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From Regulation to Reality: Scalable Digital Product Passport Implementation for European SMEs

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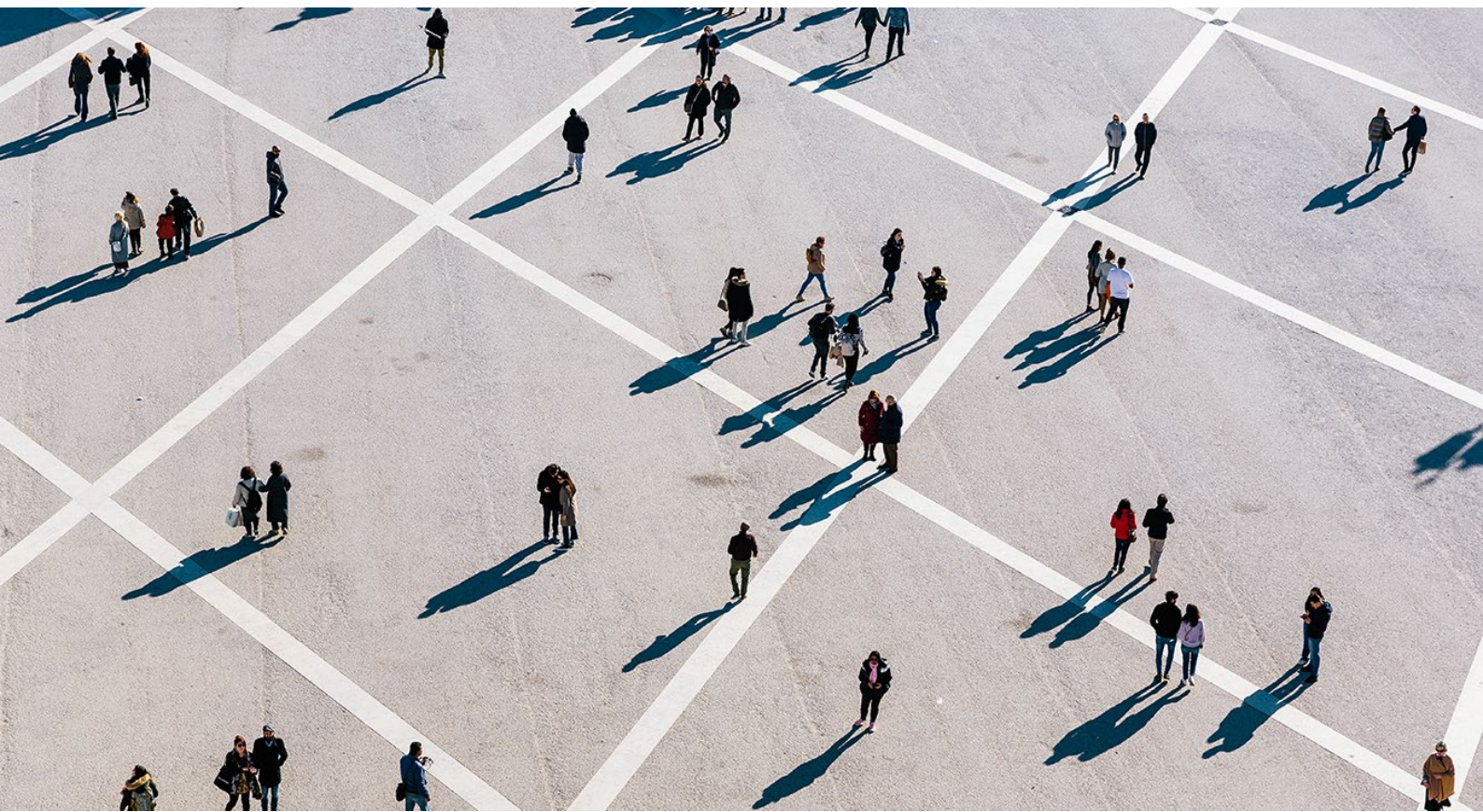


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List of Abbreviations

AI	Artificial Intelligence
CEAP	Circular Economy Action Plan
CIRPASS	Collaborative Initiative for a Standards-based Digital Product Passport for Stakeholder-Specific Sharing of Product Data for a Circular Economy
CSOs	Consumer Service Organizations
DPP	Digital Product Passport
EC	European Commission
EGD	European Green Deal
EMA	European Medicines Agency
ENISA	European Union Agency for Cybersecurity
EPREL	European Product Registry for Energy Labelling
EPRS	European Parliamentary Research Service
ERP	Enterprise Resource Planning
ESG	Environmental, Social, and Governance
ESPR	Ecodesign for Sustainable Products Regulation
EU	European Union
IP	Intellectual Property
IW	Institut der deutschen Wirtschaft
MES	Manufacturing Execution System
MIS	Management Information System
NFC	Near Field Communication
NGOs	Non-Governmental Organizations
NIST	National Institute of Standards and Technology (USA)
PIM	Product Information Management
PLM	Product Lifecycle Management
QR	Quick Response (Code)
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
RFID	Radio Frequency Identification
SBS	Small Business Standards
SCIP	Substances of Concern in Products
SME/SMEs	Small and Medium-sized Enterprise(s)
SPI	Sustainable Products Initiative
URL	Uniform Resource Locator

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1 Introduction and Research Design

The regulatory foundation for Digital Product Passports (DPP) represents the culmination of a deliberate and interconnected policy evolution within the European Union, driven by the urgent need to address climate change, resource depletion, and environmental degradation – maturing from a broad strategic vision to concrete regulatory implementation, ultimately crystallizing in the DPP as a central enabling mechanism for circular economy transformation.

The European Green Deal (EGD), introduced by the European Commission in December 2019, therefore set the stage by establishing the strategic foundation for Europe's most ambitious sustainability transformation (Almeida et al., 2023). Representing the world's first comprehensive public commitment to achieve climate neutrality by 2050, the EGD set an intermediate target to reduce net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels (European Commission, 2019). Within this comprehensive framework, the transition to a circular economy emerged as a critical pillar, recognizing that fundamental changes to production and consumption systems would be essential to achieving the Deal's ambitious environmental objectives (European Commission, 2019). Building directly upon the strategic vision established by the EGD, the European Commission adopted the new Circular Economy Action Plan (CEAP) in March 2020 as one of the Green Deal's main building blocks (Spani, 2020). CEAP represented a strategy to upscale the circular economy approach and announced a sustainable products policy framework with the creation of data spaces for circular applications, which conceptually paved the way for DPP-like instruments (Spani, 2020). This plan provided concrete, actionable measures to ensure that the ambitious environmental objectives set forth in the EGD could be adequately supported through comprehensive policy interventions addressing the entire product lifecycle (Spani, 2020). Critically, the CEAP explicitly recognized that achieving circularity at scale would require enhanced transparency and information flows throughout product value chains. As a key part of this the CEAP announced the Sustainable Products Initiative (SPI), a policy package designed to make sustainable products the norm in the EU with the goal of fostering responsible supply chains and pushing back against greenwashing (European Environmental Bureau, 2021).

Recognizing the complexity and novelty of implementing digital product information systems at scale, the European Commission funded the CIRPASS (Collaborative Initiative for a Standards-based Digital Product Passport for Stakeholder-Specific Sharing of Product Data for a Circular Economy) project under the Digital Europe Program from October 2022 to March 2024 (Alcayaga et al., 2024). The project's core objectives centered on building consensus around standards-based DPP

systems, identifying drivers, barriers, opportunities, and challenges for DPP deployment, and providing actionable recommendations for policymakers, businesses, and IT service providers (Alcayaga et al., 2024). The Ecodesign for Sustainable Products Regulation (ESPR; Regulation EU 2024/1781), which entered into force on July 18, 2024, served as the cornerstone of the European Commission's regulatory approach to achieving more environmentally sustainable and circular products, as stated in Article 6 of the ESPR (European Parliament and Council, 2024). The proposed framework establishes a system for setting Ecodesign requirements for specific product groups, including the establishment of digital product passports and aims to significantly improve the circularity, energy performance, and environmental sustainability of products, thereby contributing to the EU's strategic objectives.

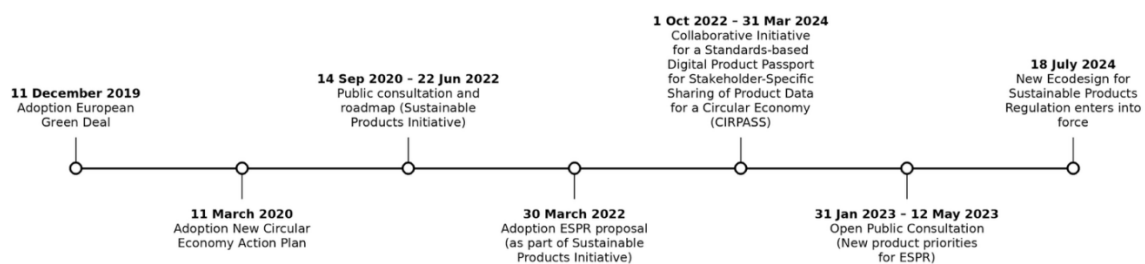


Figure 1- ESPR related policy milestones

Positioned at the intersection of product policy, information governance and circular economy practice, the Digital Product Passport is conceived as a central instrument for making relevant, product-specific information reliably accessible to diverse stakeholders across the product lifecycle. By providing standardized, machine-readable data on product composition, environmental performance, reparability and end-of-life treatment options, DPPs are intended to guide purchasing and usage decisions towards more sustainable alternatives and to enable more efficient disassembly, sorting and high-quality material recovery, thereby translating the Green Deal's and CEAP's circularity objectives into concrete decisions along the value chain (Alcayaga et al., 2024).

At the same time, the ESPR currently functions primarily as a horizontal framework whose product-group delegated acts – expected to define the precise scope, data elements, access conditions, and technical specifications – are still under development, as follows from e.g. Articles 1(1), 4(1), 10 and 11 (European Parliament and Council, 2024). In this interim phase, sectoral regimes are particularly instructive because they already specify passport logic in comparatively concrete terms and thereby foreshadow how the ESPR framework is likely to be operationalized across product groups, most notably through the battery passport requirements under the EU Batteries Regulation and the digital product passport system introduced in the Construction Products Regulation (Rizos & Urban, 2024).

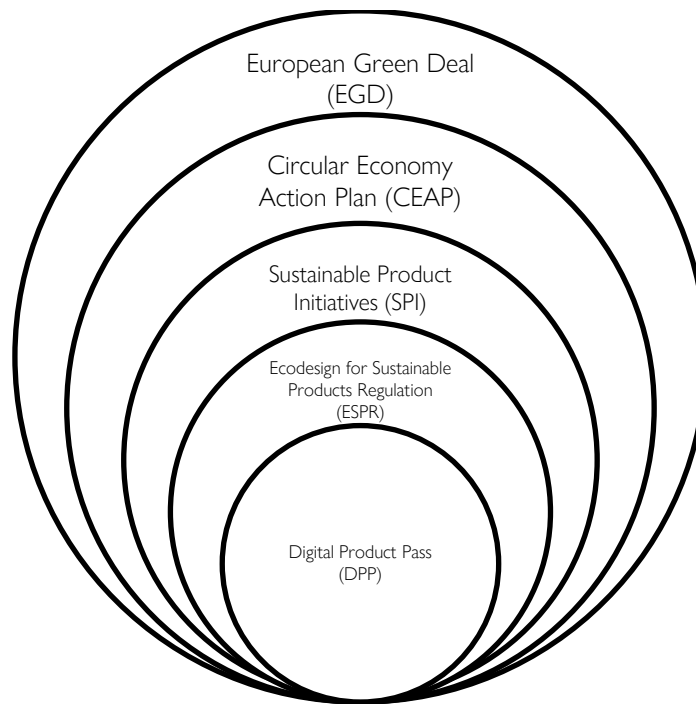


Figure 2 – Interplay of the regulatory initiatives

At the same time, realizing this regulatory and functional potential presupposes that firms can generate, maintain, and exchange granular, reliable, and interoperable product data across increasingly complex supply networks – a set of requirements that proves particularly demanding for small and medium-sized enterprises (SMEs). These enterprises confront a multifaceted array of challenges in DPP deployment, encompassing difficulties in tracking rapidly evolving regulatory requirements, constrained financial resources, limited technical expertise for digital transformation, organizational barriers to implementation, and persistent standardization gaps (Bernier et al., 2024). Even comparatively advanced SMEs and prospective DPP-as-a-Service providers perceive substantial complexity surrounding system integration, data standardization, security, and privacy, with many noting that operationalizing DPP requirements "at scale" remains elusive even for relatively informed actors – implying that less digitally mature SMEs will encounter even more implementation hurdles (Bernier et al., 2024). In this context, the DPP embodies a pronounced transparency-complexity paradox. While designed to mitigate information asymmetries and foster circularity across value chains, it simultaneously imposes considerable informational, organizational, and technological demands that risk disproportionately burdening SMEs and undermining the inclusivity of the EU's circular economy transition.

To address these multifaceted challenges and operationalize the DPP's transformative potential for small and medium-sized enterprises, this paper pursues three principal research objectives.

First, it seeks to delineate the regulatory frameworks and technical requirements shaping DPP deployment alongside the specific challenges confronting SMEs. Second, it develops practical implementation frameworks demonstrating how scalable solutions can address these barriers. Third, it evaluates how these approaches can be translated into practical implementation processes under typical SME resource constraints. These objectives are addressed through systematic desk research and literature analysis, synthesizing peer-reviewed academic sources, official EU regulatory documents and project findings, as well as industry reports to establish a comprehensive evidence base. By structuring the paper across regulatory understanding, problem identification, and practical solution frameworks, this secondary research approach delivers targeted, implementation-oriented guidance for SMEs navigating DPP requirements within resource constraints.

2 Regulatory Frameworks and Technical Background

To understand why many firms – and SMEs in particular – struggle with Digital Product Passport (DPP) implementation, it is essential to first clarify the binding regulatory expectations that define what a DPP must achieve, and the technical and organizational capabilities implicitly required to operationalize these expectations across complex value chains. The regulatory landscape therefore warrants closer examination, with particular focus on the Ecodesign for Sustainable Products Regulation (ESPR), which provides the legal basis for the DPP. Yet regulatory intent alone does not determine implementation feasibility. Translating legal requirements into operational DPP systems depends on standards, architectures, and governance arrangements capable of enabling interoperable, machine-readable, and stakeholder-specific information exchange – a translation challenge explicitly addressed in implementation-oriented work such as CIRPASS and repeatedly highlighted in the academic literature on DPP data needs and governance tensions (Ducuing & Reich, 2023; Jensen et al., 2023). Establishing this regulatory and technical baseline is therefore a prerequisite for delineating the requirements shaping DPP deployment and for subsequently explaining why these requirements tend to generate burdens for SMEs.

2.1 Regulatory Landscape

With the ESPR, the EU moved from a primarily energy-related ecodesign paradigm to a broader sustainability-oriented product policy architecture, in which product performance requirements and product information requirements can be set for defined product groups. The DPP is embedded in

this approach as a scalable compliance-and-market mechanism. Rather than prescribing a single static dataset for all products, the ESPR establishes a harmonized framework (Article 1(1)) and then foresees product-group-specific rules for what data must be provided, to whom, in what format, and under which governance conditions (Article 9(2)) (European Parliament and Council, 2024). This logic matters for firms as it turns DPP compliance into a moving target with obligations crystallizing progressively, product group by product group, as secondary legislation is adopted and updated.

The first ESPR and Energy Labelling Working Plan (2025–2030) operationalizes this prioritization logic and clarifies where DPP requirements are most likely to become salient first. The Commission’s working plan identifies priority product groups such as steel and aluminum, textiles, furniture, tires, and mattresses as well as numerous energy-related products, and it anticipates horizontal measures such as reparability-oriented requirements and recyclability requirements for electrical and electronic equipment (Directorate-General for Environment, 2025). Even where a firm is not yet directly subject to a product-group delegated act, the working plan serves as an anticipatory regulatory signal that informs capability development – particularly for SMEs.

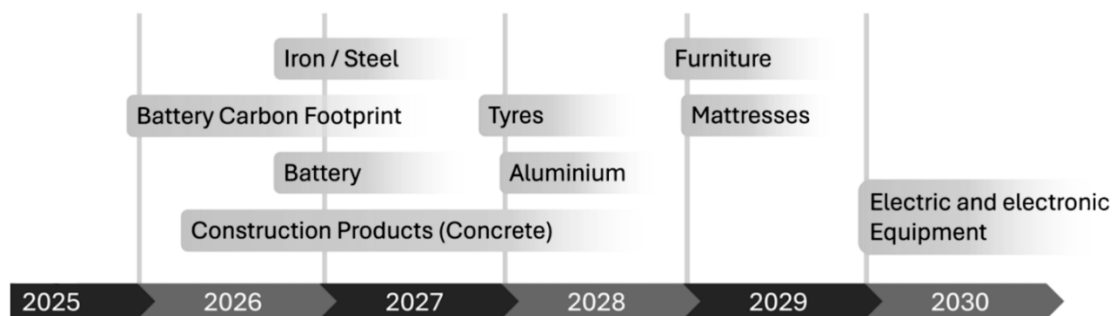


Figure 3 - Timeline for the DPP rollout across product categories

“DPP compliance” is best understood not as a single checklist, but as a structured bundle of requirements that will vary by product group. These requirements can be broken down into information and content requirements, data governance and access rights as well as operator responsibilities and lifecycle duties. While the detailed minimum requirements for Digital Product Passports (DPPs) are still being developed by the responsible EU Commissions, the regulatory framework already clarifies that the scope, granularity, and technical operationalization of the DPP will be product-group specific and aligned with the product’s environmental relevance and market significance (Huber & Wangler, 2025).

2.2 Regulatory & technical requirements

In regulatory terms, the Digital Product Passport (DPP) functions as the instrument through which product-group information requirements are operationalized, with the specific dataset being determined through delegated acts. Although the exact data fields will differ across product groups, the ESPR already identifies indicative categories of information that a DPP may include. In particular, Article 9(2)(a), in conjunction with Annex III, points to information such as: (i) the product's technical performance, (ii) the materials used and their origins, (iii) repair activities, (iv) recycling capabilities, and (v) life-cycle environmental impacts (European Parliament and Council, 2024). Analytically, these categories imply that DPP datasets will combine relatively static product attributes with dynamic lifecycle information, thereby supporting decision-making by heterogeneous actors ranging from consumers and repairers to recyclers and authorities (Jensen et al., 2023; King et al., 2023). This information should be purpose-driven and lifecycle-relevant with each data element clearly defined in scope and justified by a concrete user benefit for one or more stakeholders across the product lifecycle (University of Cambridge Institute for Sustainability Leadership & Wuppertal Institute, 2022). Furthermore, as noted in Recital 33, the data to be provided must relate to the product model, batch, or individual item, as specified in the relevant delegated act. (European Parliament and Council, 2024).

Crucially, the ESPR does not only define what information should be made available via the Digital Product Passport but also specifies essential requirements for the technical design and operation of DPP systems. In particular, Article 10 of the ESPR requires that the DPP must be connected “through a data carrier to a persistent unique product identifier” that should be “physically present on the product” and that all data included be based on “open standards, developed in an interoperable format, and be machine-readable, structured, searchable, and transferable through an open interoperable data exchange network without vendor lock-in” (European Parliament and Council, 2024). The unique product identifier constitutes a foundational element of the Digital Product Passport (DPP) system architecture, as it enables the unambiguous linkage between a physical product and its corresponding digital record containing product-related information. Ideally, as reflected in recital 46 of the ESPR, this identifier should be implemented using an appropriate physical data carrier – such as a QR code or an NFC/RFID tag – and be resolvable via a persistent, internet-based Uniform Resource Locator (URL), thereby ensuring reliable and continuous digital access to the passport throughout the product's lifecycle (Plocienni et al., 2022). Additionally, the data carrier may also include cross-sectoral basic data elements, i.e. data that can be consulted offline. These elements should make it possible to

consult data from the data carrier even when the online information cannot be accessed (Archer et al., 2024).

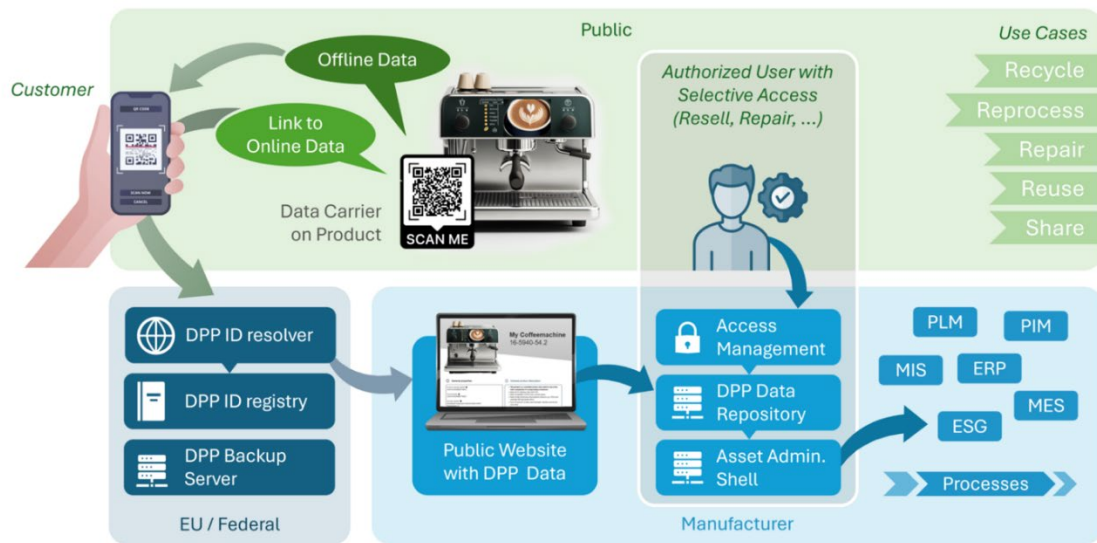
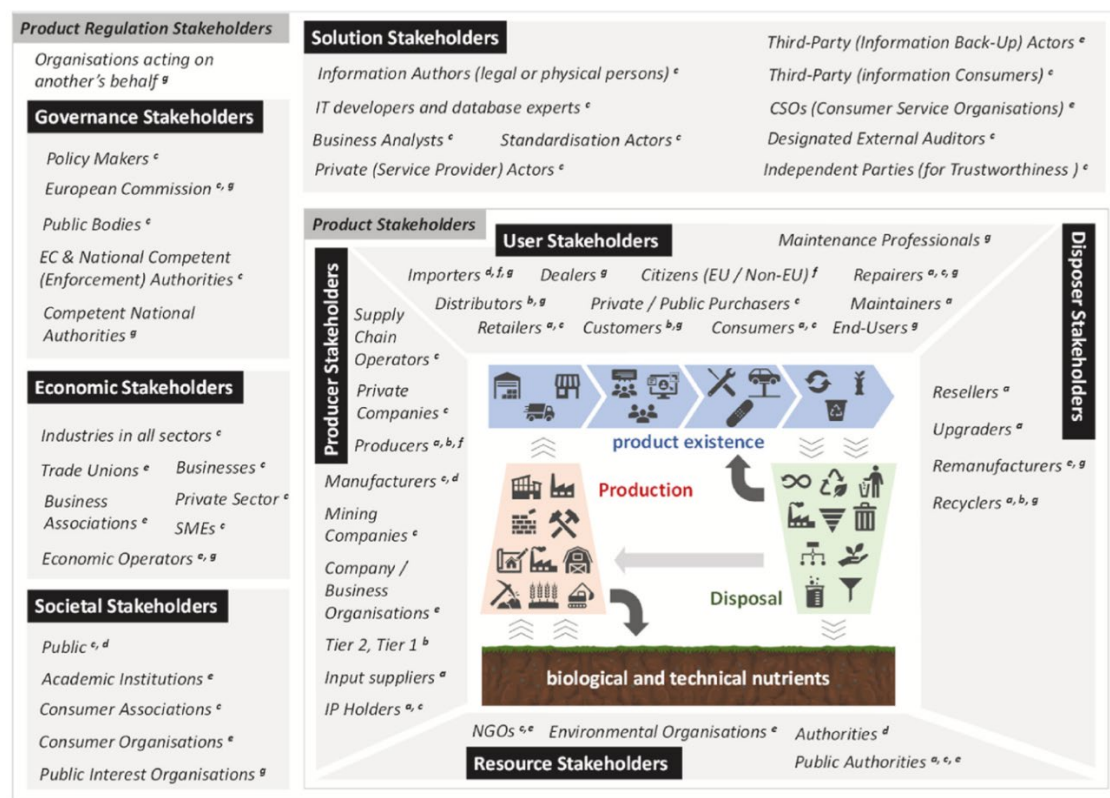


Figure 4 - Conceptual implementation of a DPP infrastructure (Huber & Wangler, 2025)

Access to DPP information is conceived as role-differentiated rather than uniform. As outlined above, the ESPR delegates the concretization of the DPP's scope, granularity, and access conditions to product-group delegated acts, including the specification of which actors may consult the passport, which information they may access, and which authorized actors may introduce, modify, or update defined data elements over time. In parallel, the ESPR's implementation logic anticipates that differentiated access requires robust identity and role verification across a distributed ecosystem. Accordingly, as stated in Article 11 of the ESPR, the Commission is empowered to adopt implementing rules for mechanisms such as digital credentials to authenticate authorized actors and enable secure access to non-public DPP sections (European Parliament and Council, 2024). Because ESPR delegated acts are still being developed, the Battery Regulation is currently the clearest legally binding example of how the EU operationalizes stakeholder access rights in a passport system. Its battery passport annex explicitly separates publicly accessible model-level information, model-level information restricted to persons with a legitimate interest (and the Commission), information restricted to notified bodies and market surveillance authorities, and individual-battery data restricted to persons with a legitimate interest (European Parliament and Council, 2023). Crucially, the regulation's tiered content structure makes the EU's underlying access logic explicit by differentiating information visibility according to stakeholder function. Consumers and the general public are provided with aggregated composition and sustainability-relevant information, whereas more granular technical details – such as dismantling

instructions, component identifiers, and detailed composition data – are confined to restricted access layers intended for professional actors engaged in repair, reuse, refurbishment, and recycling operations. (European Parliament and Council, 2023). This structure provides a defensible template for ESPR-aligned DPP governance across other product groups, even if the exact fields differ. Building on the SPI consultation evidence base, King et al. (2023) confirm that product-passport information needs and concerns are stakeholder-contingent. Different passport use-cases distribute benefits and burdens unevenly across stakeholder groups, which makes role-differentiated access and purpose-bound data disclosure a core design principle rather than an optional add-on. An overview of the affected stakeholders is shown below.



(a) Annex 18, Table 99 (b) Annex 18, Figure 1 (c) Annex 18, 'Potential stakeholders' benefits, pg 592-596 (d) Annex 18, 'Roles', Table 101 (e) Annex 18, pg 617-621 (f) Feedback Organisations (to Impact Assessment, Open Public Consultation) (g) COM(2022)142 Ch.III

Figure 5 - Affected Stakeholders (King et al., 2023)

A consistent finding across the DPP scholarship is that the passport's circular-economy value depends less on the existence of a "record" than on the assignment and execution of lifecycle duties – namely, who must create the passport, who must keep it available, who may update which parts, and how responsibilities shift when products are repaired, refurbished, remanufactured, repurposed, or become waste (Jensen et al., 2024; Wan & Jiang, 2025). In this sense, DPP implementation is best

conceptualized as an ecosystem orchestration problem in which responsibilities must be operationalized across interdependent actors and across time, rather than a one-off compliance disclosure at the point of placing a product on the market (Jensen et al., 2024; King et al., 2023). Even though ESPR product-group delegated acts will specify the exact operational requirements, the EU's approach already makes clear that DPP compliance attaches to the economic operator placing the product on the market (Article 27(1)) and that “availability, integrity, and controlled updating” are treated as ongoing obligations rather than static documentation (Recital 36; Article 11(f)) (European Parliament and Council, 2024). This becomes particularly concrete in sectoral regimes that already specify pass-port operations in detail, especially batteries and construction products.

Taken together, these requirements indicate that DPP implementation extends far beyond a documentation exercise and instead constitutes a distributed information-infrastructure challenge. It requires persistent product identification and a reliable linkage between physical items and their digital records, interoperable data structures and semantic consistency so that information remains machine-readable and comparable across systems, and mechanisms for data exchange, discovery, and retrieval across heterogeneous value-chain actors. At the same time, it depends on robust access control and trust mechanisms that safeguard integrity and accountability, as well as lifecycle-ready operational capabilities such as versioning, updating, and long-term availability management. These capability areas provide a structured basis for assessing where SMEs face disproportionate implementation burdens and where external support mechanisms may be necessary.

3 Challenges for SMEs

The practical burden that Digital Product Passports (DPPs) create for small and medium-sized enterprises (SMEs) is best understood as a process challenge rather than a single compliance hurdle. While the ESPR is progressively concretized through product-group delegated acts, firms must already prepare for an operational system that combines lifecycle information provision with interoperable exchange and controlled access. Importantly, the legislator explicitly anticipates SME-related disproportionality risks: Recital 33 highlights that, where DPP implementation relies on standards that are not free of charge, the impact assessment should examine whether such reliance is appropriate and how disproportionate costs for micro, small and medium-sized enterprises can be avoided (European Parliament and Council, 2024). This concern is also translated into operational support expectations. In particular, Article 22(2) embeds SME-oriented implementation facilitation into the delegated-act pipeline by requiring the Commission, where appropriate, to accompany delegated acts with digital tools

and guidelines reflecting SME specificities, alongside consultation of SME-representative organizations (European Parliament and Council, 2024). Complementarily, Article 22(3) places a corresponding duty on Member States to adopt measures enabling SME compliance, identifying minimum elements such as one-stop shops or similar mechanisms and signaling further instruments including financial support, access to finance, and training or technical assistance (European Parliament and Council, 2024).

Against this legal backdrop, the DPP literature increasingly conceptualizes implementation as an ecosystem orchestration task, in which feasibility depends on coordinated data mobilization, governance, and role alignment across supply-chain actors rather than on isolated firm-level reporting capability (Langley et al., 2023; Jensen et al., 2024). Accordingly, SME challenges can be located along an end-to-end pathway of achieving a functioning DPP. Starting with regulatory scoping and interpretation; moving to dataset definition and internal readiness; then to upstream data acquisition and supplier collaboration; followed by data standardization, governance, and assurance; and culminating in passport issuance and lifecycle operations such as updating and maintaining availability. This process view mirrors the CIRPASS SME cost-benefit study, which clusters recurring difficulties around issuing DPPs, updating and maintaining DPPs, and interacting with DPP data downstream (Bernier et al., 2024).

3.1 Regulatory scoping and interpretation

DPP scoping is difficult for SMEs because obligations are not expressed as one stable checklist. Under the ESPR, concrete duties (including DPP-related requirements) are set through product-group delegated acts, so SMEs must determine if, when, and how their products will be covered as sector rules emerge. Although Article 4(4) requires the Commission to grant sufficient time for compliance – explicitly taking account of SME and microenterprise needs and generally preventing delegated acts from applying earlier than 18 months after entry into force – SMEs still face a continuous monitoring and interpretation burden because the compliance target is defined progressively (European Parliament and Council, 2024).

Regulatory scoping is also shaped by the ESPR's ongoing priority-setting and review logic, which makes early preparation dependent on both binding law and forward-looking policy signals. Article 18 mandates that the Commission prioritize products and develop planning instruments, providing a basis for working plans that can be updated over time as needs evolve (European Parliament and Council, 2024). For SMEs, this means that interpreting “when DPP becomes relevant” often

depends not only on delegated acts once adopted, but also on instruments such as the Ecodesign for Sustainable Products and Energy Labelling Working Plan 2025–2030 (COM (2025) 187 final), which signals likely early product groups and thereby functions as a practical early-warning reference (European Commission, 2025).

A further interpretive burden follows from cross-regime mapping, because DPP preparation often intersects with existing EU information obligations. Recital 34 explicitly points toward linking ESPR information requirements to other Union law (e.g., REACH safety data sheets) and, where feasible, connecting DPPs with existing EU databases and tools such as EPREL (European Product Registry for Energy Labelling) and SCIP (Substances of Concern in Products) (European Parliament and Council, 2024). While such linkage may reduce duplication in principle, it increases the practical workload for SMEs because datasets, definitions, and disclosure constraints differ across regimes and are not always aligned.

Finally, scoping must account for standardization dependencies and their cost implications. ESPR explicitly recognizes that implementation may depend on standards that are not free of charge and that this can create disproportionate SME costs. Recital 33 calls for impact assessments to consider whether reliance on paid standards is appropriate and how disproportionate costs for SMEs can be avoided (European Parliament and Council, 2024). In practice, SMEs must plan for both evolving delegated-act obligations and the time and cost of accessing and applying relevant standards – an issue also reflected in CIRPASS, which groups SME burdens around issuing, maintaining, and using DPP data in ways that depend on early clarity about scope and compliance dependencies (Bernier et al., 2024). SME consultations similarly highlight uncertainty about minimum requirements and regulatory expectations, especially in complex sectors (SBS, 2024). From a governance perspective, scholarship also cautions that DPP-related debates often under-specify governance choices, which can push firms – especially SMEs – into an interpretive “grey zone” where technical decisions and legal compliance become hard to separate (Ducuing & Reich, 2023).

3.2 Dataset definition and internal readiness

Defining a “passport dataset” is difficult for SMEs because the final data fields and required granularity are not yet fixed across product groups. SMEs must therefore translate an evolving regulatory direction into an internal target dataset that is likely to change as delegated acts mature. ESPR anticipates this implementation gap. Article 22(2) requires the Commission, where appropriate, to accompany delegated acts with digital tools and guidelines covering SME specificities and to consult SME-representative organizations (European Parliament and Council, 2024).

Internal readiness is further constrained by data fragmentation inside SMEs. DPP-relevant information is typically spread across engineering, procurement, quality, compliance, and aftersales, and often exists as documents or inconsistent fields rather than structured data. This turns dataset definition into a reconciliation task: aligning product variants, naming conventions, and bills of materials across systems that were not designed for interoperability (Lopes & Barata, 2024).

Dataset definition also extends beyond “what the product is” to what happens to it over time. Many DPP concepts assume that some information changes during use, repair, or refurbishment, which creates readiness requirements for event capture and updating that many SMEs are not organized for (Wan & Jiang, 2025).

Internal readiness is also limited by people and process capacity. In the SBS study on textiles, SMEs emphasize that DPP preparation would often require clearer internal ownership (i.e., deciding who is responsible for product data across functions) and more formal routines for collecting and validating information, yet many firms lack dedicated staff and still rely on manual or semi-structured records (SBS, 2024). As a result, even when data exists somewhere in the organization, it is frequently not in a form that can be consolidated into a consistent, repeatable dataset without substantial coordination work. SBS also indicates that SMEs perceive this as an administrative load risk, because the effort falls on small teams that already manage parallel regulatory and operational duties (SBS, 2024).

3.3 Upstream data acquisition and supplier collaboration

A core SME challenge is that many DPP-relevant data points sit upstream, outside the firm’s direct control. Even where an SME is the economic operator responsible for placing the product on the market, key inputs (e.g., material composition, origin, recycled content claims, process data, component identifiers) are typically generated by suppliers across multiple tiers. As a result, DPP readiness depends on supply-chain coordination and “orchestration” rather than on isolated firm-level reporting capacity (Langley et al., 2023; Jensen et al., 2024).

Upstream acquisition is also complicated by cross-regime data reuse and inconsistent legal-data boundaries. For SMEs, this means supplier data often needs to be mapped across different regulatory contexts and disclosure rules, which increases the effort required to request, interpret, and consolidate upstream information in a consistent way.

A further challenge is that supplier collaboration is shaped by confidentiality, commercial sensitivity, and asymmetric bargaining power. Tiered access concepts in sectoral passport regimes illustrate this tension: the Batteries Regulation ties information access and update rights to role-differentiated rules in Annex XIII and requires that access/updates be restricted according to those rights (European Parliament and Council, 2023). In practice, this kind of governance logic can make upstream data requests harder for SMEs because suppliers may resist sharing granular data unless legitimate-interest conditions, confidentiality protections, and liability boundaries are clearly defined (Ducuing & Reich, 2023).

Finally, upstream mobilization is particularly difficult in highly fragmented, multi-tier value chains, where data gaps and uneven digitization are common. In textiles, for example, EPRS highlights that traceability and reliable data transfer across tiers are central but challenging due to complex global supply structures and inconsistent information availability (European Parliamentary Research Service, 2024). SBS similarly finds that SMEs in the textile sector expect difficulties in obtaining upstream data in a usable format and are concerned that the effort of collecting and validating such information will fall disproportionately on small teams with limited bargaining power vis-à-vis suppliers (SBS, 2024). Implementation-oriented CIRPASS work similarly treats data availability and inter-actor coordination as central barriers for real-world deployment (Alcayaga et al., 2024).

3.4 Data standardization, governance and assurance

A key challenge is that interoperability is mainly a semantic problem, not just a formatting issue. DPP information typically comes from heterogeneous sources (internal systems, suppliers, certificates), and research shows that implementation quickly runs into inconsistent meanings for basic concepts such as “material,” “component,” “recycled content,” or “repair event.” Without shared semantics, data may exist but still cannot be reliably compared, aggregated, or processed across actors (Zhang & Seuring, 2024).

A closely related challenge is standard diversity and partial coverage across sectors and use-cases. The literature finds that DPP use-cases span compliance, procurement, circular operations, and service/repair, which implies that information needs differ by stakeholder and purpose; this makes

“one universal dataset” unrealistic and increases the risk of fragmented implementations and incompatible data models (Zhang & Seuring, 2024; Lopes & Barata, 2024).

Governance research then highlights that data-sharing rules are contested because product data is economically sensitive. Ducuing and Reich (2023) show that DPP initiatives can fail when governance remains under-specified, because questions of access rights, control, accountability, and liability determine whether data sharing is feasible and trusted – especially when firms are asked to disclose commercially sensitive information downstream. Ecosystem perspectives add that governance choices shape who bears costs and who captures benefits, which is particularly relevant for SMEs with limited influence over ecosystem rules (Gieß & Möller, 2025).

A further challenge is assurance and auditability: DPP information must be defensible, not merely available. Research on DPP “quality infrastructure” argues that scalable passport systems require traceable verification services and systematic data-quality mechanisms, because interoperable data exchange can also scale errors and questionable claims if quality controls are weak (Niederhausen et al., 2025). Related work also explores automated approaches (e.g., machine-learning-based checks) as a response to the practical workload created by validating large volumes of heterogeneous submissions (Cruz et al., 2025).

Evidence from applied, business-oriented research reinforces that these challenges are not abstract. A report from the “Institut der deutschen Wirtschaft (IWV)” on DPP practicability finds that many companies are still insufficiently digitalized for DPP requirements, that product data is often stored in analogue form, and that data governance practices (needed for data quality, integrity, and security) are frequently missing. It also notes that companies often hesitate to share data externally due to legal and technical barriers (Neligan et al., 2023). For SMEs, this matters because limited internal digitization and weak data governance make standardization and assurance efforts disproportionately labor-intensive, especially when upstream inputs arrive in non-standard formats and must be normalized and substantiated before they can be published in a passport.

Overall, the research suggests that these issues should be treated as one connected bundle rather than separate tasks. If data is not described in a consistent way, it cannot be reused reliably across actors, and if governance and assurance are weak, even well-structured data will not be trusted or shared at the level needed for DPP purposes. This helps explain why SMEs often experience DPP preparation as “more work than expected”. The effort is not only in compiling information, but in making it understandable, credible, and usable beyond the firm’s own systems and terminology (Zhang & Seuring, 2024; Ducuing & Reich, 2023).

3.5 Passport issuance and lifecycle operations

Passport operation creates a long-term burden for SMEs because issuance is not the end point. Once a DPP exists, it must remain usable and available over time. Sectoral rules already show how far this continuity expectation can go. Under the Batteries Regulation, Article 78(e) requires that the battery passport “shall remain available” even if the responsible economic operator ceases to exist or ceases activity in the Union (European Parliament and Council, 2023).

Operationally, SMEs must also manage the issuance step itself in a reliable way. The ESPR requires that the DPP be accessible through a data carrier connected to a persistent unique product identifier (Article 10) (European Parliament and Council, 2024). In practice, this introduces recurring execution risks – e.g., mismatches between product variants and passport records, inconsistent identifier use across sites or suppliers, or failures of the physical carrier in real logistics and use conditions – which can undermine both compliance and downstream usability.

Day-to-day passport operation further depends on controlled access and protection of sensitive information. The Batteries Regulation illustrates this operational logic by linking rights to access, introduce, modify, or update passport data to tiered access rules (Article 78(f)) (European Parliament and Council, 2023). Governance research stresses that such access-control choices are not merely technical; they shape trust and willingness to share high-quality data, especially where commercially sensitive information is involved (Ducuing & Reich, 2023).

Maintaining the passport over time is a distinct workload, because lifecycle-relevant information may need to be updated as products move through use, repair, resale, refurbishment, or end-of-life handling. SME-oriented evidence captures this clearly. The CIRPASS SME cost–benefit study groups recurring difficulties into issuing DPPs, updating and maintaining DPPs, and interacting with DPP data downstream (Bernier et al., 2024). Academic work similarly notes that without robust routines for change control and event capture, passports risk becoming outdated or inconsistently updated, reducing their reliability (Wan & Jiang, 2025).

Finally, SMEs must be prepared for a broader pattern of downstream interaction. Passports are read not only by authorities, but also by customers and professional actors (e.g., repair and recycling), which can create operational pressure to respond to queries, manage data exchange, and handle access requests consistently. CIRPASS treats these “downstream interaction” demands as a distinct SME burden cluster, reflecting that they require repeatable processes rather than one-time documentation (Bernier et al., 2024).

4 Practical implementation framework for SMEs

The challenges identified in Chapter 3 indicate that DPP implementation becomes feasible for SMEs only when it is institutionalized as a repeatable operating model rather than treated as a one-off compliance project. This chapter therefore proposes a practical SME implementation framework that translates regulatory uncertainty, data dependencies and interoperability requirements into a small set of maintainable routines. The framework is organized around three interlocking pillars: (i) a product-data backbone that remains usable over time, (ii) proportionate technical enablement to reduce recurring manual effort, and (iii) compliance-by-design operations that stabilize issuance, controlled disclosure and updating. This orientation is consistent with CIRPASS evidence that the main SME burden lies in recurring activities – issuing passports, maintaining them and responding to downstream data interactions – rather than in a single documentation exercise (Bernier et al., 2024).

4.1 Building a product data backbone that stays usable

A practical starting point for SMEs is to define a small, essential passport dataset that matches (i) the requirements most likely to apply in the first delegated acts and (ii) a limited set of internal and customer-facing use cases. This avoids the common failure mode of attempting to “pre-build the final DPP” before product-group rules stabilize and before upstream data access is secured. Since DPP use cases vary across stakeholders and sectors, a single universal dataset is rarely realistic; an incremental, use-case-driven approach is more robust (Zhang & Seuring, 2024).

Once this minimum scope is defined, SMEs can create a product data backbone: a structured internal core product dataset that consolidates what already exists across engineering, procurement, quality, compliance and aftersales into a coherent overview. Recent Commission research frames the DPP as requiring accurate, complete and up-to-date product information that is machine-readable and linked to unique identifiers via data carriers. For SMEs, this reinforces that the implementation problem is less about producing documents once and more about maintaining a reliable internal product dataset that can be updated over time (Senatore et al., 2025). The objective is not to replace all legacy tools, but to establish one consistent internal representation linking product variants to bills of materials, supplier references and compliance-relevant attributes. This directly addresses a recurring barrier identified in DPP reviews: information is often present, but not reliably integrated into consistent, reusable data (Lopes & Barata, 2024).

Because many DPP-relevant data points sit upstream, data availability improves only if supplier dependence is treated as a managed workflow rather than ad hoc document chasing. Practically, this means mapping each required field to its most likely owner (internal function, tier-1 supplier, or deeper tiers) and establishing a repeatable request-and-response routine with defined formats and minimum evidence expectations. This aligns with the ecosystem literature, which frames DPP feasibility as coordinated data mobilization across multiple actors rather than isolated firm-level reporting capacity (Jensen et al., 2024; Langley et al., 2023). To reduce friction, SMEs can formalize supplier collaboration through a standard “supplier data packet” routine. Each packet specifies required fields, accepted formats (e.g., code list vs free text), minimum evidence (e.g., certificate number, test report reference, declaration date), and a response deadline aligned with procurement or release cycles. Over time, this converts supplier data acquisition from case-by-case email chasing into a predictable recurring exchange, which is consistent with ecosystem accounts that treat DPP feasibility as coordinated mobilization across actors (Jensen et al., 2024; Langley et al., 2023).

A recurring reason SMEs experience DPP preparation as “more work than expected” is that data transformation is underestimated. A workable SME operating model therefore treats transformation and normalization as an explicit step: harmonizing units, aligning naming conventions, resolving duplicates, and managing product-variant logic. The benefit is that transformation work is done once and reused across passport updates, customer requests and compliance checks, instead of being repeated whenever a new query arises. CIRPASS’ finding that burdens cluster in recurring tasks implies that repeated rework becomes a major cost driver unless transformation routines are stabilized early (Bernier et al., 2024).

Finally, data quality remains stable only if the dataset is useful inside the firm, not only for external compliance. SMEs are structurally constrained in staffing and cannot sustain a large “compliance-only” dataset without operational value. SBS finds that SMEs in the textile industry often lack dedicated data roles and fear administrative overload, emphasizing clear internal ownership and routines that fit existing workflows makes upkeep more feasible because updates occur where information is already handled rather than through a parallel reporting process (SBS, 2024).

4.2 Proportionate automation for data validation and preparation

From an SME perspective, the most realistic role for advanced digital tools is to reduce workload in checking and preparing data, not to replace accountability. This matters because the regulatory direction already implies that passport information must be managed with strong quality discipline. The

ESPR frames the DPP as an operational information instrument and requires that passport data be maintained so that it remains accurate and reliable over time, even as detailed product-group requirements will be specified via delegated acts (European Parliament and Council, 2024).

A practical technical concept is therefore to treat AI as a validation and acceleration layer around the product data backbone. This means the backbone remains the system of record, while AI supports tasks such as completeness checks, plausibility screening, anomaly detection, and consistency validation prior to publishing data in a passport. This aligns with research arguing that DPP scalability depends on assurance mechanisms and a supporting “quality infrastructure,” because interoperable exchange can also scale errors if validation is weak (Niederhausen et al., 2025).

To keep automation proportionate, SMEs can prioritize validation on fields where errors are common, and consequences are high (e.g., composition claims, recycled-content declarations, supplier identifiers, or repair-relevant component references). In applied research, machine-learning approaches have been explored to support data-quality assessment in DPP contexts, illustrating that automated checks can help triage human attention and reduce repetitive manual review (Cruz et al., 2025). For SMEs, the value is not “full automation,” but scalable screening that frees scarce staff time for exceptions and supplier follow-up.

A further technical barrier for SMEs is the document-to-data gap. Critical product information often exists in PDFs, certificates, declarations, and spreadsheets. A proportionate automation concept is to use AI-assisted extraction to pre-fill structured fields from existing documents, while keeping human approval as the gate for any externally disclosed data. This reduces the time cost of transforming semi-structured records into structured datasets – an effort SBS highlights indirectly when SMEs describe limited staffing and heavy administrative load created by repeated data preparation (SBS, 2024).

Technical challenges also include semantic alignment. Even when data exists, it may not match emerging DPP information models or sector semantics. Here, AI can support SMEs as a mapping assistant by suggesting correspondences between internal field names and external concepts, flagging ambiguous terms, and highlighting missing qualifiers. The mapping decision itself remains a governance choice, but the workload can be reduced. This is consistent with research that identifies semantic alignment as a major barrier to reliable interoperability and comparability across actors and use cases (Zhang & Seuring, 2024).

Two external reference points help specify what “good” looks like for automated validation in regulated settings. First, the National Institute of Standards and Technology (NIST) AI Risk Management Framework emphasizes that trustworthy AI requires documented governance, measurement,

and monitoring, with clear human accountability for risk decisions rather than non-transparent automation (NIST, 2023). Second, the European Medicines Agency's Data Quality Framework operationalizes "fit for purpose" data quality in a regulatory context through explicit procedures for data lifecycle management, traceability, and quality controls – not as an abstract ideal, but as a maintainable routine (EMA, 2023). These analogies are useful for SMEs because they shift the question from "Can we automate?" to "Can we prove that controls exist and are consistently applied?"

Because DPP information may be inspected by business partners or authorities, automation must remain auditable. A practical SME safeguard is to treat AI outputs as decision support rather than truth. SMEs must record what checks were performed, what thresholds were applied, which source documents were used, and who approved exceptions. This reinforces the assurance logic in DPP research, that credibility depends on traceable controls and verifiable quality mechanisms, not simply on data availability (Niederhausen et al., 2025; Ducuing & Reich, 2023). It further reflects the legal requirement that passport data remain verifiable at scale, instead of drifting into claims that cannot be substantiated (European Parliament and Council, 2024).

4.3 Operationalizing compliance and interoperability through stable routines

To make compliance manageable under evolving delegated acts, SMEs benefit from translating obligations into a stable internal structure that can absorb change. A practical approach is to maintain an internal control map linking (i) product scope, (ii) required data elements, (iii) evidence sources, (iv) responsible internal owner, and (v) update triggers. This provides continuity when requirements evolve and helps SMEs avoid repeated reinvention of processes. The need for such stability follows from the ESPR's staged implementation model, where operational requirements for the DPP will be specified through product-group delegated acts (European Parliament and Council, 2024).

Interoperability is more feasible for SMEs when implemented as a layered architecture rather than a single all-in-one platform. In practical terms, the internal data backbone can remain inside the firm (or within trusted service infrastructure), while disclosure is managed through separate layers: a public layer for information intended for wide access, and restricted layers for professional users or authorities where legitimate-interest and confidentiality conditions apply. This aligns with the DPP ecosystem logic that governance and technical architecture must enable differentiated access and controlled disclosure, otherwise trust breaks down and firms under-share (Ducuing & Reich, 2023).

A useful implementation pattern for this layered disclosure is credential-based sharing, where a verifier can receive only the claims needed for a given purpose rather than full datasets. In credential-based sharing, credential presentations can support selective disclosure and derived proofs, enabling a verifier to receive only the claims needed for a given purpose rather than full datasets (Flamini et al., 2024). This is relevant for SMEs because it offers an interoperability mechanism that reduces over-disclosure risk without forcing fully open publication of commercially sensitive attributes.

A workable operating model also requires explicit rules for role-based disclosure, because SMEs must avoid both over-disclosure (risking commercial harm) and under-disclosure (risking non-compliance or loss of circular-economy value). The Batteries Regulation provides a concrete reference point for tiered information logic and differentiated access rights, which SMEs can use as a practical template when designing disclosure discipline even before ESPR product-group measures are final (European Parliament and Council, 2023).

Lifecycle operation becomes feasible for SMEs only if updating is treated as routine rather than exceptional. This means defining when updates are triggered (e.g., repair, component replacement, reconfiguration), who is authorized to make which changes, and how changes are recorded and validated. The importance of this operationalization follows directly from Chapter 3 evidence: CIRPASS identifies updating and maintaining passports as a distinct and recurring SME burden cluster (Bernier et al., 2024). Consistent with this, lifecycle relevance depends on reliable change control; without it, passports become outdated and lose credibility for downstream decisions (Wan & Jiang, 2025).

Finally, SMEs need to plan for continuity of access, not just availability at the moment of sale. Sectoral rules already indicate that long-term availability expectations can extend beyond the life of the operating firm. Under the Batteries Regulation, the passport must remain available even if the responsible economic operator ceases activity in the Union (Article 78(e)) (European Parliament and Council, 2023). A complementary operational reference is the practical guidance for SMEs provided by the European Union Agency for Cybersecurity (ENISA). This guidance highlights basic continuity measures such as maintaining reliable backups and planning recovery steps so that essential services can be restored after disruption (ENISA, 2021). For SMEs, this supports a practical requirement to avoid brittle hosting and ownership arrangements by defining in advance who takes over passport hosting, how data are transferred, and how continuity is validated.

Taken together, compliance-by-design operations can be implemented by SMEs as a stable routine set: an internal control map that can absorb delegated-act change, layered disclosure with role-based access discipline, controlled updating with auditable change records, and continuity

planning that preserves long-term availability. This keeps interoperability workable under SME constraints while directly addressing the recurring burden patterns documented in CIRPASS and the governance constraints emphasized in the research literature (Bernier et al., 2024; Ducuing & Reich, 2023).

5 Discussion and Recommendations

This paper set out to clarify why Digital Product Passport implementation is disproportionately demanding for small and medium-sized enterprises and to develop practical means of addressing that burden. The regulatory analysis established that DPP compliance is not a one-off documentation task but a distributed information-infrastructure obligation that accrues progressively through product-group delegated acts (European Parliament and Council, 2024), while the review of SME challenges located that burden along an end-to-end pathway from regulatory scoping to lifecycle operation. Against this backdrop, the paper proposed a three-pillar implementation framework intended to make these requirements more manageable under SME resource constraints.

A central implication of the framework is that the recurring burden of DPP data preparation does not necessarily need to be addressed entirely through capabilities developed internally by individual SMEs. Activities such as schema design, data mapping, transformation, validation, and passport generation can, in principle, be supported through dedicated technology and standardized workflows, while firms retain responsibility for providing accurate source data, relevant evidence, and the domain knowledge required to interpret that information. This division of responsibilities suggests that DPP readiness can be approached as an organizational and technical capability that combines internal product knowledge with external or automated data-processing support. For SMEs, the practical implication is therefore a reframing of the central question: rather than asking whether the complete DPP capability must be built in-house, firms can assess which capabilities need to remain internal and which recurring technical activities can be supported through proportionate technological solutions.

Read as a whole, the framework's principal contribution is to make DPP implementation more tractable at the point where SMEs are particularly constrained: the preparation and management of internal product data. By treating a usable data backbone (Section 4.1) and proportionate automation (Section 4.2) as foundational elements, the framework concentrates effort on activities that can be standardized, repeated, and partially supported through technology. This can reduce the need for SMEs to perform the same mapping, transformation, and validation activities manually whenever product information is prepared for a new compliance or disclosure requirement.

The demands that remain more difficult to address through this approach — including controlled lifecycle updating, role-differentiated disclosure, and the mobilization of upstream supplier data (Sections 4.3 and 4.1) — are not principally problems of internal data preparation but of coordination across organizations. A framework focused on strengthening intra-firm data processes is consequently less able to resolve obligations that are inter-organizational by nature (Jensen et al., 2024; Ducuing & Reich, 2023). This represents an important boundary of the proposed approach. Its benefits are likely to be greatest where SMEs already maintain reasonably structured product information, while implementation becomes more demanding where source data remain fragmented, incomplete, or predominantly unstructured. The framework therefore provides a practical route for strengthening those dimensions of DPP readiness that firms can directly control while recognizing the continuing dependence on suppliers and other actors across the wider ecosystem.

Taken together, the framework's design suggests a distinction between DPP challenges that can primarily be addressed within an SME's own organizational and technical boundaries and those that depend on coordination across the wider value chain. The measures proposed in Chapter 4 for consolidating fragmented records into a structured product-data backbone and applying proportionate validation and automation directly address the internal-readiness and assurance challenges identified in Sections 3.2 and 3.4. Their principal contribution lies in reducing repeated data-preparation effort and establishing more consistent processes for transforming existing product information into structured, reusable, and auditable data.

At the same time, the framework has clear boundaries. Its strongest leverage lies in organizing and improving data that the firm already holds or can directly control. It is therefore less able to resolve challenges where the necessary information or action lies outside the firm's organizational boundaries. Upstream supplier attributes, discussed in Section 3.3, depend on the willingness and capability of external actors to provide sufficiently structured and reliable information. Similarly, lifecycle operations and differentiated disclosure, discussed in Section 3.5, require coordination among multiple actors over time. These limitations are consistent with the ecosystem perspective in the literature, according to which DPP implementation depends not only on internal data capabilities but also on coordinated data mobilization and governance across the value chain (Langley et al., 2023; Wan & Jiang, 2025). The framework should therefore be understood as a means of strengthening the aspects of DPP readiness that SMEs can directly influence while recognizing that full implementation ultimately depends on broader ecosystem coordination.

Three recommendations follow from this assessment. The first, directed at SMEs, is to begin developing DPP-related data capabilities before all product-specific delegated acts are finalized. Rather

than attempting to construct a complete DPP infrastructure prematurely, firms can establish a structured product-data backbone, clarify internal ownership of relevant information, and develop repeatable processes for mapping, validating, and maintaining product data. Where appropriate, dedicated technological support can be used to reduce the recurring burden of data preparation and validation without transferring responsibility for the accuracy and integrity of the underlying information.

The second recommendation concerns upstream data acquisition. SMEs should treat supplier data mobilization as a distinct workstream initiated early in the implementation process rather than as a late-stage data-entry task. Many DPP-relevant attributes cannot be generated internally because the necessary information is held by suppliers or other actors in the value chain. Closing these gaps therefore requires repeatable request-and-response routines, clearly defined data expectations, and appropriate evidence requirements. Such relationships take time to establish and cannot be resolved through internal automation alone.

The third recommendation is directed at providers of DPP-related technical solutions and supporting infrastructure. Auditability, interoperability, schema versioning, and transparent data transformation should be treated as core capabilities rather than secondary technical features. SMEs should be able to trace how source information has been transformed, identify which validation procedures have been applied, and retain clear responsibility for approving externally disclosed information. Technical solutions should therefore support, rather than obscure, the governance and assurance processes required for credible DPP implementation.

6 Conclusion and Outlook

This paper examined whether the demands of Digital Product Passport implementation must fall disproportionately upon small and medium-sized enterprises, and it arrives at a qualified conclusion. The preparation of a firm's own product data for disclosure, which represents the point at which resource-constrained enterprises are most exposed, can be rendered manageable through the combination of a structured data backbone and proportionate automation. The obligations that extend beyond the individual firm, encompassing the mobilization of upstream supplier data and the coordination of lifecycle operations, prove considerably more resistant and remain only partially resolved. This constitutes the central result of the analysis, which was established while the regulatory regime governing the DPP is still in formation, and its practical significance for SMEs is therefore contingent upon the trajectory that regime follows.

The regulatory architecture established in the opening chapters does not impose its requirements at a single moment. Under the Ecodesign for Sustainable Products Regulation, the substance of DPP compliance is set not by the framework regulation itself but by the product-group delegated acts that follow it, and these are adopted sequentially rather than together. The obligation therefore hardens incrementally, one product group at a time, as each act fixes the data elements, granularity, and access conditions that until then existed only as regulatory direction. Textiles occupy an early position in this sequence, which places one of the first major consumer goods sectors among the earliest for which provisional interpretation will give way to binding specification. Until each act is adopted, the schemas against which firms prepare their product data cannot be drawn from binding law and must instead be assembled from the standards and conceptual references available at the time. The trajectory ahead is consequently one of convergence, as the provisional arrangements in use across the sector are progressively measured against, and required to align with, the binding specifications that the delegated acts will eventually establish.

How this convergence bears on small and medium-sized enterprises divides along the same line that organizes the paper's central result. For the preparation of internal product data, the hardening of the regime is a manageable prospect. A firm whose data is organized around a defensible interim structure faces re-alignment against a now-fixed specification rather than complete reconstruction, and the recurring work this entails is of the kind a capable technology layer can carry. External obligations follow a different path. Each delegated act fixes not only the data a passport must contain, but also the conditions under which it must be sourced, kept current, and disclosed across the value chain. As these conditions acquire binding force, so do the obligations that reach beyond the individual firm, and no amount of internal preparation can satisfy them, since they rest on the cooperation of upstream suppliers and the coordination of lifecycle information across organizations. The practical weight of the regime therefore shifts over time. The internal readiness problem, hardest at the outset, becomes progressively more tractable, while the coordination problem that internal effort cannot reach moves to the foreground as the binding specifications extend to it. The SME future under the DPP is in this sense decided less by whether firms can prepare their own data than by whether the wider ecosystem furnishes the means to meet the obligations that cross organizational boundaries.

The paradox set out at the start of this paper treated the DPP's burden as a single weight on SMEs, with the attendant risk of excluding them from a transition the instrument was designed to advance. The analysis here refines that picture. The burden is not one weight but two, and they behave differently under pressure: the internal one yields to scalable preparation, while the one that crosses

organizational boundaries does not. The exclusion risk the paradox identified is therefore real but mislocated. It does not reside primarily in whether a firm can ready its own data, as the framing implied, but in whether it can meet obligations whose fulfilment was never within its sole control. The contribution of this paper is thus to show that the tension is more tractable than it first appeared, and at the same time more precisely located. The DPP can be made to include the resource-constrained firm on the terms it can govern alone, but its full inclusivity remains an open question of the European circular economy, answerable only at the level of the ecosystem the instrument presumes.

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From Regulation to Reality: Scalable Digital Product Passport Implementation for European SMEs

White paper

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