow of DPP data while preserving the intellectual property of battery manufacturers and OEMs. Where necessary, they should also become proactive in creating novel data spaces for DPP-based battery information, to facilitate and accelerate circularity in the battery sector.

5.1.4.5 Resources

The battery sector and the related automotive sector appear to have the necessary resources for deploying the DPP and utilizing its circular business potential, both in terms of knowledge as well as financial capabilities.

An important resource that should be created, possibly through a public-private partnership, would be a cross-sector data space for batteries to facilitate rule-based DPP information flows while reducing the costly need for bi-lateral agreements. The nucleus for such a cross-sector data space for batteries should be an existing initiative like, e.g. Catena-X, to avoid starting from scratch.

Cases where public financial support could be needed, involve the automation of remanufacturing and recycling by CEOPs, for whom the business risk is not worth taking in the mid-term. This should only be considered if there is a clear macroeconomic and societal benefit associated to such financial support. It could possibly be provided via interest-reduced loans by the European Investment Bank.

5.1.5 Timeline

The timeline proposed in the figure below is mainly based on our interpretation of information received from the EC about the regulatory process for the ESPR and the Battery Regulation. The timeline is limited to regulation and standardisation in the period 2024 to 2027. In addition, it includes the assumed average start and end dates of the DPP pilot projects under the EC's Digital Europe programme, as they are considered an important resource in support of the DPP deployment across sectors, including batteries. This limit in time and scope was done, because including further categories of factors as well as the period from 2028 to 2030 would have involved a very high level of uncertainty up to the point of making this part of the timeline too arbitrary to be useful.

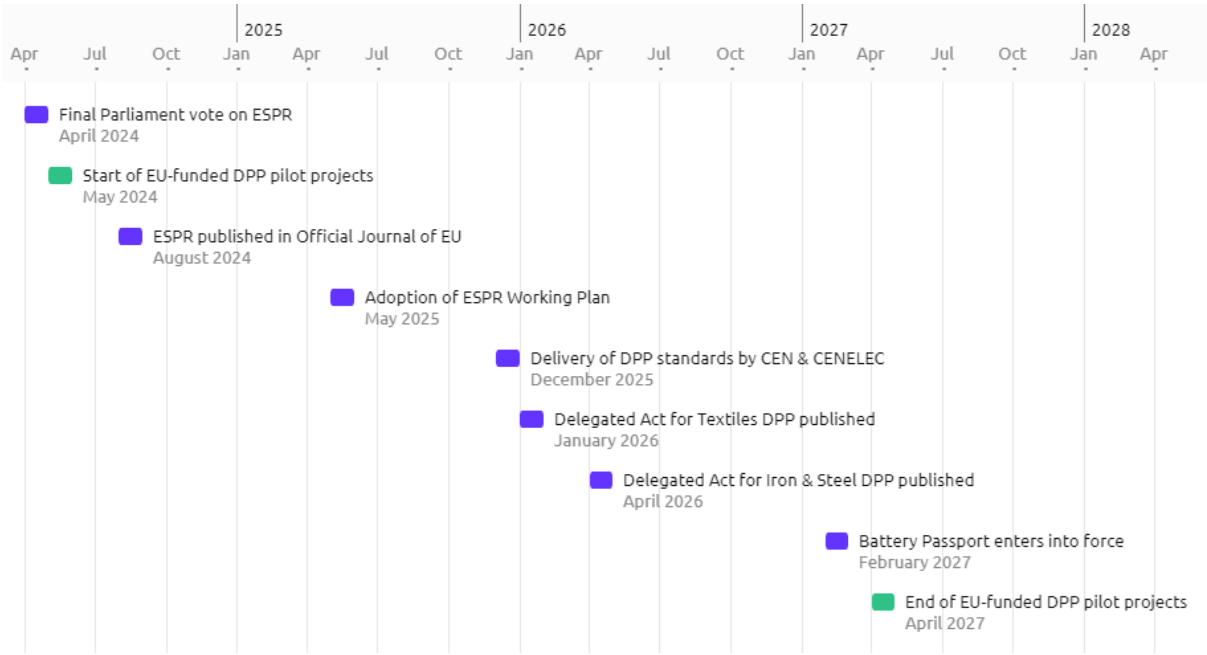

Figure 5: Batteries DPP roadmap – Proposed timeline 2024-2027

5.2 Electronics

5.2.1 Where are we today?

Some of the questions addressed in this sub-section are: What are the specific drivers for a DPP in the electronics sector? Which technologies and standards are particularly relevant to the electronics sector in regard to the DPP? What sector-specific features characterize market actors? Which sector-specific resources are available?

5.2.1.1 Drivers

5.2.1.1.1 Regulation

The electronics sector is already subject to regulatory requirements for mandatory product information on EU level. These regulations are mainly focused on chemical substances, particularly hazardous substances, energy efficiency, and electronic waste.

REACH Regulation

Under the REACH Regulation, manufacturers and importers are obliged to gather information on the properties of their chemical substances and to register that information in a central database at the European Chemicals Agency (ECHA).[55]

See the Textiles Roadmap below for further details on the REACH Regulation.

RoHS Directive

The RoHS Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment[56] could be considered complementary to the REACH Regulation for the electronics sector.

EPREL - European Product Registry for Energy Labelling

Since 1st January 2019, suppliers (manufacturers, importers or authorised representatives established in the EU) must register their products in the European Product Registry for Energy Labelling (EPREL).[57] The database primarily provides information on a product's energy use. In addition, it also provides information about its possible water consumption, noise emission, extension of the warranty, availability of spare parts, duration, and product support.

Waste legislation

In addition to the above regulations, the electronics sector is subject to a host of waste regulations, particularly the WEEE Directive 2012/19/EU on waste electrical and electronic equipment[58]. The WEEE Directive aims to promote the collection of waste electrical and electronic equipment (WEEE) as well as its recovery, recycling, and preparation for reuse, in order to reduce the quantity disposed. According to Eurostat, the collection rate of WEEE in the European Union was 46.2 % in 2021, measured as the weight of WEEE collected relative to the average weight of electronic equipment put on the market in the three preceding years, i.e. 2018-2020.[59] This was still 16.8 % below the target of collecting 65 % of waste electrical and electronic equipment in the EU.

In addition to the existing regulation, electronics is also considered one of the key sectors for action under the Circular Economy Action Plan[60]. Translating this plan into further regulatory action is challenging, as electrical and electronic equipment (EEE) includes a large variety of products that vary in size, weight, and material composition.

For further details on horizontal and vertical regulations relevant for the electronics sector, see CIRPASS deliverable D2.1 “Mapping of legal and voluntary requirements and screening of emerging DPP-related pilots”.[61]

5.2.1.1.2 Economic factors

Besides regulation, there are also economic factors potentially driving the need for a DPP in electronics.

Product diversity and complexity

The complexity of electronics products, both in the B2B and the B2C domain, can be considered on average much higher than for products from some other sectors, like, e.g., textiles. The WEEE Directive categorizes EEE products into six clusters, based on specific product features, including size[62]:

1. Temperature exchange equipment (refrigerator, air conditioners, radiators, heat pumps, etc.)
2. Screens, monitors, and equipment containing screens having a surface greater than 100 cm (computer monitors, television sets, laptops, etc.)
3. Lamps
4. Large equipment – any external dimension more than 50 cm (household appliances, IT and telecommunication equipment, musical equipment, medical devices, monitoring, and control instruments, etc.)
5. Small equipment – no external dimension more than 50 cm (household appliances; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure, and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents)
6. Small IT and telecommunication equipment – no external dimension more than 50 cm

This rough categorization gives an idea of the complexity and large variety of EEE, which poses special challenges in the context of a circular economy, together with the composition of EEE products.

Complex electronics products can contain up to 60 elements from the periodic table, including:

- Precious metals such as copper, gold, silver.
- Critical raw materials (including rare-earth elements). For example, gallium and silicon metal used for integrated circuits, neodymium, and dysprosium for magnets in small motors and hard drives, tantalum for capacitors.
- Plastics (especially engineering plastics such as acrylonitrile butadiene styrene (ABS), polycarbonate/acrylonitrile butadiene styrene (PC/ABS) and high impact polystyrene (HIPS).

The high complexity of the products is often matched by high complexity, high volatility, and low transparency in the supply chain, which increases the effort for supply chain management in view of rising compliance demands. Increased transparency and reliability of product data could be an economic incentive to strive for DPP(-like) solutions in the sector.

Supply of materials and components

Both volume and variety of materials and components needed in the electronics sector pose an increasing challenge in two respects: ensuring reliable supply at manageable cost and containing the economic, social, and environmental cost of electronic waste.

Especially the increasing difficulty of ensuring a steady, cost-effective supply of certain rare earth materials seems to make increasing circularity in electronics economically desirable in its own right, even without considering regulatory pressure.

Business requirements for circularity and sustainability

The combination of regulatory requirements and supply chain needs have the potential to turn circularity and sustainability into business requirements. They will increase the competitiveness of businesses that proactively push for circularity in their business ecosystem and aim to reduce their carbon footprint through Net Zero strategies beyond regulatory requirements. In this context, a DPP could become a suitable lever for ensuring product data sharing as an enabler for circular business models.

The move to a voluntary DPP in electronics could become economically more feasible and attractive due to the mandatory DPP in batteries, which would already directly affect all electronics manufacturers and traders that have batteries with a mandatory DPP in their products. Through the blueprint provided by the batteries DPP, the organisational effort and cost for introducing a voluntary DPP in electronics based on similar standards and processes, as the mandatory DPP could become economically attractive.

5.2.1.2 Technologies

5.2.1.2.1 Sector-specific product dictionaries/ classification systems

In addition to the WEEE classification system mentioned above, there are different classification systems in EPREL and in the ESPR. However, all of them only cover a part of DPP requirements, depending on their focus and scope:

ETIM is an international classification standard for technical products which covers Electronics finished goods. ECLASS is a reference data standard for the classification and unambiguous description of products and services. While it can be used over a wide range of industries, one of its standards addresses products related to the fields of electric engineering, automation, process control engineering.

IEC Common Data Dictionary (IEC CDD) is an International Standard (IEC 61360-4 DB) of concepts for all industrial/technical domains (electrotechnical and non-electrotechnical; e.g. industry, building, energy, healthcare, …) based on the methodology and the information model of IEC 61360 series.

RePlanIT is an ontology for the sharing of ICT product data between manufacturers, sustainability experts and technology providers for the circular economy. (https://github.com/RePlanIT/Ontology).

ITU-T/ETSI standard: ITU-T L. L.D4PI “An information model for digital product information on sustainability and circularity”. The proposed Recommendation will provide a collection of information items organised to represent circularity, environmental sustainability and health information about ICT products and inform any actor during the product lifespan and final recycling.

eReuse.org is a data model developed by UPC in collaboration with social ICT refurbishers and recyclers in Catalonia. It will be exploited by an upcoming EBSI pilot in collaboration with IOTA. The final open-source release is expected by mid-February 2024.

International Material Data System (IMDS) is a global data repository that contains information on materials used by the automotive industry to facilitate the meeting of regulatory obligations placed on automobile manufacturers and thus on their suppliers.

5.2.1.2.2 Adoption level of data carriers

Data carriers for linking to digital product information are not very common in electronics.

Five product groups regulated by the respective delegated acts under the energy label regulation already have QR codes on the package and the product for consumers. Scanning this QR code connects the user with the data stored in the centralized EPREL database.

Due to the large variety of products and value chains, there seems to be no clear preference for a specific data carrier.

5.2.1.3 Market actors

The electronics sector is very heterogeneous in terms of products and the companies producing, selling, and recycling them. This makes generalizing statements about market actors in electronics potentially flawed from the start. The few generalizations we dare to offer for discussion need to be complemented at a later stage by more thorough analyses of market actors in specific product group sub-markets, ideally those sub-sectors that appear most promising for introducing a DPP.

5.2.1.3.1 Responsible Economic Operators (REOs)

Openness to adopting new technologies

The electronics sector includes a number of innovative high-tech companies. While it is hard to generalise, and specific empirical evidence on this topic is scarce, we would assume on average a high degree of openness to adopting new technologies. If this would translate directly into openness to fully embracing the opportunities of data-driven circularity enabled by a DPP, could be, however, doubtful.

Digital maturity level of most companies in regard to data management

Digitalization in electronics seems to be more advanced than in other sectors. However, we assume that at least the larger companies in the sector have a high digital maturity level of most companies in regard to data management.

Share of SMEs in this sector

According to the EC's Annual Report on European SMEs 2022/2023[63], electronics is the sector with the relatively lowest share of SMEs across the 14 analysed industry ecosystems. While SMEs are the largest employer in 11 of the 14 ecosystems, electronics is one of the few sectors where large enterprises employ more people than SMEs. That said, even in the electronics ecosystem, micro-SMEs have a share of around 86 % of all companies.

5.2.1.3.2 Circular Economy Operators (CEOPs)

There is a growing number of CEOPs in electronics, particularly in the area of refurbishing and reselling high-end electronics, like, e.g. notebooks and smartphones by established brands. One of the barriers for CEOPs is the limited level of automation in remanufacturing and recycling as well as the lack of effective systems for collecting unused electronics piling up in the homes of private users.

5.2.2 Where we are going!

Some of the questions addressed in this sub-section are: Which market trends and development pathways in regard to sector-specific factors appear already to be highly certain for the coming years? What does this mean for the development of the DPP in this sector?

5.2.2.1 Regulation

The upcoming ESPR on eco-design requirements for sustainable products will be of high relevance for electronics, due to its goal of reducing the negative life cycle environmental impacts of products in the context of the EU's Circular Economy Action Plan.

ICT products and other electronics and energy-related products are mentioned among the envisaged priority product groups of the Commission's first working plan for the design of ESPR Delegated Acts. However, the ESPR also mentions in Article 8(4) that the Commission is authorized to exempt product groups from the requirement to have a DPP where other Union law includes a system for the digital provision of information related to the ESPR objectives.

Because this is applicable to the EPREL database mentioned above, electronics that have an energy label may be exempted from the obligation of having also a DPP. However, the ESPR, which should be adopted formally in the summer of 2024, is still relevant for electronics through its general push for circularity and product data transparency.

5.2.2.2 Economic drivers

Due to the larger number of materials used in electronics, which depending on the product group include a significant amount of critical raw materials (CRMs), increasing prices for CRMs and availability issues are quite certain to increase over the coming years, as demand is rising. This provides an economic incentive for data-driven circularity, for which the DPP could be a key enabler.

The need to improve the efficiency of processes such as maintenance, repair, and refurbishing, all of which are labour intensive, is an additional driver.

5.2.2.3 Resources

A pilot for a DPP for IT equipment is currently ongoing under the European Commission's Blockchain Pre-Commercial Procurement activities. Within the Digital Europe Programme there is at least one project currently in the grant preparation phase which will feature DPP pilot projects for electrical and electronic products. This project, and possibly further projects that are expected to be funded through the Horizon Europe Programme, will prepare the ground for an eventual early voluntary DPP deployment in electronics. Because these activities are anticipating on regulatory requirements, they offer an interesting playground to test DPP-enabled circular use cases.

5.2.3 Where could we go?

Some of the questions addressed in this sub-section are: What major realistic options for DPP development are available in this sector? How do these options differ and how should they be evaluated?

5.2.3.1 Drivers

Regulation

As mentioned above, as electronic products are in the EC's first working plan, we deem it not impossible that the EC may consider electronics to be one of the target sectors for a regulated DPP in the future. However, there seem to be no concrete plans for a regulated DPP in electronics yet. To complete the list of options, it is possible that the EC could propose such a regulated DPP in electronics by 2030, after 2030, or not at all. There is no indication, which of these options would be the most likely. It may also depend on the performance of the first introduced DPPs, if there would be sufficient

political support for another DPP in a complex sector like electronics, or if the EU will look for other existing or new mechanisms to increase circularity in this sector. We are aware that the deliberations above are highly speculative, but that is in the nature of a section on options, if more precise information on regulatory drivers is not available.

A different driver related to regulation is the possibility that the DPP might be used in the future to simplify product compliance requirements.

Cost of raw materials and need to limit increasing WEEE streams

The electronics industry faces challenges similar to the batteries sector, when it comes to the cost and availability of raw materials for their products. The rising cost, price volatility, and potentially decreasing supply chain resilience could increase the economic pressure for data-driven circular solutions, including a DPP, to better utilize the circularity potential of products on the market and of electronic waste.

Spillover effects from batteries sector

The batteries sector is the first to have a mandatory DPP. At the same time, the regulated batteries are essential elements of many complex electronics products. While batteries in most electronics products are not expected to be required to have a DPP, the closeness between these two sectors could lead to a spillover effect, i.e. if the DPP works in batteries and proves to be economically effective for REOs and CEOPs, this could provide an incentive for at least parts of the electronics sector to consider pushing for a DPP in their domain as well.

The DPP as an efficiency enabler

In the case of high-value electrical and electronic systems, the need to improve the efficiency of labour-intensive processes such as maintenance, repair, preparing for re-use, sorting, disassembly (potentially down to the component level), refurbishing and remanufacturing may also become an additional driver.

5.2.3.2 Technologies

Potential need for robust, machine-readable data carriers

Some stakeholders see a need for machine-readable standardised data carriers in the electronics sector. They consider it to be important that the data carrier has to be on the product and that it needs to be machine-readable from a distance. Furthermore, they argue that data carriers need to be attached to the product in a very robust way to avoid loss or damage. In their view, solving these challenges is necessary, to make circular use cases in electronics feasible on scale through data-driven automation. Their concern is that otherwise data carriers could become a bottleneck hampering automation in remanufacturing and recycling of electronics at the scale needed to significantly increase circularity in this sector. Other stakeholders are not convinced of the need to have data carriers that are machine-readable from a distance.

5.2.3.3 Considerations on DPP pathways in electronics

There are several available DPP pathways in electronics for the 2027-2030 timeframe, which would be the earliest possible period in which a DPP in electronics could come into effect. Among the factors influencing the choice of the most suitable pathway are the maturity level reached in the deployment of the DPP system and the DPP readiness of electronics market actors.

The electronics sector has the benefit of not being the first sector in which a DPP will be introduced. This means that, if and when the electronics industry massively decides to adopt the DPP, either voluntarily or due to regulations, they will benefit from plenty of existing knowledge on the best ways to do so.

However, this refers only to the core DPP system technology, and many sector-specific challenges will remain to be addressed, like the large diversity and complexity of the products in this sector and the high volatility of the supply-chain making it practically impossible to know the material content of a given product produced on a given day, due to the multi-sourcing of electronic components. Downstream, the high diversity of possible circular use cases adds a second source of complexity. Circular activities such as repair, reuse, refurbish, sorting, etc. can be applied at many different levels: consumer goods, sub-system, printed circuit board (PCB), and electronic component.

These challenges will require extended efforts to develop the data standards and ontologies in a way which takes the specifics of the various sub-sectors and the needs of emerging circular business models adequately into account.

5.2.4 Where should we go?

Some of the questions addressed in this sub-section are: What would be the most effective way to implement the DPP in this sector? How would the suggested DPP pathway help in advancing the circular economy in this sector?

5.2.4.1 Drivers

Beyond 2027, economic factors, like raw material prices and availability, should become the main drivers for DPP deployment in the electronics sector. Instead of waiting for the regulator pushing the industry forward, which appears not certain to happen before 2030, it would be rather industry, primarily electronics sub-sectors with products of high value and complexity, to push for a non-mandatory DPP to address the above-mentioned economic factors through data-driven circularity.

5.2.4.2 Technologies

The EC and industry should increase their investments in innovative technological solutions aimed at replacing or home-sourcing critical materials in electronics as well as on research enabling further efficiency increases in the automation of circular use cases for electronics, based on data available through an electronics DPP.

5.2.4.3 Standards for circularity data

The existing efforts to standardise product attributes related to sustainability and circularity, such as initiated in the IEC CDD and by ITU-T/ETSI should be encouraged, as the development of enabling ontologies.

5.2.4.4 Market actors

Economic operators in the electronics sector should fully embrace the circular business opportunities enabled by a DPP and get actively involved in the process shaping it. More specifically this could mean to include electronics-specific data points in the DPP which would help facilitate maintenance and reuse of electronic products.

CEOPs, especially remanufacturers and recyclers of electronics, should expand the data-driven automation of sorting and remanufacturing processes in existing and planned plants. The associated

long-term investments could have a 5-10-year horizon, entailing a significant degree of uncertainty and risk regarding demand. However, the potential economic rewards appear equally significant and could justify such long-term investments after a thorough analysis of specific business cases. In this effort, CEOPs should collaborate more closely with electronics manufacturers.

DPPaaS providers should join forces with REOs and CEOPs for exploring and enabling new circular use cases and expanding existing data ecosystems, in a way that facilitates the flow of DPP data while preserving the intellectual property of electronics manufacturers.

5.2.4.5 Resources

We assume that large parts of the electronics sector could already have the necessary resources for deploying the DPP and utilizing its circular business potential, both in terms of knowledge as well as financial capabilities. This may, e.g., apply to large providers of household appliances as well as suppliers of electronic products and components for the transport sector and the energy sector. Due to the variety and complexity of the electronics sector, this assumption would need to be specified and verified through a concrete analysis of specific segments of electronics, which outside of the scope of this roadmap.

An important resource that should be created, possibly through a public-private partnership, would be a cross-sector data space for electronics to facilitate rule-base DPP information flows while reducing the costly need for bi-lateral agreements.

Critical Raw Materials (CRMs) are currently not sufficiently recovered from end-of-life products. Thus, there is a clear need for funding better CRM recovery processes. CRM recovery initiatives should involve municipalities, waste collectors, recyclers, and other relevant stakeholders. The emergence of such initiatives should be incentivised and accelerated through public financial support, for example via interest-reduced loans by the European Investment Bank (EIB).

5.2.5 Timeline

The suggested timeline is based on the possibility that a DPP for electronic products might be introduced in the year 2030. The elements of this timeline have a very low degree of certainty. Electronics is on the list of potential product groups to be regulated under ESPR. However, this does not automatically translate into the obligation of having a DPP, as it appears not unlikely that ESPR article 8.4 will be applied to those product groups that already bear an energy label.

Thus, it is yet unclear, if a regulated DPP will be introduced in the future.

A non-mandatory, industry-driven DPP for electronics by 20230 appears even less likely, as it would require a very diverse set of sub-sectors and their representatives to define and implement such a DPP. Nonetheless we have included this remote possibility in the timeline.

The timeline for the introduction of a DPP in electronics should be considered more as a proposal to industry and policymakers rather than a reflection of the current planning status by the EU or industry. In view of the potential benefits of a DPP for helping to make the electronics sector more circular, we recommend considering the introduction of a DPP for electronics by 2030.

Figure 6: Electronics DPP roadmap - Proposed timeline 2025-2030

5.3 Textiles

5.3.1 Where are we today?

Some of the questions addressed in this sub-section are: What are the specific drivers for a DPP in the textiles sector, particularly apparel and shoes? Which technologies and standards are particularly relevant to the textiles sector in regard to the DPP? What sector-specific features characterize market actors? Which sector-specific resources are available?

5.3.1.1 Drivers

5.3.1.1.1 Regulation

The textiles sector is already subject to some regulatory requirements for mandatory product information on EU level.

REACH Regulation

The Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)[64] aims to protect human health and the environment from risks posed by chemicals. REACH requires industry to manage the risks from chemicals and to provide safety information on the substances. For this purpose, manufacturers and importers are obliged to gather information on the properties of their chemical substances and to register that information in a central database at the European Chemicals Agency (ECHA)[65].

The REACH Regulation is covering all industries dealing with chemicals. The part particularly relevant for textiles is that relating to substances in articles, whether those substances are intended to be released and whether they are substances of very high concern (SVHC). Substances intentionally released from articles must be registered for that specific use, if they are present in those articles in quantities over 1 ton per producer or importer per year.

The REACH Regulation is currently being revised under the European Green Deal (2019) and the Chemicals Strategy for Sustainability (2020)[66]. The goal is to further improve the protection of human health and the environment against hazardous chemicals and to encourage innovation to develop safe and sustainable alternatives.

Textile Labelling Regulation

The Textile Labelling Regulation[67] is highly relevant in the context of the DPP in textiles. As it is currently being revised, it can be expected that there will be some connection between the revised Textile Labelling Regulation and the upcoming Delegated Act for a DPP in textiles.

In addition to these EU level regulations, there are also relevant national regulations, like, e.g., in France the AGEC, which aims at providing information on production and supply chain to give consumers a higher transparency on these product aspects.

How regulation drives the DPP

The revision of both the REACH Regulation and the Textile Labelling Regulation could be considered strong drivers for the planned mandatory DPP in textiles under the ESPR. Unifying access to the product information required under both regulations via a DPP would be a logical next step for providing the product information transparency needed for consumers and CEOPs in an emerging circular economy.

5.3.1.1.2 Political factors

Less than 1% of textile waste is recycled into new textile fibres according to an Ellen MacArthur Foundation report published in 2017.[68] The resulting global textile waste problem has made textiles a topic very high up on the political agenda in the EU.

The Circular Economy Action Plan mentions textiles as one of the focal sectors for the EU's circularity policy. And NGOs are advocating vocally measures against detrimental phenomena like fast fashion and the associated waste problems caused by unsustainable consumption in the EU which are often "solved" unsatisfactorily via exporting old textiles to developing countries, with most of these textiles usually ending up in landfills or being burned.

On the production side, unsustainable labour conditions in sweatshops in Asia have increased the political will to increase producer responsibility in textiles (as well as in other sectors), which has led to the EU's Corporate Sustainability Due Diligence Directive (CSDDD).

5.3.1.1.3 Economic factors

Especially large fashion brands are assumed to have good reasons for a high interest in supply change transparency and in fighting counterfeit products. Thus, it is expected that they would be highly supportive of a DPP that would facilitate this.

Brands and retailers have further economic incentives, such as:

- Prove that their products are better than other products in terms of sustainability, which has become a buying criterion for a growing number of consumers.
- Reduce the competitive disadvantage of their sustainable, circular products compared to cheaper competitors through higher transparency towards consumers.
- Be able, thanks to a DPP, to buy back their products for refurbishing, remanufacturing, and recycling.
- Keep materials in their own value chain and reuse recycled materials for new products.
- Create event data about the product use cycle to optimize product design decisions, based on the hypothetical assumption that the DPP would contain data at item level and would allow to manage dynamic data.
- Stabilize production cost in view of rising prices and price volatility for virgin raw materials.

For textile sorters and recyclers, the value of a DPP lies in enabling them to make improved sorting decisions to capture the value of textiles by repurposing according to the waste hierarchy. To be of value for their processes it is important for them that the product data is correct and trustworthy.

Another indirect economic driver could be automation, which is still relatively low in textiles, thus offering opportunities for competitive advantages to those who innovate in this direction. The value to be reaped from a DPP is particularly in getting reliable data for automation in recommerce and recycling of textiles.

5.3.1.2 Technologies

In the field of product data generation and/or automated data exchange, the textile and fashion sectors are determined today by significantly complex international value chains, often small production volumes, and logic and system breaks, as the figure below shows.

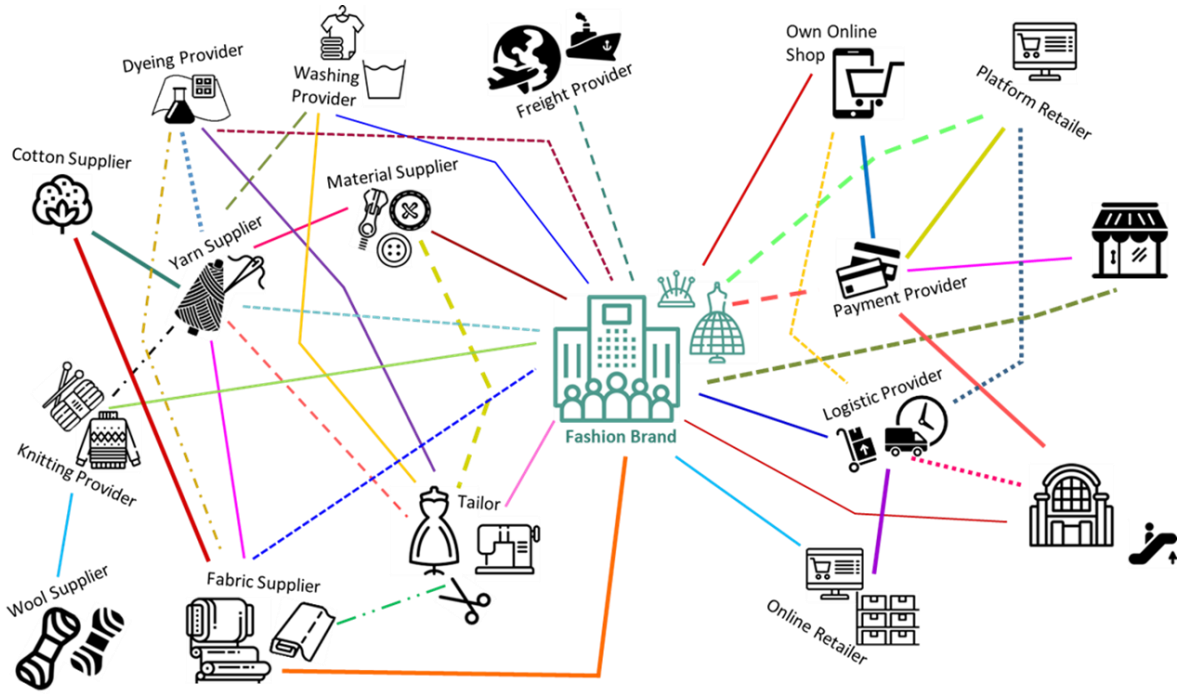

Figure 7: Supply chain network in the fashion industry[69]

5.3.1.2.1 Sector-specific product dictionaries/ classification systems

This results in the fact that today a variety of competing and non-harmonised dictionaries/ classification systems exist for the textiles sector on international and national level, including:

- For **shoes** there is the **EAS** (European Article System), which is used by industry and retailers.
- For **sporting goods** there is the **FEDAS** classification system, which is accepted by BTE (Bundesverband des Deutschen Textil-, Schuh- und Lederwareneinzelhandels – Federal Association of the German Textile, Shoe and Leather Goods Retailers).
- For **fashion retail** there is the **BTE** classification system, which is used by many retailers mainly in German-speaking countries.
- Another system in the German-speaking **fashion industry** is the **DTB** (Dialog Textil Bekleidung – Dialogue Textile Clothing) classification system. It has been used in the German industry, but is not maintained anymore.
- **Refashion**, the French textile industry's eco-organisation for clothing, household linen and footwear, has a **classification of product categories**.[70]
- For **different articles including fashion** there is the **Icecat** classification system by the product data platform provider of the same name in the Netherlands.
- **Textile Exchange** has a **material classification system (ASR-2013)**, which aims to provide standardized codes for raw materials, processes, product categories and product details for the textile supply chain.[71]

- **GOTS (Global Organic Textile Standard)** and **Textile Exchange** jointly developed a **classification on materials, processes, and products** for the harmonized application of their policies for scope and transaction certificates.[72]
- The **GINETEX** care label standard is a **material classification**. It is integrated in GTS L.
- For different articles including fashion there is the **BME** (Bundesverband Materialwirtschaft, Einkauf und Logistik – German Federal Association of Materials Management, Purchasing and Logistics) **Cat ECLASS classification system**. It could be considered outdated, but it is used by protection wear producers, and many retailers use it.
- For the sectors electronics, construction, and do-it-yourself (DIY), and here especially corporate fashion assortments, there is **ETIM**[73]. It is only relevant for textiles in do-it-yourself markets.
- **NL Fashion by GS1 Netherlands** is an extended GDSN-oriented classification catalogue. It is not maintained anymore.
- For **circularity in textiles and fashion** there is the circularity.ID Open Data Standard and ontology for textiles and fashion, Version 4.0 (soon V5.0) by **circular.fashion**. It provides a data protocol and ontology to make product data available for circularity checks and for textile sorting, reuse, and recycling.
- Across all sectors of the textiles value chain a cross sector industry initiative with the same name developed the so-called **Global Textile Scheme (GTS)** classification system with defined semantics, which allows the translation of existing product data of a data sender into predefined and encoded product-describing data, which can be decoded by the data user into its own natural language and mapped to its own data formats. GTS integrates several classification systems such as EAS, FEDAS, BTE, and DTB. The raw material classification of GTS is aligned to the raw material classes of Textile Exchange and GINETEX.
- **UNECE** has almost finished developing a **tracking and tracing-oriented data protocol for circularity** as well, which has a different focus as the previously described ontologies and which is valuable, but currently not DPP oriented.

Status of classification systems in terms of adoption, maturity, maintenance, and licensing

Most of the shoe sector works with EAS. Maintained by associations and paid by membership fees.

Most of the sporting industry and retail work with FEDAS – a revision is planned in 2024.

The GTS meta-standard has been available on the market since Summer 2023. It appears to have gained interest from market players and NGOs. GTS covers components, demand data (between brands and suppliers) and offers the management of a broad range of product-related certificates.

Textile Exchange's ASR-213 (see above) covers production processes, raw materials, product categories and details from source to finished goods. Granularity can be extensive, when the full supply chain is traced.

5.3.1.2.2 Data carriers

Today the textile labelling regulation results in the fact that each apparel item has a sewn-in label, often very long, as local laws require the text in the language of the market it is sewn to. Some stakeholders add a 2 D (QR) code, but on an individual base, as due to the technical process the printing of an additional 2 D (QR) code does not create additional costs. The often-voluminous set of care labels in many languages often create a lack of comfortability for the consumers, with the result,

that the care labels get cut out, which is waste of costs and resources and is sadly ironic, as this defeats the purpose, why the care label has been made mandatory.

GINETEX, the globally leading and standardisation body for care labels, which has a lot of know-how in this field, is at the time of writing (February 2024) in talks with EU legislators, to move mainly all international care label texts to the QR code and just show the care-label symbol and the explaining text in one language.

The status quo is that brands and retailers include data carriers for logistics, retail management, loss prevention etc. However, these data carriers are either removed at the point of the sale or constructed in a way that they are destroyed after a few washing cycles.

A unique feature of textiles is that the product is washed, which has an impact on data carriers and identification. Thus, the data carrier has to withstand washing. It is not clear yet how to effectively ensure that the data carrier is not removed from the product or damaged during use, e.g. when the textile is washed. The data carrier is not necessarily a QR code on the textile label. It could also be a scannable tag, for instance.

Adoption level of data carriers in textiles

The most commonly used data carrier in textiles today is the Barcode, mainly on hangtags and removable attached to the product. It is a critical for B2C payment transactions.

QR code is mainly used in the consumer business (B2C), mainly as part of the care label. A weakness of current labelling of consumer textiles is that in addition to the QR code printed texts of different information items is required, which is not only a cost driver, but often results in printed narrow bands of extensive length. This long band with a bulk of text in various languages, often presenting country-specific price recommendations, is not comfortable to wear for consumers, who consequently take the first chance to cut the care labels out. This is not sustainable, defeats totally the purpose, and is a threat to a data carrier most likely needed for the DPP. Furthermore, QR codes can wash off from the care labels, and they are frequently cut out by consumers.

RFID UHF tags are widely used for retail management, but usually only for hang tags and less on the product itself. RFID UHF tags are more and more used as an ' embedded solution ' for loss and theft protection as well as for self-checkouts.

Available systems and platforms that could facilitate DPP adoption

Due to the aforementioned logic and system breaks, there do exist many data communication channels – determined by use cases and/or data groups, e.g. tracking and tracing platforms (for tracking and tracing data), supplier or client master data platforms, individual machine-to-machine applications, PIM solutions or channel manager software (distributing selected master data and mainly inventory data for brands, selling on online market places).

Most small companies are in our view not able to handle the resulting complexities. The figure below illustrates the complexities which B2B market actors face due to multiple platforms.

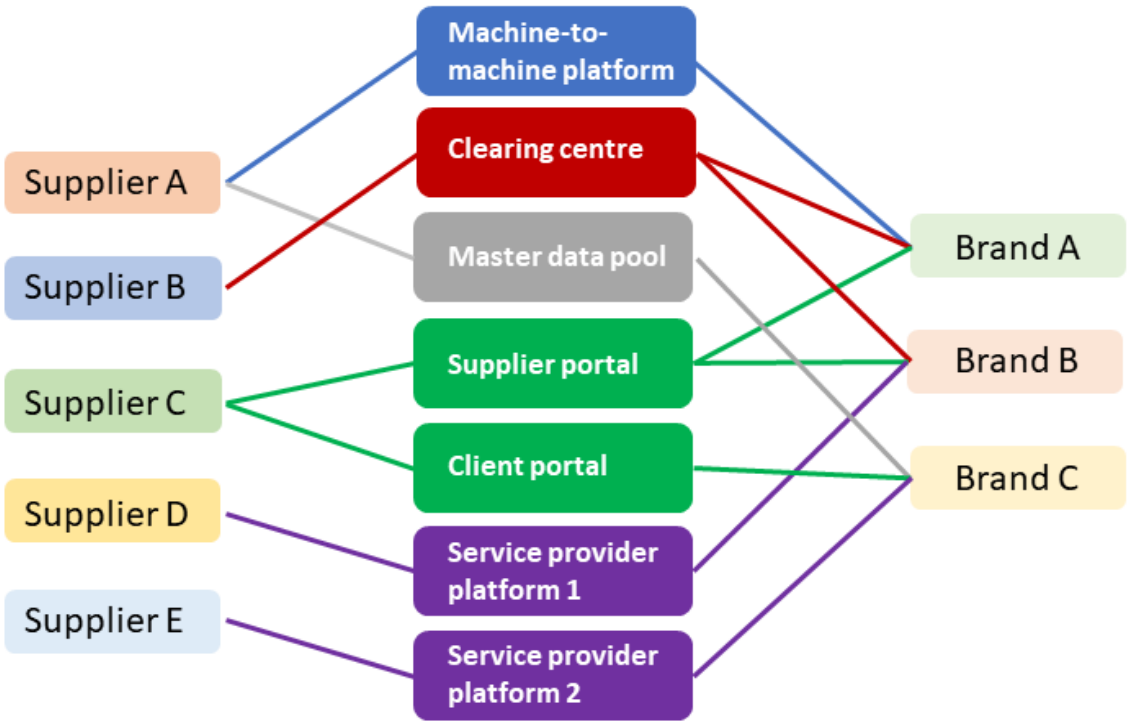

Figure 8: Complexities created by different platforms in textiles[74]

There are several platforms available. They all cover certain data groups. What is missing is one standardized classification system across data groups with defined semantics, which could serve as a sort of IT Esperanto and provide an end-to-end basis for translating the data between the different platforms directly.

The current heterogenous network of many platforms with different use cases and diverging data-group focus will not be sufficient to serve the data needs which a Digital Product Passport under ESPR requires.

5.3.1.3 Standards

In this context, results from a report published by Deloitte regarding implementation costs of a DPP for manufacturers and retailers are worth mentioning. The report argues that the implementation costs will largely depend "on the shape of the adopted standards and their method of implementation." The report argues: "Deployment of a DPP based on well-defined, open standards (ISO, GS1) would be the most cost-effective solution, especially in the long term."[75]

As the textiles sector is overwhelmingly using GS1 standards, theoretically it would already be in a good position, if the conclusion from the Deloitte report is correct.

Most standards for identification, capture, and exchange of product information used in the textile sector are generic standards that are not limited to the textile sector, like, for example GLN & GTIN, EDIFACT and EPCIS/, QR code, GTIN or RFID. Most of these standards are international standards by GS1, including all RFID standards, which were developed by EPC Global, a suborganization of GS1 Global. The focus of these standards on 'identify – capture – share' has led to a situation where there is, according to textile experts, very low acceptance of these standards on the supply side of textile value chains.

Thus, with the previously mentioned GS1 standards package most of the following data groups in the current ESPR legal text cannot be covered in the textiles sector: (a) durability; (b) reliability; (c) reusability; (d) upgradability; (e) reparability; (f) possibility of maintenance and refurbishment; (g) presence of substances of concern; (h) energy use and energy efficiency; (ha) water use and water efficiency; (i) resource use and resource efficiency (j) recycled content; (ka) possibility of recycling; (l) possibility of recovery of materials (m) environmental impacts, including carbon and environmental footprint; (n) expected generation of waste.

These aspects need to be considered in the definition of DPP data requirements in textiles. The aspects listed above are expected to be regulated in a forthcoming Delegated Act independently from the DPP system requirements.

5.3.1.3.1 Challenges for using standards in textiles

Besides the GS1 standards, there are some far less widespread standards for special market segments.

Before going into further detail, it is important to note that in the last 60 years, apparel and shoes were buyer markets with the main focus on price, not on sustainability. Thus, only very few visionaries have thought about material cycles and how to save natural resources.

As a result, the use cases behind the few existing standards and/or classification systems were determined by the fragmented views of individual organizations that always focus on individual use cases. So far, no respected industry player or association has aligned or integrated the fragmented landscape and developed a comprehensive, unified standard.

This will not be possible overnight and will need activities for generating a suitable standardisation basis and the necessary stakeholder alignment. However, a precise alignment across various sectors and their full international value chains appears to be difficult.

The publishing of the ESPR data groups offers a first chance for a qualified estimate regarding the question, for which data groups international standards exist or do not exist as well as for which data groups additional evaluation is needed and for which data groups information from raw material and production material suppliers is required.

Interviews with various stakeholders showed that a clear standard for the Product Environmental Footprint (PEF) is hoped for and is so far missing. The same is true for a clear standard on the quality of waste and feedstock.

5.3.1.4 Market actors

Market actors in textiles and apparel are facing serious challenges in regard to their DPP readiness. Big players often have change management challenges, or in other words, they are slow in embracing technological changes. SMEs, on the other hand, often have the flexibility, but lack the know-how and the necessary resources, both human and financial. Fashion companies of all sizes are not technology companies but are very product-focused. Due to short life cycles, their budgets are traditionally focused on competitive products, not data.

5.3.1.4.1 Economic operators

The textile and apparel industry in the EU is characterised by a very large share of SMEs. According to EURATEX, the European Apparel and Textile Confederation, more than 99.8 % of companies in textile and apparel are SMEs, many of them micro enterprises. More than 85 % of companies in the industry employ less than 10 people, and just 0.2 % of companies have more than 250 employees.[76]

Another sector-specific challenge for companies in textiles and apparel is that one economic operator can represent multiple functions in the value chain. This could have significant impact on the processes and data groups one company needs to handle. In any case, having more than one function within the supply chain could add additional administrative and financial burdens for REOs that may be ill equipped for them in the first place.

For example, a vertical retailer has obviously a retail function with retail processes and mainly POS-related data but also a "brand function" with sourcing processes and supply side related data. This sounds harmless, but makes the standardisation of end2end data models and data translation mechanisms additionally complicated.

Openness towards adopting new technologies

The COVID-19 pandemic, which brought many and long-time store closings, resulted directly in a high burn rate of operating capital. The corresponding reduction of the workforce to the very minimum resulted in significant stress levels among the remaining employees.

As a consequence of this generally reduced workforce, there is generally a low level of openness towards adopting new technologies and the change of traditional processes in the textiles sector. If new regulation or market developments require changes in their business procedures, most companies would prefer – and seem to already plan in any anticipation of the coming ESPR – to respond with the same tools and structures they already. Beyond improvements within already deployed technologies and structures they do not anticipate more fundamental technological changes.

Companies are often aware they have to adapt and adopt new technologies, but they are reluctant to do so. They are open to change but they are concerned about handling too many diverse technology systems by different providers. Many smaller companies do not use advanced tech systems and could not afford them.

Many companies do not know their tier 2 and tier 3 providers in the supply chain. Even obvious data sources, like, e. g., the Bill of Materials, are often not known, as the related processes have been outsourced by many stakeholders to improve price levels. The suppliers often do not want to share these data, as the sources behind these data are part of their value creation and considered sensitive information. This creates challenges for REOs, mainly for smaller companies.

As a consequence of this lack of properly managed data at many economic operators, third-party providers are likely to fill the technology gap of economic operators.

A mandatory DPP could facilitate the adoption of supply chain technology solutions for transparency at economic operators. But getting suppliers on board would still be difficult for the afore-mentioned reasons.

Suppliers would benefit indirectly from the automation of data generation at the economic operator, as the current manual requests for data by their clients, which will increase significantly with the DPP, forces them as well to organize themselves more efficiently. However, this will take time and might create frictions within the transition period.

Digital maturity level of most companies in this sector in regard to data management and technologies relevant for the DPP

The digital maturity level in the sector is generally very low and dominated by manual processes. A fashion brand in Germany, for example, has to deal with 37 interfaces on average. According to an expert, the textiles industry seems to be running on Excel.

5.3.1.4.2 Circular Economy Operators (CEOPs)

There are already a number of CEOPs in the textiles sector, including collectors, repairers, sorters, upcyclers, preprocessors, and recyclers. However, their capabilities, scope and size do not yet seem to have reached critical mass. The following figure illustrates the diversity of actors in the textiles value chain, which CEOPs are a part of.

Table 2: Actors in the textiles and apparel value chain

Production	Trade	Waste and re-X
Farmer	Product identity provider	Waste collector
Breeder	Wholesale trader	Waste aggregator
Slaughterhouse operator	Warehouse provider	Waste sorter
Raw fibre treatment provider	Transport provider	Waste import/export trader
Tanner	Brand owner	Refurbisher
Spinner	Third-party reseller	Repairer
Weaver	Retailer	Recycler
Designer	Consumer	Waste disposal provider
Finishing provider		
Manufacturer		

While the DPP provides business opportunities to CEOPs, they currently may not have the necessary knowledge and financial capabilities for fully grasping these opportunities adequately.

5.3.1.4.3 Other data users apart from CEOPs

Laundries and dry cleaners: Today brands focus with the quality of their products mainly on the goal, to pass the quality control of their wholesale clients than on long durability, including safe and often repeatable washing or dry-cleaning cycles. For obvious reasons, this results in frequent conflicts between dry cleaners and their clients, who naturally see the cause behind problems at the dry cleaner and not at the brand. A DPP, providing the right data will contribute indirectly on improvements of these fields. If washing or dry-cleaning cycles should be part of the tracking processes around the DPP, they should be addressed in the upcoming preparatory study by the JRC.

Corporate fashion and industrial laundries: These close connected data user groups are one of the very few economic stakeholders, where already today durability is a natural part of their economic business model.

The existing ISO norms describing the required durability grades should be a role model for apparel and shoe products, beyond corporate fashion and mainly protection wear.

The blind spots in this user group are topics like, e.g., dismantling and recycling of products at the end of their life cycles. More than in other textile sectors, there exist conflicting interests in regard to recycling. This will need new and special ways of circular design to address this challenge.

5.3.1.4.4 Service providers

Acceptance of service providers in the textiles sector is high. There is a growing number of specialised PLM/ERP-as-a-service offerings for the textiles/fashion sector, which is becoming a fast-growing sub-sector in textiles due to the high needs especially of SMEs.

5.3.1.5 Resources

There are a number of finished or ongoing projects on national and European level related to textiles circularity and sustainability. These projects can be considered useful knowledge resources for the deployment of a DPP in textiles.

The following list provides an overview on a number of relevant projects:

- **ECOSYSTEX – European Community of Practice for a Sustainable Textile Ecosystem**. ECOSYSTEX was launched in early 2023 to accelerate collaboration in the textile sustainability and circularity field. It includes 28 EU-funded member projects, including Horizon projects mentioned below, which are focusing on textile sustainability. Website: https://textile-platform.eu/ecosystex
- **Horizon project CISUTAC** – Circular and Sustainable Textiles and Clothing (2022-2026). CISUTAC is extending the GTS classification and semantic taxonomy to a circular textile data standard. Website: https://www.cisutac.eu
- **Horizon project TRICK** – Empower Circular Economy with Blockchain Data Traceability (2021-2024). The project includes a textiles pilot. Website: https://www.trick-project.eu
- Horizon project SCIRT – System Circularity and Innovative Recycling of Textiles (2021-2024). Website: https://scirt.eu
- **Horizon project T-REX** – Textile Recycling Excellence (2022-2025). The project aims to create a harmonised EU blueprint for closed-loop sorting and recycling of household textile waste. Website: https://trexproject.eu
- **Horizon project HEREWEAR** – Empowering local, circular & bio-based textiles (2020-2024). The HEREWEAR project aims at creating an EU economy for locally produced circular textiles and clothing made from bio-based resources. Website: https://herewear.eu
- **DigInTraCE**. A DPP application project with a SmartTag demo on textiles. Website: https://www.digintrace.eu
- **Nordic Blockchain Alliance** (2022-2023). Exploration of the potential of a joint Nordic Blockchain in the lifestyle industries to facilitate circular business models and carry a future European Product Passport. Website: https://www.nordicinnovation.org/programs/nordic-blockchain-alliance
- **Horizon project tExtended** (2022-2026). tExtended aims to introduce an innovative approach to the cycling of discarded textiles with the development of a Blueprint, a knowledge-based masterplan for the optimized cycling for different textile flows. Website: https://textended.eu/
- **Televalue** – Business Finland, 2022-2024, Value Chains for Sustainable Production, Use and Cycles of Textiles national project. Website: https://www.tuas.fi/en/research-and-development/projects/telavalue/

- **PEFCR**. Development for all apparel and footwear products under European Commission's EF initiative (2019 to 2024), to feed into textile sector-specific LCA ontology. Website: https://pefapparelandfootwear.eu/
- Swedish R&D project **Trace4Value**. It aims to investigate the development, opportunities, and challenges of a Digital Product Passport (DPP) in textiles by creating a real-time pilot.[77]
- **Sustainability Data Exchange (SDEX)**, a national project in Germany to exchange sustainability data in a structured and machine-readable form between Bundesverband der deutschen Sportartikelindustrie (federal association of German sports product industry) and European Outdoor Group.[78]
- **German project Fashionsort.ai** (2023-2026). The project aims to create an innovative digital sorting solution for the European textile industry.[79]
- Portuguese R&D project **STV Go Digital.** It aims to digitise the value chain of the textile and apparel sector.[80]

In addition to projects, there are also initiatives and organisations relevant for circularity in textiles that can be considered a knowledge or support resource for a DPP:

- **Finnish Textile & Fashion association (STJM)**. STJM is the central organisation for textile, clothing and fashion companies in Finland.[81]
- **Global Textile Scheme (GTS)** initiative, which brings together IT providers (PLM/ERP/PIM) table with suppliers, brands and retailers and service providers, like e.g. retraced GmbH. The focus is to develop a joint classification system with defined semantics from fibre to feedstock, allowing the translation of DPP relevant data.[82]
- **Tracking Certified Materials (Trackit) by Textile Exchange**. Trackit is a traceability programme developed for the standards of Textile Exchange, a global non-profit working in the fashion and textile supply chain.[83]

Beyond these projects and initiatives, there seem to be no publicly funded support mechanisms available that could directly facilitate DPP adoption in textiles.

In conclusion, there is no shortage of projects that will generate insights and best practices for facilitating the deployment of a DPP in textiles.

5.3.2 Where we are going!

Some of the questions addressed in this sub-section are: Which market trends and development pathways in regard to sector-specific factors appear already to be highly certain for the coming years? What does this mean for the development of the DPP in this sector?

5.3.2.1 New regulations expected to affect the textiles sector 2024 – 2027

The **Revision of the REACH Regulation** is on the way, as mentioned above. The revision was scheduled to be presented by the Commission to the European Parliament in Q4/2023. However, as of January 2024, it is not clear, when this will happen.[84] Depending on this, the revised REACH Regulation could enter into force between 2025 and 2027, or later.

The revision of the **textile labelling regulation** has been started. Its exact schedule remains unclear.[85] However, as it may seem to run in parallel with the planned Delegated Act for a product passport in textiles, it could be seen as complementary to the DPP in textiles.

In December 2023, a provisional agreement was reached between the European Parliament and the Council on the Ecodesign for Sustainable Products Regulation (ESPR), allowing to progressively set

performance and information requirements for key products placed on the EU market. Their selection will follow the ESPR working plan, to be adopted once the ESPR enters into force, in line with the procedures laid down in the Regulation. This will likely happen before the end of 2024.

The ESPR compromises text resulting from the trilogues which explicitly states that "In the first working plan, the Commission shall prioritise [...] textiles, notably garments and footwear". This is in line with the results of the public consultation on the future ESPR working plan and product priorities which took place early 2023: textiles were the product group that achieved the highest score in this prioritization exercise.

In the coming years, based on the Working Plan, the Commission will propose specific requirements for product groups or horizontal measures via Delegated Acts, coming with an extensive consultation process. As under the current Ecodesign directive, Delegated Acts will be subject to preparatory studies, dedicated to impact assessments and public consultations, in line with “Better Regulation” principles. This will also be the case for the textiles product group.

In order to support the fulfilment of these commitments, the European Commission has launched a preparatory study by the Commission’s Joint Research Centre (JRC).[86] This preparatory study aims to provide a basis on which the Commission can consider the introduction of ecodesign requirements, including those linked to the DPP, green public procurement criteria and revised EU Ecolabel criteria for textile products. This study is expected to conclude by the end of 2024.

Work on a Delegated Act for textiles is expected to start after the conclusion of the preparatory study, and will include aspects related to the DPP for textiles The exact schedule of the DA is not clear yet, adoption could be expected at earliest in 2026. Regarding entry into force, that date will be stated in the Delegated Act and will take into consideration the need for businesses to suitably prepare for compliance with ecodesign requirements, including on aspects related to the DPP

In general, a significant increase of regulatory-related demand for product-describing attributes can be expected, e.g. in regard to customs rules.

5.3.2.2 New or revised standards relevant for textiles certain to come 2024 – 2027

The extension of the **PRICAT message** in the **UN/EDIFACT standard** is, to our knowledge, currently not possible, because an extension by more than an anticipated limit of 150 data points does not seem realistic.

The **GTS standard** is relevant in the context of a DPP in textiles, because it allows the automated generation of DPP relevant along the value chain even for micro companies and without data limitations (might it be 100, 200 or 500 DPP relevant data points).

5.3.2.3 Upcoming projects

Within the Digital Europe programme there is at least one project currently in the grant preparation phase with DPP pilot projects in textiles, i.e. CIRPASS-2.

Looking further ahead, there are open Horizon Europe funding opportunities related to circularity in textiles, which will lead to further projects relevant to a DPP in textiles:

- HORIZON-CL6-2024-CircBio-01-2: Circular solutions for textile value chains based on extended producer responsibility
- HORIZON-CL6-2024-CircBio-02-1-two-stage: Circular solutions for textile value chains through innovative sorting, recycling, and design for recycling

There are certainly further projects of relevance coming up.

5.3.3 Where could we go?

Some of the questions addressed in this sub-section are: What major realistic options for DPP development are available in this sector? How do these options differ and how should they be evaluated?

Considering the current status and the predetermined developments described above, there are different options for how DPP development in the textiles sector could take shape.

General factors determining the variation among these options could be the speed of changes, e.g. in regulation or in technological innovation, as well as the expected effect of DPP introduction on market actors in terms of the digitization levels and DPP readiness.

Before taking a high-level view of four possible options at the end of this sub-section, we will first have a closer look influencing these options.

5.3.3.1 Drivers

5.3.3.1.1 Regulation

Speed of regulatory changes regarding a DPP in textiles

The speed of the implementation of a DPP in the textiles sector is mainly influenced by the speed of regulation. More precisely, it is to a large extent determined by the date a Delegated Act on a DPP in textiles comes into effect. This may be closely linked to the speed of the revision of the textiles labelling regulation.

Boundaries of textiles definition

In the future, garments and other textiles may contain an increasing number of electronic components, possibly including electronic data carriers. There are different ways how regulation could define the boundaries for textiles compared to electronics, for which different rules apply. The central question is: when will a textile product containing electronics, e.g. RFID chips, still qualify as textile rather than electronics?

Should the regulatory definition of garments and other textiles become more inclusive, i.e. allowing a large share of electronic components, this could mean that a larger part of the electronics sector would be directly or indirectly affected by the DPP. And vice versa, if the definition is rather restrictive, some former textiles products would become electronics, thus being excluded from the requirement for a DPP, as long as there is no mandatory DPP in electronics.

Potential effects of the Corporate Sustainability Due Diligence Directive (CSDDD)

In December 2023, the Council and the European Parliament had reached a provisional agreement on the Corporate Sustainability Due Diligence Directive (CSDDD).[87] As of February 2024, it is not yet clear, when and with which modifications the CSDDD will come into effect. Assuming the CSDDD will be finally agreed in 2024, there could be at least two ways in which the CSDDD could impact a DPP in textiles:

1. CSDDD information requirements on social conditions in the supply chain of a garment could be turned into a matching mandatory information requirement in the DPP for textiles. The textiles sector has a bad track record of bad labour conditions in many factories across developing countries. A growing number of consumers is sensitive about the conditions under which the garments they buy

have been produced. Giving them easy access to relevant information via the mandatory part of the DPP would make sense, as it would support transparency and sustainability for consumers.

2. The other option is that CSDDD information requirements on social conditions in the supply chain do not become mandatory information requirement in the DPP for textiles. Assuming that voluntary product data could be included in the DPP, each economic operator could decide, if they would like to include CSDDD-related information in the DPP. At least those economic operators who have applied a high degree of due diligence on checking their product's supply chain could be expected to include related information in the non-mandatory part of the DPP, as it would support any potential claims of sustainability in the supply chain.

5.3.3.1.2 Economic drivers

Cost of raw materials

Today, virgin raw materials for textiles, both natural fibres and synthetic fibres, seem to be still too cheap for allowing fibres gained from textile waste to compete. We expect this to change during the period 2024-2030, especially for natural fibres. Climate change is expected to have an increasingly negative impact on cotton harvests, for example. This may not apply to the same extent to synthetic fibres.

Due to advances in sorting and mechanical recycling of textile waste, a scenario where the costs of secondary raw materials for textiles are going down, could be considered realistic. As data transparency on ingredients of textiles via a DPP is expected to facilitate the automation of textile recycling, a scenario where the cost of virgin raw materials exceeds the cost of secondary raw materials in textiles by 2030 appears to be among the possible, if not likely, scenarios.

Consumer demand

Consumer demand in the EU will have a strong impact on the cost of different types of raw materials. If the current preference of most consumers towards fast fashion and synthetic fibres remains undiminished by 2030, this would potentially slow down the competitiveness of recycled materials and second-life products in textiles. However, a scenario where consumer preferences are slowly changing towards more sustainable textile products appears to be more likely, at least for EU countries with relatively high per-capita incomes and high levels of environmental awareness.

Increased need for sustainability data in e-commerce marketplaces

The increased need for sustainability data in e-commerce marketplaces result in significant challenges for the brands, as they need to provide sustainability-related attributes on the GTIN granularity level of article, colour, and size, which is today mainly done manually. Most affected brands are increasingly wondering, how they can automate the related processes. The ongoing DPP-related standardisation efforts by CEN/CENELEC will deliver answers in regard to the DPP system, going beyond the current challenges in textiles, apparel, and shoes.

5.3.3.2 Technologies

5.3.3.2.1 Data carriers

When it comes to data carriers, automation in recommerce and recycling of textiles could provide as strong push towards RFID tags: Textile sorters would prefer RFID UHF or NFC (ISO 15693) data carriers, because they are automatically readable. RFID UHF is already more common, a bit cheaper, and easier

to implement than NFC. NFC (ISO 15693) works well for sorters. RFID UHF with firm attached devices are also used for theft protection, but mainly as reusable devices, which are removed at the POS.

RFID UHF today cannot be read by smart phones, which is suboptimal, because a potential DPP future where each garment is equipped with an RFID inlay could be a chance to save significant costs for source-tagged theft protection – if it had the right (UHF GEN 2) air frequency interface standard.

RFID could play a more prominent role in B2B, e.g. in sorting. There could be an RFID tag with a QR code printed on it. Integrating RFID readers in smartphones would be technically feasible, but it would require commitment by leading smartphone producers like Apple, Samsung, and others.

In general, RFID tags, could be useful from a data and inventory management perspective over the product lifecycle, as they may not be as much exposed to be worn out and damaged as a barcode or a QR code printed on a tag. Better inventory management would help to reduce overproduction and lost sales. Such inventory management improvements could be realized, if the inventory numbers were correct.

However, RFID tags and other data carriers containing electronic components could have an adverse impact on the recycling process for textiles. The problem is that when metals from chips and textile fibres get mixed in the recycling process, this can be problematic for the reuse. Little amounts of metal could already cause negative impacts. This issue is not just related to electronic data carriers, but also to other parts of a garment, including zippers and metal buttons.

There seem to be at least two ways to address this issue, as far as data carriers are concerned:

- Optimise the shape, size, and application of electronic data carriers on textiles in way that they can be separated easily from textile fibres.
- Optimise technologies for sorting and recycling in a way that allows to automatically separate and remove electronic data carriers from textiles.

5.3.3.3 Standards

The main standardisation aspects for future pathways in textiles include standards for textile circularity and particularly textile waste recycling as well as standardised classification systems for consistent data in textiles. As the CIRPASS work has focused on general standards relevant for a DPP system, a sector-specific analysis of potential future standards is out of scope for this report.

5.3.3.4 Market actors

There are different options on how the introduction of a mandatory DPP in the textile sector will affect market actors. Questions to be considered are:

- How will the DPP impact the future economic development of SMEs and large brands?
- Will DPP accelerate the consolidation of the textiles market? In the textile sector, the vast majority of companies are SMEs, but the largest share of turnover is generated by some large players. Could/Should the DPP rather consider the needs of large brands or the needs of SMEs? Or would it be possible for the DPP to equally cater to the needs of both large brands and SMEs?
- Will large market players, who can meet requirements and take advantage of traceability/transparency data, dominate?
- Or will the DPP support small players in thriving due to increased visibility?
- What kind of data ecosystems will market actors need?

Depending on the answers to these questions, different options and pathways emerge. From a circular economy perspective, it might become less relevant for the effectiveness of the DPP, if an economic operator is a large or small company, but rather if this company is selling sustainable textiles that are durable and easy to recycle.

Different use of DPP service providers by Responsible Economic Operators

An important factor in regard to REOs is to what extent they will use DPP service providers, not just for backups of DPPs generated by the REO, but also for managing the whole DPP management process, from creation to data storage and updates. Producers in the textiles sector seems to have been using service providers for IT and data-related services to a wide extent. If this impression drawn from expert interviews could be validated, it might indicate an above-average likelihood of a relatively high use of DPP service providers.

Integrated solutions offered by IT providers

Experience shows that changes happen faster, if they are demanded by customers. Practically all relevant retailers, both stationary and online, demand more and more sustainability from the brands. This creates significant complexities, due to the lack of support from the leading IT software providers who provide to their customers systems and tools in the areas of PLM, ERP, CAD, and PIM.

If the established IT providers, driven by B2B customer demand, would offer integrated DPP solutions, this could accelerate the DPP deployment in textiles and apparel.

5.3.3.5 Resources

5.3.3.5.1 Pilot projects

Between 2024 and 2027, a number of EU-funded pilot projects will develop and validate the DPP system for industrial-grade use at scale. There will be at least one project, CIRPASS-2, that will deploy the DPP specifically for textiles. The results of these pilot projects will provide practical insights on the technical robustness and cost-effectiveness of the deployed DPP. This will prepare the ground for a smooth transition towards the commercial phase of the DPP in textiles after the mandatory DPP will come into force on EU level, which is expected for summer 2027.

5.3.3.5.2 SME support

The pilot projects are also expected to provide additional insights on the capabilities and needs of SMEs in their roles as economic operators, circular economy operators, and DPP-as-a-service providers.

Especially for the large number of insufficiently digitalised SMEs in the textile sector, we consider a well-orchestrated set of support measures on EU level and on national level to be crucial for the effective deployment of the DPP. Otherwise, there would be a high risk that a large number of SMEs would not be able to manage the DPP well, which would either affect their cost-effectiveness or the quality of the DPP data provided by them.

5.3.3.6 Outline of scenarios based on dominant factors for textiles

Based on the exploration of factors influencing the available DPP pathways in textiles, we suggest to summarise them into two dominant factors: 1. maturity level of the DPP system in textiles, and 2. DPP readiness of textiles market actors. The matrix below accordingly provides four alternative scenarios to be considered for the timeframe 2027-2030, which would be the earliest possible period in which a DPP in textiles could come into effect.

Note that these are simplified scenarios whose sole purpose is to achieve more clarity on decision-making options for optimizing factors improving the circularity impact of a DPP in textiles. Possible scenarios are not limited to the four scenarios presented, but could be any variation of combinations between different system maturity and market actor readiness levels.

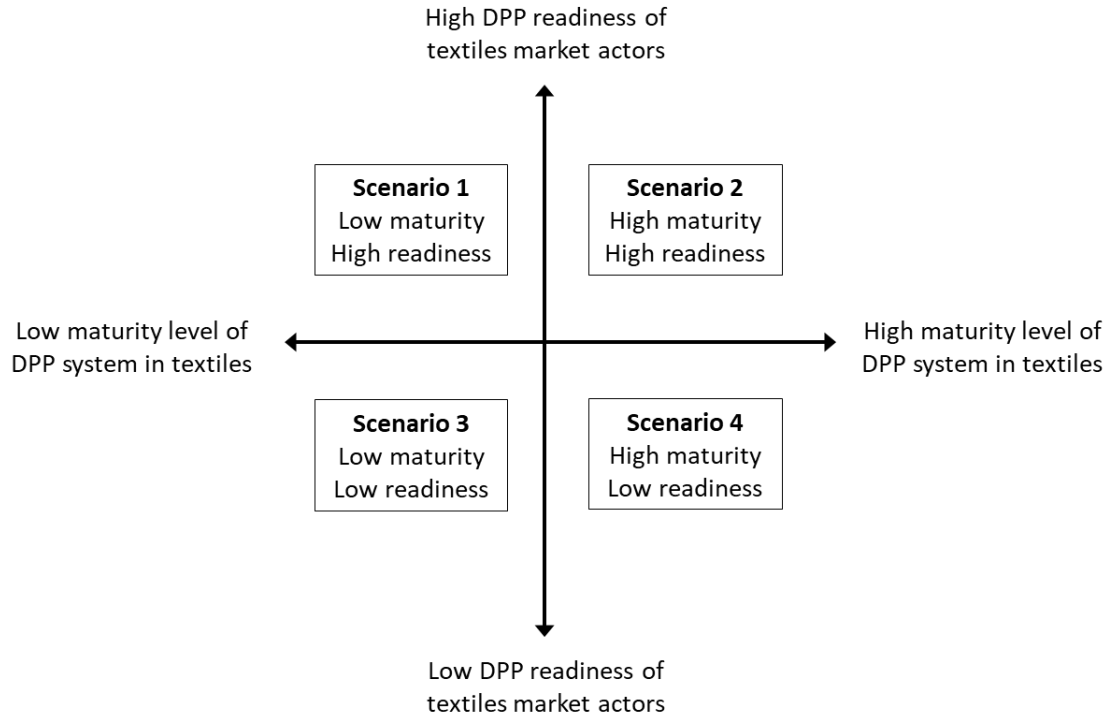

Figure 9: Scenario matrix of dominant factors influencing a DPP in textiles

Scenario 1 – low maturity & high readiness

The textiles sector has the benefit of not being the first sector, in which a DPP will be introduced. Thus, we consider a low maturity of the generic architectural and technological elements of the DPP system not very likely. That said, there may still be sector-specific challenges to be addressed, like e.g. the specific issues of data carriers in textiles, which may only find mature solutions in the years after DPP introduction.

A high readiness of the majority of REOs, which by the end of the period will probably still be micro enterprises, appears to be highly unlikely for the whole period. However, it is not unlikely that a number of big fashion brands will achieve a high readiness level. That may also apply to IT providers and special DPPaaS providers in the sector.

Scenario 2 – high maturity & high readiness

If a DPP in the textiles sector comes into effect in summer 2027, as currently envisaged by the EC, a high maturity of the DPP system appears unlikely, despite the about four months of experience gained from the battery passport starting in February 2027. At the same time, due to not being the first sector, the maturity will probably not be low either.

For the reasons mentioned under scenario 1, a high readiness level of all market actor, particularly the majority of REOs, does not appear likely within the given period, even in view of possible supportive interventions for strengthening the DPP readiness of SMEs.

Scenario 3 – low maturity & low readiness

Due to the reasons mentioned above, we would expect at least a medium maturity of the DPP system at the time a DPP is coming into force in the textiles sector. For this reasons scenario 3 does not appear likely.

However, the low readiness level of a majority of market actors, both REOs as well as CEOPs, should be considered a realistic possibility, which needs a focused effort by public and private stakeholders to be avoided.

Scenario 4 – high maturity & low readiness

Out of the four basic scenarios, this could be the most probable. A high maturity of the cross-sector DPP system is possible given the more than three-year run-up period of the DPP in the batteries sector, which will provide ample opportunities for system validation and improvement prior to the launch of the DPP in textiles. That said, some textile-specific elements of the system might still need to further evolve up to 2030, as discussed above.

Most REOs, who will be SMEs, are not expected to be fully ready for introducing a DPP in 2027. Their low readiness level is caused by low data management capacities both in terms of expertise as well as implemented technical systems. The use of IT service providers may alleviate the issue to some extent. However due the cost involved in using such providers, it may negatively impact the competitiveness of numerous micro enterprises, if not counterbalanced by supportive measures.

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The presented scenarios require further exploration. Even in their current shape, they may be useful for evaluating the available options and their impacts as well as triggering necessary discussions on the required innovations for optimizing the circularity potential of an upcoming DPP in the textiles sector.

5.3.4 Where should we go?

Some of the questions addressed in this sub-section are: What would be the most effective way to implement the DPP in this sector? How would the suggested DPP pathway help in advancing the circular economy in this sector?

5.3.4.1 Drivers

5.3.4.1.1 Regulation

The upcoming delegated act for a DPP in textiles needs to take the high share of SMEs, especially micro enterprises, in this sector into account. This should be done, e.g. through an extended transition period and/or initially low fines for non-compliance.

In this context, regulation should motivate compliance rather through incentives than through penalties. Such an incentive could be an aligned and optimized use of DPP data groups across all data-related legislations, aiming to reduce reporting duties for different regulatory requirements on EU level.

In order to create a level playing field for circular, sustainable textiles as one of the goals of a DPP, the EU should enforce its Common Market rules through DPP-enabled cross-border checks. The purpose of these enhanced checks would be to better identify and exclude textiles imported from non-EU countries that do not fulfil the legal requirements.

5.3.4.1.2 Economic factors

The trend towards internalizing negative externalized environmental and social impacts of textiles on regulatory and consumer demand level should continue and be further strengthened through measures on all levels, from information campaigns to tax incentives for more circular textile products. This could get the textiles sector closer to a level playing field, facilitated through a DPP that makes the negative impacts and value chain effects of textiles more transparent.

A huge part of the supply chain in textiles is outside of Europe. This means, there is an economic incentive for REOs and CEOPs in the EU to get suppliers from Asia and other textile-manufacturing regions aligned with the goal of an envisaged increase in the sector's circularity. The DPP could be an important lever for achieving this.

5.3.4.2 Technologies

5.3.4.2.1 Data carriers

Innovative solutions need to be developed for data carriers in textiles that equally meet the requirements of consumers, resellers, and recyclers. Non-electronic data carriers like the traditional printed tag appear to be too much prone to damage and destruction to be useful in circular business scenarios with product-lifetime extensions and automated recycling. Electronic data carriers might be more suitable for circular business scenarios. However, they also come with specific challenges that need to be addressed, like ease of access for consumers and easy removal in the recycling process.

5.3.4.2.2 AI support for surveillance authorities

The effectiveness of the DPP in textiles and other sectors should be enhanced via novel AI tools, which hardly exist today and would require an EU-level innovation effort to accelerate their development.

In order to ensure that, e.g., detailed durability levels for apparel and shoe products required by the DPP regulation are effectively controlled and maintained in the Common Market, customs and market surveillance authorities need to be appropriately equipped to automate the process. The ability to control textile and apparel goods and e-commerce activities from outside the EU, especially those flooding the EU market with cheap fast fashion in minor quality below legal requirements, is crucial for ensuring that a DPP positively impacts circularity and sustainability.

5.3.4.3 Standards

For the effective integration of the various textile-specific dictionaries/classification systems, it is important to have smooth interoperability, e.g., via an integrated classification system like GTS, which seems to be currently the only system of that kind.

Industry-wide awareness for such standards is important for a smooth deployment of a DPP in textiles.

5.3.4.4 Market actors

REOs

REOs within and outside of the EU need to adapt to the challenges and opportunities of data-driven circularity in textiles. Due to the large share of micro enterprises in textiles, not every REO is expected to already have the necessary capabilities.

A consolidation of the market, i.e. the disappearance of some uncompetitive micro enterprises, appears hard to avoid without distorting the market at the taxpayers' expense. However, at the same time, SMEs, including micro enterprises, could and should be drivers of creativity and innovation in a

circular European textiles industry. Even those who are fundamentally competitive may face challenges for which they may not have sufficient knowledge and financial capabilities. Thus, it should be further explored how innovative SMEs among REOs in the EU could be strengthened through the creation of knowledge transfer mechanisms and collaboration platforms, in order to maintain a strong circular economy basis within the textiles sector.

CEOPs

CEOPs, including sorters, resellers, and recyclers, face the challenge and opportunity of data-driven automation for increasing circularity in textiles. This will require investments in innovative, automated solutions, for which they may not be well equipped both knowledge-wise and financially. Policymakers on EU level and national level should consider establishing support mechanisms for effective knowledge transfer and easy access to interest-reduced loans, e.g. from the EIB, in order to strengthen their capacities for processing growing amounts of second-life textiles and end-of-life textiles in a growing circular economy.

Service providers

It is important to get IT companies that have been serving the textiles sector on board as soon as possible. We expect them to be the main providers of support for economic operators in textiles, particularly SMEs, who may have limited capacity to perform the tasks involved in compliant DPP generation and data management themselves. By aligning IT providers early, this could help providing DPP-ready products early so that economic operators could have the necessary tools by the end of 2027, when a mandatory DPP for textiles is expected to be in force.

5.3.4.5 Resources

For SMEs in textiles to be able to perform their duties as economic operators, they will require European and national support on various levels, including training on DPP requirements, grants for improving their data management capabilities, and more. SMEs will in addition also need financial support for using external DPP service providers, as the financial situation of most SMEs in the sector may not allow them to outsource all their DPP data management to an IT provider without support.

5.3.5 Timeline

The timeline proposed in the figure below is mainly based on our interpretation of information received from the EC about the regulatory process for the ESPR and the Delegated Acts (DAs) for textiles. The timeline is limited to regulation and standardisation in the period 2024 to 2027. In addition, it includes the assumed average start and end dates of the DPP pilot projects under the EC's Digital Europe programme, as they are considered an important resource in support of the DPP deployment across sectors, including textiles. This limit in time and scope was done, because including further categories of factors as well as the period from 2028 to 2030 would have involved a very high level of uncertainty up to the point of making this part of the timeline too arbitrary to be useful.

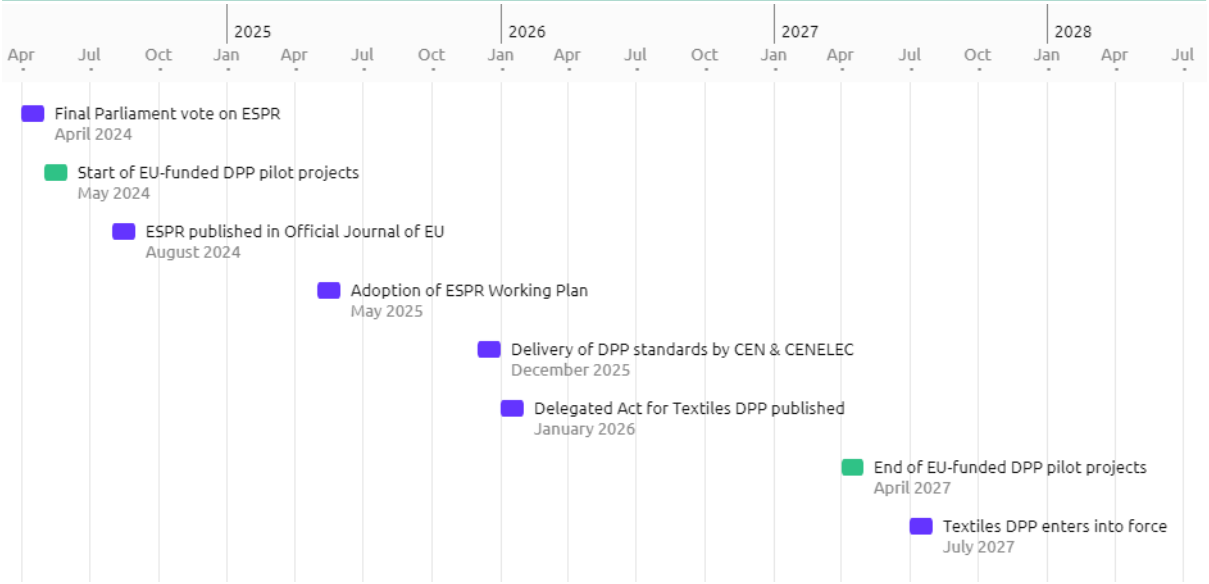

Figure 10: Textiles DPP roadmap – Proposed timeline 2024-2027

6 Conclusion

The cross-sector roadmap and the three sector-specific roadmaps presented in this report address a number of relevant factors that need to be in place for the successful deployment of DPPs in the EU. Many of these factors need to be further explored in more depth and detail to make informed decisions on the way forward.

Besides addressing gaps in technologies and standards, it is crucially important to further explore the DPP-readiness of market actors in the three focal sectors batteries, electronics, and textiles as well as other sectors that are about to get ready for DPP introduction. In this context, European and national decision-makers should consider in more detail adequate measures for increasing the DPP-readiness of companies, particularly SMEs.

At the same time, we hope that the presented roadmaps give companies an orientation and an incentive for using the circular business opportunities enabled by a DPP.

References

[1] European Commission (2020), A new Circular Economy Action Plan: For a cleaner and more competitive Europe, Brussels, URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN (retrieved on 2 October 2023)
[2] Olivier L. De Weck (2022), Technology Roadmapping and Development, p. 216
[3] De Weck 2022, pp. 242-246
[4] European Commission (2022), Proposal for Ecodesign for Sustainable Products Regulation, Brussels, 30 March 2022, URL: https://environment.ec.europa.eu/publications/proposal-ecodesign-sustainable-products-regulation_en ; the latest draft of the ESPR proposal is available at https://www.consilium.europa.eu/media/69109/st16723-en23.pdf
[5] See for details on the definition of a socio-technical system: J. M. Bauer, P. M. Herder (2009), Designing Socio-Technical Systems, in: Handbook of the Philosophy of Science, Philosophy of Technology and Engineering Sciences, pp. 601-630, https://doi.org/10.1016/B978-0-444-51667-1.50026-4
[6] Abel Reiberg, Crispin Niebel, Peter Kraemer: What is a Data Space? Definition of the concept Data Space, Gaia-X Hub Germany, White Paper 1/2022, September 2022, URL: https://gaia-x-hub.de/wp-content/uploads/2022/10/White_Paper_Definition_Dataspace_EN.pdf
[7] Regulation (EU) 2023/1542 of the European Parliament and of The Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC, URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1542
[8] Regulation establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC - Analysis of the final compromise text for an agreement, Brussels, 19 December 2023, URL: https://www.consilium.europa.eu/media/69109/st16723-en23.pdf
[9] CIRPASS website, Publications by the European Commission, URL: https://cirpassproject.eu/european-commision-external-publications/
[10] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A new Circular Economy Action Plan: For a cleaner and more competitive Europe, Brussels, 11 March 2020, URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN
[11] The critical move – Finland's road map to a circular economy 2.0, URL: https://www.sitra.fi/en/projects/critical-move-finnish-road-map-circular-economy-2-0/
[12] National Circular Economy Programme 2023-2030 (NCEP), Netherlands 2023, URL: https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/documenten/beleidsnotas/2023/02/03/nationaal-programma-circulaire-economie-2023-2030, p.40
[13] NCEP, p. 129
[14] European Commission, Proposal for a Regulation of the European Parliament and of the Council establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020, Brussels, 16 March 2023, URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0160
[15] EC information page on 'Critical raw materials', URL: https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en
[16] European Raw Materials Alliance website – URL: https://erma.eu/
[17] Commission welcomes provisional agreement for more sustainable, repairable and circular products, EC Press release, Brussels, 5 December 2023, URL: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_6257
[18] Reproduced from CIRPASS Deliverable D3.2 "DPP system architecture"
[19] CIRPASS website, Project results, URL: https://cirpassproject.eu/project-results/
[20] Reading NFC tags with iOS 14, NFC Tag-Shop, 6 December 2023, URL: https://www.nfc-tag-shop.de/info/en/tutorials/reading-nfc-tags-with-ios-14/ ; Core NFC: Detect NFC tags, read messages that contain NDEF data, and save data to writable tags. Apple Developer site, URL: https://developer.apple.com/documentation/corenfc ; Near field communication (NFC) overview, Android eveloper site, URL: https://developer.android.com/develop/connectivity/nfc
[21] D4.2 will be available on the CIRPASS website, Project results, URL: https://cirpassproject.eu/project-results/

[22] URL: https://cirpassproject.eu/project-results/
[23] See for an overview on the DPP-related standards landscape the following StandICT.eu 2026 project report: Jens Gayko & Benjamin Helfritz (editors), Report of TWG Digital Product Passport: Landscape of Digital Product Passport Standards, March 2023, URL: https://www.standict.eu/digital-product-passport-standards-report, DOI: 10.5281/zenodo.7728381
[24] European Commission web information on DPP objectives: https://hadea.ec.europa.eu/calls-proposals/digital-product-passport_en and https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/digital-2021-trust-01-digipass
[25] IMDS website, URL: https://www.mdsystem.com
[26] GDSO website, URL: https://gdso.org
[27] The following report provides a good overview: Big Data Value Association (BDVA), Data Sharing Spaces and Interoperability, December 2023, URL: https://www.bdva.eu/sites/default/files/Data%20sharing%20spaces%20and%20interoperability.%20BDVA%20Discussion%20paper.%20December%202023.pdf
[28] SIMPL: Streamlining cloud-to-edge federations for major EU data spaces, URL: https://digital-strategy.ec.europa.eu/en/policies/simpl
[29] Cofinity-X website, URL: https://www.cofinity-x.com/about-us/
[30] BatteryPass project website, URL: https://thebatterypass.eu
[31] Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, URL: https://eur-lex.europa.eu/eli/reg/2023/1542/oj
[32] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and The Committee of the Regions, Europe on The Move – Sustainable Mobility for Europe: safe, connected and clean, ANNEX 2 – Strategic Action Plan on Batteries, Brussels, 17.5.2018, URL: https://eur-lex.europa.eu/resource.html?uri=cellar%3A0e8b694e-59b5-11e8-ab41-01aa75ed71a1.0003.02/DOC_3&format=PDF
[33] Battery Pass, Battery Passport Content Guidance, Version 1.1, December 2023, URL: https://thebatterypass.eu/assets/images/content-guidance/pdf/2023_Battery_Passport_Content_Guidance.pdf
[34] International Energy Agency, Global EV Outlook 2023: Catching up with climate ambitions, 2023, URL: https://www.iea.org/reports/global-ev-outlook-2023/trends-in-batteries
[35] BattINFO web page, URL: https://www.big-map.eu/dissemination/battinfo
[36] BATTERY 2030+ website, URL: https://battery2030.eu
[37] BIG-MAP deliverable D7.2 – Initial Version of the Battery Ontology, 26 February 2021, URL: https://www.big-map.eu/-/media/sites/big-map/d7-2-initial-version-of-the-battery-ontology.pdf
[38] Draft Catena-X Standard CX - 0034 Data Model Battery Pass, Version 1.0.1, 6 March 2023, URL: https://catena-x.net/fileadmin/user_upload/Standard-Bibliothek/Update_PDF_Maerz/Sustainability_Use_Case_Circular_Economy/CX_-_0034_Data_Model_BatteryPass_UseCase_CE_v_1.0.1.pdf
[39] IMDS website, URL: https://public.mdsystem.com
[40] Chuck LePard & Marelle Fogel, IMDS Through the Years, AIAG, 21 September 2016, URL: https://blog.aiag.org/imds-through-the-years
[41] Catena-X website, URL: https://catena-x.net
[42] Gaia-X website, URL: https://gaia-x.eu
[43] Battery Pass, Battery Passport Content Guidance, Version 1.1, December 2023, URL: https://thebatterypass.eu/assets/images/content-guidance/pdf/2023_Battery_Passport_Content_Guidance.pdf
[44] SAE Battery Global Traceability Committee website, URL: https://standardsworks.sae.org/standards-committees/battery-global-traceability-standards-committee
[45] Regulation (EU) 2019/1020 of the European Parliament and of the Council of 20 June 2019 on market surveillance and compliance of products and amending Directive 2004/42/EC and Regulations (EC) No 765/2008 and (EU) No 305/2011 (Text with EEA relevance.), ELI: http://data.europa.eu/eli/reg/2019/1020/oj
[46] Battery Pass website URL: https://thebatterypass.eu
[47] Catena-X battery passport consumer app, URL: https://catenax-ng.github.io/product-battery-passport-consumer-app/
[48] Global Battery Alliance: Action Partnerships – Battery Passport Pilot, URL: https://www.globalbattery.org/action-platforms-menu/pilot-test/

[49] Global Battery Alliance: Action Partnerships – Battery Passport, URL: https://www.globalbattery.org/battery-passport/
[50] Battery Pass, Secondary legislation following the Battery Regulation, December 2023, URL: https://thebatterypass.eu/wp-content/uploads/BatteryPass_Delegated-and-Implementing-Acts-following-Battery-Regulation.pdf
[51] European Commission, End-of-life vehicles Regulation web page, URL: https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles/end-life-vehicles-regulation_en
[52] European Commission/ Directorate-General for Environment, Proposal for a Regulation on circularity requirements for vehicle design and on management of end-of-life vehicles, Brussels, 13 July 2023, URL: https://environment.ec.europa.eu/publications/proposal-regulation-circularity-requirements-vehicle-design-and-management-end-life-vehicles_en
[53] A.Bassi et al., Rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries (CFB-EV), JRC Science for Policy Report, Final draft, Luxembourg 2023, URL: https://eplca.jrc.ec.europa.eu/permalink/battery/GRB-CBF_CarbonFootprintRules-EV_June_2023.pdf
[54] SAE has formed a committee to work on traceability, meaning standardisation of the Data Points similar to the DPP, web page of the committee – URL: https://standardsworks.sae.org/standards-committees/battery-global-traceability-standards-committee#
[55] Website of the European Chemicals Agency (ECHA), URL: https://echa.europa.eu
[56] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast) Text with EEA relevance, ELI: http://data.europa.eu/eli/dir/2011/65/oj
[57] EPREL website, URL: https://eprel.ec.europa.eu
[58] Consolidated text: Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE), ELI: http://data.europa.eu/eli/dir/2012/19/2018-07-04
[59] Eurostat, Waste statistics - electrical and electronic equipment, Data from October 2023, URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment
[60] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A new Circular Economy Action Plan for a cleaner and more competitive Europe, COM/2020/98 final, URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:98:FIN
[61] CIRPASS deliverable D2.1 ”Mapping of legal and voluntary requirements and screening of emerging DPP-related pilots””, available on the CIRPASS website at https://cirpassproject.eu/project-results/
[62] EWRN, WEEE2 – Definition and Understanding of the 6 Categories, presentation slide deck, 15.08.2018, URL: https://www.ewrn.org/fileadmin/ewrn/documents/191001_EWRN_Definition_6_categories_fin.pdf
[63] Di Bella, L., Katsinis, A., Laguera Gonzalez, J., Odenthal, L., Hell, M. and Lozar, B., Annual Report on European SMEs 2022/2023, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/028705, JRC134336, URL: https://publications.jrc.ec.europa.eu/repository/handle/JRC134336, pp. 44-45
[64] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), ELI: http://data.europa.eu/eli/reg/2006/1907/2022-12-17
[65] ECHA website, URL: https://echa.europa.eu
[66] Chemicals strategy web page, URL: https://environment.ec.europa.eu/strategy/chemicals-strategy_en
[67] Regulation (EU) No 1007/2011 of the European Parliament and of the Council of 27 September 2011 on textile fibre names and related labelling and marking of the fibre composition of textile products and repealing Council Directive 73/44/EEC and Directives 96/73/EC and 2008/121/EC of the European Parliament and of the Council, ELI: http://data.europa.eu/eli/reg/2011/1007/oj
[68] Ellen MacArthur Foundation, A new textiles economy: Redesigning fashion’s future (2017), URL: https://www.ellenmacarthurfoundation.org/a-new-textiles-economy
[69] Source of figure: GCS Consulting GmbH, Unterföhring, 2018
[70] Refashion classification of product categories, URL: https://refashion.fr/pro/sites/default/files/fichiers/Product Classification File - textile-EN_V2.xlsx
[71] Textile Exchange, Materials, Processes, & Products Classification — ASR-213-V1.1-2021.05.01, URL https://textileexchange.org/app/uploads/2020/10/ASR-213-V1.1-Materials-Processes-and-Products-Classification.pdf

[72] Global Standard gGmbH & Textile Exchange: Materials, processes & products classification, version 1.0, May 2021, URL: https://global-standard.org/images/resource-library/documents/certificate-policies-and-templates/Materials_Processes_and_Products_Classification_v_1.0.pdf
[73] ETIM is the international classification standard for technical products. Website: https://www.etim-international.com
[74] This figure is inspired by a similar figure from this source: GCS Consulting GmbH, Unterföhring 2018
[75] Deloitte, Impact of international, open standards on circularity in Europe, 2022, p. 45-46, URL: https://www2.deloitte.com/content/dam/Deloitte/pl/Documents/Reports/pl_Deloitte_I_GS1_I_Impact_of_international_open_standards_on_circularity_in_Europe_.pdf
[76] EURATEX, Facts & Key Figures 2022 of the European Textile and Clothing Industry, June 2022, URL: https://euratex.eu/wp-content/uploads/EURATEX_FactsKey_Figures_2022rev-1.pdf
[77] Trace4Value project website – URL: https://trace4value.se/subproject/digital-product-passport-in-textile/
[78] SDEX Web page, URL: https://www.europeanoutdoorgroup.com/knowledgehub/sustainability-data-exchange-project
[79] Fashionsort.ai Website, URL: https://fashionsort.ai
[80] STV Go Digital website – URL: http://www.stvgodigital.pt/
[81] FINATEX-STJM Website, URL: https://www.stjm.fi/en/
[82] GTS Website, URL: https://www.globaltextilescheme.org
[83] Trackit page on the Textile Exchange Website, URL: https://textileexchange.org/trackit/
[84] Revision of the regulation on the registration, evaluation, authorisation and restriction of chemicals (REACH), Legislative Train Schedule - European Parliament, URL: https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-reach-revision
[85] Revision of the textile labelling regulation, Legislative Train Schedule - European Parliament, URL: https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-textile-labeling-regulation
[86] JRC Preparatory Study on Textile Products, URL: https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/467/home
[87] Corporate sustainability due diligence: Council and Parliament strike deal to protect environment and human rights, Council of the EU, Press release, 14 December 2023, URL: https://www.consilium.europa.eu/en/press/press-releases/2023/12/14/corporate-sustainability-due-diligence-council-and-parliament-strike-deal-to-protect-environment-and-human-rights/