Digital Product Passport as Enabler for the Circular Economy

Relevance and practicability for companies

Adriana Neligan / Carmen Schleicher / Barbara Engels / Thorsten Kroke

Berlin/Cologne, 22.09.2023

IW Report 47/2023

Economic studies, reports and facts

Herausgeber
Institut der deutschen Wirtschaft Köln e. V.
Postfach 10 19 42
50459 Köln

Das Institut der deutschen Wirtschaft (IW) ist ein privates Wirtschaftsforschungsinstitut,
das sich für eine freiheitliche Wirtschafts- und Gesellschaftsordnung einsetzt. Unsere Aufgabe ist es, das Verständnis wirtschaftlicher und gesellschaftlicher Zusammenhänge zu verbessern.

Authors

Dr. Adriana Neligan
Senior Economist
neligan@iwkoeln.de
0049-(0)30 - 27877-128

Carmen Schleicher
Student assistant
schleicher@iwkoeln.de

Barbara Engels
Senior Economist
engels@iwkoeln.de
0049-(0)221 - 4981-703

Thorsten Kroke
Authorized signatory
kroke@iwkoeln.de
0049-(0)221-4981-831

Das IW in den sozialen Medien

Twitter
@iw_koeln

LinkedIn
@Institut der deutschen Wirtschaft

Instagram
@IW_Köln

All studies can be found at www.iwkoeln.de

In dieser Publikation wird aus Gründen der besseren Lesbarkeit regelmäßig das grammatikalische Geschlecht (Genus) verwendet. Damit sind hier ausdrücklich alle Geschlechteridentitäten gemeint.

Status:
September 2023

Table of contents

JEL classification

D22 - Firm Behavior: Empirical Analysis
O33 - Technological Change: Choices and Consequences; Diffusion Processes
O44 - Environment and Growth
Q01 - Sustainable Development
Q55 - Technological Innovation

Summary

Political relevance of the Digital Product Passport. Politicians are currently discussing a Digital Product Passport (DPP) as a central instrument for building a circular economy. Latter is seen as an important enabler for climate neutrality. Although there is no standardized, cross-sectoral and cross-company product passport system yet, there are already individual solutions for collecting information for certain product groups. To increase transparency throughout the entire product life cycle a DPP shall be made available digitally for all actors. A DPP should include information about the product, such as manufacturer, material, characteristics, repair, and disposal options. The DPP must fulfil both content-related and technical requirements.

Readiness for the Circular Economy. The topic of the circular economy has not yet arrived on a broad scale in companies. Only a few companies are comprehensively aligning their business model in a circular way, for example by considering the entire product life cycle, optimising the design of products and/or developing new circular business models. At the same time, some relevant product characteristics for a circular economy - such as durability as part of the quality promise "Made in Germany" - are already strongly developed. Other characteristics such as reparability, easy maintenance and refurbishment are not in the focus of companies yet but are key for the transformation to a circular economy.

Digital and Data Readiness. Many companies in Germany do not meet the requirements for implementing the DPP yet. Numerous companies are not yet sufficiently digitalized and there are large sector differences in the level of digitalization. Furthermore, they do not meet the requirements to manage data efficiently because product data is often still stored in analogue form and many companies do not have data governance, which is the basis for ensuring data quality, data integrity and data security. Many companies do not share data with other companies - mainly due to legal, but also technical barriers.

Structure of a DPP. Ideally, the DPP contains a transparent provision of a unique identification, a precise description of the product and its characteristics as well as all environmentally relevant information for producers, suppliers, and consumers. The legal content and technical requirements must be complied with and at the same time sector-specific needs must be considered. The DPP should serve as a transport container, follow clear structures and be modular and expandable. A structured and, above all, standardized collection and transfer of information is required so that all stakeholders involved can view and supplement relevant information on the product. Standards for the identification, classification and recording of environmentally relevant information are particularly relevant. The ECLASS data standard, with its interoperability, modular system and conformity with standards and global norms, offers many advantages for the development of a DPP.

1 Introduction

In a circular economy a new understanding of economic activity and an alternative approach to raw materials are required. Resources should be used for as long as possible to reduce both the material and energy consumption as well as the waste and emissions of an economic system to a minimum. To this end, addressing the efficient use, recycling of resources, but also the replacement of certain raw materials - for example, with secondary raw materials - is of high importance for German industry (Geissdoerfer et al., 2017; Lichtenthäler/Neligan, 2023; Neligan et al., 2022a). However, this transformation is only at the beginning: material cycles still need to be better closed. In the European Union (EU) and Germany, the circular use of materials, which is the share of material recovered and reintroduced into the economy in total material use, was 12 and 13 percent respectively in 2021 (Eurostat, 2023).

Resource cycles can be realized in different ways in companies. The necessary view on the entire product life cycle requires new approaches for its essential phases - design, production, use and reuse of products (Lichtenthäler/Neligan, 2023). A key prerequisite for a circular economy is knowledge of both the upstream stages and the effects of one's own actions on downstream stages of the value chain.

Digitalization is an important enabler of the adaptation of product and service systems as well as the development of modified or even new circular business models, as it enables the intelligent use of innovations and access to data, for example via a Digital Product Passport (DPP) (Neligan et al., 2023). Via the DPP, information about the product such as manufacturer, material, characteristics, repair and disposal options should be made available digitally, as in a “product memory”. The aim is to make the entire product life cycle transparent for all stakeholders. DPPs have numerous advantages for companies. This also includes the development of digital business models in the sense of a "product as a service". At the same time, DPPs pose some challenges for companies, especially small and medium-sized enterprises (SMEs), as their processes and products are not yet digitalized, at least in part, and much data is not collected or not stored digitally. In addition, there are still many open questions regarding the design of DPPs, for example on data security. So far, there are few concrete proposals in the scientific literature on what a DPP might look like. The present study closes this gap. It shows how future requirements can be designed in a practicable and manageable way. Specifically, it answers the following questions:

- **Relevance and regulation of DPPs:** Why is a DPP needed? Why does the policy provide for a DPP? (Chapter 2)
- **Definitions, stand-alone solutions and requirements:** What is a DPP? Which stand-alone solutions are already available? What are the policy requirements for the DPP? What is the role of the DPP for companies? (Chapter 3)
- **Readiness of the companies:** To what extent are companies prepared for the implementation of the DPP? What are the prerequisites for the implementation in the companies, what are the possible obstacles? (Chapter 4)
- **Operational implementation:** What might a concrete prototype for a DPP look like? (Chapter 5)
- **Conclusion with evaluation:** What are the opportunities and risks in designing the DPP? How can the prototype proposal be further developed? (Chapter 6)

2 Relevance and regulation of DPPs

This chapter provides an overview of the role of DPPs from a political perspective. On the way to climate neutrality, both the European Green Deal (EU Green Deal) and the current German coalition agreement with the planned National Circular Economy Strategy (Nationale Kreislaufwirtschaftsstrategie) see a circular economy as a central measure that mobilizes the entire industry. By means of environmentally compatible product design (eco-design), companies should in future take greater account of closed-loop recycling in product planning and development.

Digitalization is a prerequisite for the transparency required to depict the interrelationships of a closed-loop process (Neligan et al., 2023). Actors along the value chain must be able to communicate efficiently - and thus automatically - via interfaces to be able to transmit relevant information without losses and in a resource-saving manner. Information in form of digital data is necessary to measure and evaluate the success of circular material flows and business models (Neligan et al., 2021; Lichtenthäler/Neligan, 2023). Product data governance plays a key strategic role (Piétron et al., 2022). The DPP provides a solution for implementing various circular strategies to obtain, use, retain, and retrieve all necessary information (DIN/DKE/VDI, 2023; PSQR, 2023).

Various political advancements at both the European and national level see DPPs as enablers of a circular economy (Figure 2-1). A DPP was first mentioned in general terms as an instrument in the EU Green Deal of 2019 and specified in the proposal of the EU Ecodesign Regulation in 2022 (European Commission, 2019; European Commission, 2020a; European Commission, 2022a):

- **EU Green Deal and Circular Economy Action Plan:** A key pillar of the EU Green Deal is the Circular Economy Action Plan published in 2020, which identifies DPPs as a solution to mobilize the potential of product information digitalization as part of a sustainable product policy but does not specify it further.

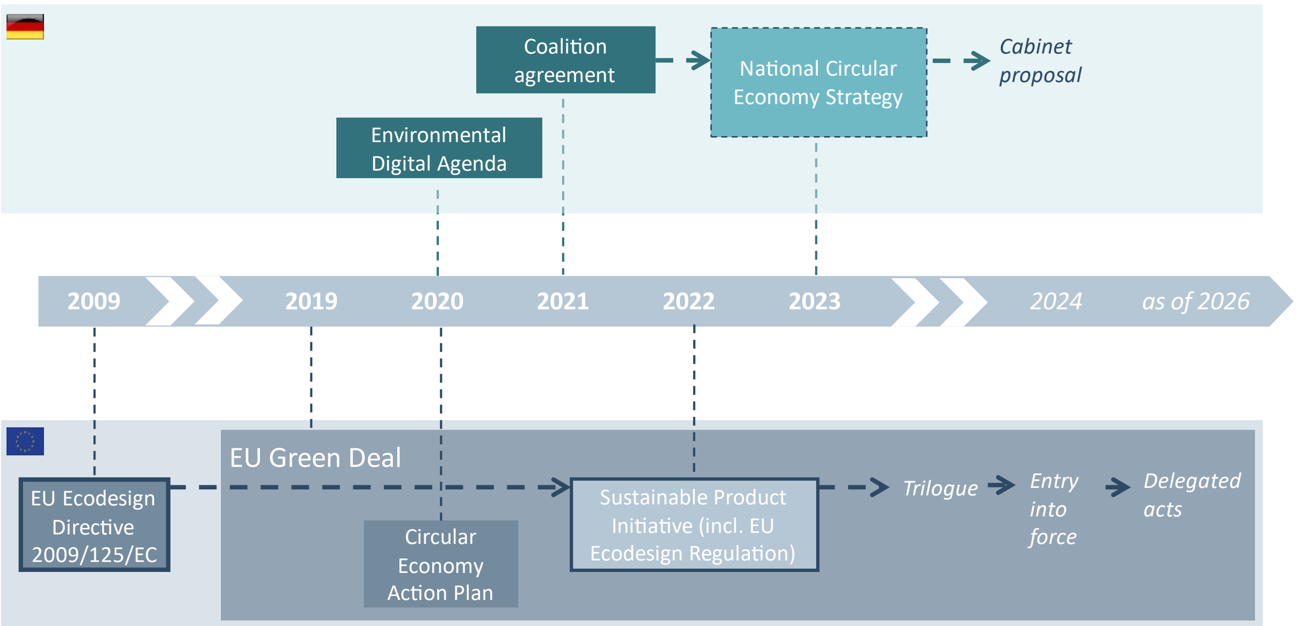
- **EU Ecodesign Regulation:** As part of the Sustainable Product Initiative of the EU Green Deal, there has also been a draft of an Ecodesign for Sustainable Products Regulation (EU Ecodesign Regulation) since 2022. The aim is to make sustainable products the norm. This is to be achieved by creating access to sustainability information along the supply chain. In addition, there should be incentives for more sustainable product and business models for improved value retention. An optimized regulatory framework for sustainable products will also be sought. The new regulation includes performance and information requirements for almost all physical product categories in the EU market, unless their environmental characteristics are already regulated by other relevant pieces of legislation (BDI, 2022; BDI, 2023; BMUV, 2023a). Within the framework of the EU Ecodesign Regulation, a working plan will be drawn up. It contains criteria for prioritizing products and a non-binding list of product groups that the EU Commission intends to address in the coming years in terms of ecodesign via delegated acts. A product group is defined by the EU Commission (2022a) as a set of products that have similarities in terms of their purpose, use, functional characteristics, and consumer perception.

In future, the DPP is intended to become the standard for all product groups covered by the regulation. The aim of DPPs is to increase transparency regarding the environmental impact of products and to enable a longer product life. In addition, DPPs are intended to help authorities with testing and inspection and to strengthen consumer rights (BDI, 2023; BMUV, 2023a). Important product-specific information on origin, material composition, condition, repair and disassembly options, and end-of-life handling is to be stored and made available along the industrial value chain. It is also planned that there will be a product passport register in which the information contained in the product passports required under the delegated acts envisaged for each product group will be stored.

It is currently expected that the EU Ecodesign Regulation will enter into force by 2024 following the conclusion of the current negotiations in the trilogue between the European Commission, European Parliament and European Council. As a result, first delegated acts for individual product groups should be available from 2026 and 2027 at the earliest (BDI, 2023). It can also be assumed that the focus will be on the introduction of DPPs for the value chains identified as central in the Circular Economy Action Plan, such as batteries, textiles, and construction, but also consumer electronics or packaging (Stretton, 2022).

Figure 2-1: DPP: Not new, but of current relevance

Development over time



Source: Own representation

At national level, there are two pushes for DPPs, but they do not provide specific guidance on design and implementation:

- In the 2020 Digital Agenda for the Environment (Umweltpolitische Digitalagenda), one measure is a DPP for final products that enables sustainable consumption choices to be made and facilitates the recycling of products. In principle, the DPP should be applicable to all products and services. Initially, the focus should be on particularly resource- and energy-intensive goods such as information and communication technology (ICT) products (BMUV, 2020; Götz et al., 2021).

- The German coalition agreement of 2021 provides for a National Circular Economy Strategy. A paper outlining the fundamentals of this strategy has been available since April 2023 and is currently being further developed in the stakeholder process. A DPP is to be introduced to be able to fulfill, among other things, information requirements for products and extended producer responsibility in the sense of EU requirements, including environmentally compatible product design (ecodesign). The DPP is intended to support the transparency and closed-loop management of substances while maintaining the principle of data economy (BMUV, 2023b; Neligan et al., 2023; SPD, Bündnis 90/Die Grünen and FDP, 2021).

So far, however, it is unclear what DPPs for different product groups will look like and when they will become mandatory (DIN/DKE/VDI, 2023; Götz et al., 2021). There are also initial sector- or product-specific isolated solutions at EU level that are moving in the direction of DPPs. They are outlined in Chapter 3.1.

3 DPP: definitions, isolated solutions and requirements

At both national and European level, DPPs are being pushed politically as a standardized information tool to be able to meet the increased requirements for products and the associated information obligations. This chapter provides available definitions of DPPs, presents existing isolated solutions and describes necessary requirements for DPPs.

3.1 Definition

The DPP can be understood as a concept for collecting and sharing product-related information on manufacturer, material, characteristics, repair, and disposal (Jansen et al., 2023). The policy defines the term ‘product passport` as follows:

- In the planned EU Ecodesign Regulation, the European Commission defines the term ‘product passport’ as a product-specific data set that contains certain information and is accessible electronically via a data carrier (European Commission, 2022a, Article 2 (29), p. 53).
- In the context of the German environmental digital agenda, the DPP is defined as a ‘complete lifecycle’. The DPP is a standardized and comparable data set that summarizes the components, materials and chemical substances for a product or also information on reparability, spare parts or professional disposal. The data should originate from all phases of the product life cycle and be used for various purposes in all these phases (design, manufacture, use, disposal). The higher transparency in the product life cycle should enable more sustainable actions for consumers, industry and waste management and facilitate mandatory reporting (BMUV, n.d.; BMUV, 2020; Götz et al., 2021).

In addition to the DPP itself, a corresponding infrastructure must be available for processing the information. Stable IT systems are needed to collect and exchange data. The literature also distinguishes between a DPP and a DPP system (Jansen et al., 2023):

- The **DPP** is the artifact consisting of the information provided and shared by the interacting actors in the value chain of a product.
- The **DPP system** is the basic comprehensive information system in which DPPs are integrated. This enables the data required for DPPs to be integrated in a shared information world. It promotes interaction between the various players along the value chain of a product and facilitates the assignment of a physical product to the corresponding DPP.

In summary, the DPP should serve at least the following three functions (further requirements are defined in Chapter 3.3):

- **Clear identification and description:** The comprehensive use of DPPs requires the clear identification of the product, the description of the product and its characteristics, and the transparent presentation of environmentally relevant information. Here, the concrete instance of the product, for example a single concrete product, is relevant.

- **Standardized and uniform data management**: In principle, a DPP can be used by companies along the entire value chain (manufacturers, suppliers, retailers, etc.) as well as by consumers. This requires standardized and uniform management of product data and environmentally relevant information.

- **Managing complexity**: Along the value chain, depending on the industry and the actor, the contents of the DPP vary in complexity. If one imagines a company from the basic materials industry that produces intermediate products for further industrial processes, the supply chain - and thus the 'life cycle' - from raw material to resource is probably very short. However, if you look at a company further down the value chain, the product and therefore the product-related information is many times more complex. Particularly in the case of products with a high share of intermediate inputs many companies from different sectors are already involved in the creation of the product.

3.2 Isolated solutions for digital information collections

Although there is hardly a uniform, cross-industry and cross-company product passport system yet, isolated solutions for information collection for specific product groups already exist. There are various approaches to information provision, data collection and presentation for electrical and electronic equipment, chemicals, fertilizers, packaging and packaging waste, and end-of-life vehicles (see Götz et al., 2021 for an overview). Batteries is the first product group for which a DPP is going to be mandatory. Other industries also have promising concepts for implementing DPPs, such as the building resource passport (DIN/DKE/VDI, 2023). Important specific solutions are briefly described below:

- **Batteries:** The planned new EU regulation on batteries and waste batteries looks at the entire life cycle and imposes new requirements on batteries from design, to manufacturing, to waste management of all battery types purchased in the EU. From 2026, a digital battery passport is to become mandatory for traction batteries, light transport batteries and industrial batteries with a capacity of more than 2 kilowatt hours, with information on capacity, performance, shelf life, chemical composition and with the need for separate disposal. Crucial to this is the use of new digital concepts, in particular the battery passport and the networked data room, for secure data exchange, increased transparency of the battery market, and traceability of large batteries throughout their life cycle (European Commission, 2022b; European Parliament, 2023).

- **Energy-related products:** The EU Energy Labelling Directive sets out requirements for individual product groups with regard to uniform Europe-wide labeling on the consumption of energy and other resources, as well as additional information requirements on product data sheets for corresponding products. All energy consumption-relevant products that bear an energy label, including refrigerators and air conditioners, must be entered in the European Product Registry for Energy Labelling (EPREL) with their product data sheets containing information on energy labeling and other details. This product database consists of a public part (for end consumers, among others) and a non-public part, which is only accessible to the European Commission and market surveillance authorities and is subject to strict security measures (EU Parliament/EU Council, 2017, Götz et al, 2021). The EU Ecodesign Directive for energy-related products and its product group-specific implementing measures also require information requirements on aspects of the circular economy (see Chapter 3.3.1).

- **Textiles:** The EU strategy for sustainable and recyclable textiles provides for the introduction of information requirements and a DPP. As part of the new EU Ecodesign Regulation a DPP for textiles with information requirements regarding compliance with the circularity principle and other important environmental aspects is to be introduced. The introduction of a digital label is also under review (European Commission, 2022b).
- **Buildings:** The EU Buildings Directive makes it compulsory to issue energy performance certificates for buildings when they are sold or newly leased, which contain the actual energy status of the buildings. Since 2021 the EU has been working on a new version to make buildings emission-free. To this end, the energy certificate obligation will in future also apply to major renovations, to the renewal of leases and to all public buildings. A renovation passport is also planned as a tool to facilitate gradual renovation toward zero-emission levels (European Commission, 2010; European Commission, 2023g). The concept of the material passport is often mentioned in the context of buildings to hold information on products and components that are to be reused or recycled (see Götz et al., 2021). Based on the successfully established Energy Performance Certificate, the German Sustainable Building Council (DGNB) has developed a Building Resource Passport, which provides key information around resource use, climate impact, and recyclability for each building (DGNP, 2023). There is also the environmental product declaration according to DIN EN ISO 14025 (Environmental Product Declaration) initiated by the construction industry, which provides product information on the sustainability of building materials in a standardized data set and could lay the foundation for the product passport (DIN/DKE/VDI, 2023; BMUV, 2023c).
- **Circular Economy:** The Product Circularity Data Sheet according to ISO/CD 59040 develops a general methodology to improve the accuracy and completeness of circular economy information. The goal is to implement a qualitative approach to data exchange between companies when sourcing or supplying products for trustworthy reporting. This guidance is intended to apply to all organizations regardless of type, size or nature (ISO, 2023).

Elements of traceability, monitoring and data sharing requirements are also included in a number of other regulations and policies. For example, the EU Data Strategy aims to harmonize and standardize access to data. The Data Act aims to clarify legal, economic, and technical issues related to access to data. Adopted in June 2023, the regulation, which still needs to be formally endorsed by the EU Parliament and the Council of Member States, includes requirements on access by usually business users to data generated by their networked devices, rules on data access and use by government agencies, data sharing contracts, and cloud switching (Demary, 2022). The goal of the Data Act is to ensure that more data is available in Europe and that the potential of data management can be exploited. As digitalization increases, datasets become interconnected, and environmental impact assessments are required throughout the product lifecycle, legislation for different product categories is becoming increasingly interconnected. There are initiatives in the textiles, construction, electronic waste, plastics, chemicals, and automotive sectors toward more sustainable business practices (Stretton, 2022).

3.3 Requirements

The realization of a DPP is a complex undertaking. The content of the DPP is indirectly linked to content-related and directly to technical requirements, which are interdependent (Figure 3-1). The content requirements for the manufacture of products determine their characteristics, which in turn are captured in the DPP under certain technical conditions. It is also a challenge to find the right balance between sharing information and protecting data (Sipka, 2022). The following subsections go into more detail about the content as well as technical requirements for DPPs.

Figure 3-1: Requirements for a DPP

Overview for an electronic product-specific data set

Source: Own representation

3.3.1 Content requirements

In recent years,EU product policy has received new impetus in the direction of ecodesign (see also Chapter 2). Up to now, the focus within the framework of the EU Ecodesign Directive has been on reducing the environmental impact of products with high energy consumption (European Parliament, 2009). With the Ecodesign Work Program 2016-2019, aspects of material efficiency were introduced as a new criterion for the first time. The issue of repairability, durability and availability of spare parts will be addressed with new ecodesign requirements for many products. This has already been addressed for household appliances in 2021 and mobile end devices in 2022 (BMUV, 2022, Neligan et al., 2023). With product group-specific requirements regulated in the future via an EU Ecodesign Regulation, the way will be paved across Europe to ensure easier recycling, simple repair, longer service life, and resource savings as early as the product design stage (European Commission, 2022; Neligan et al., 2023). The following ecodesign requirements are intended to apply to a specific product group in each case, or common requirements can also be set horizontally for several product groups if technical similarities make it possible (European Commission, 2022a):

- Durability, reliability, reusability, retrofittability, repairability, ease of maintenance and refurbishment
- Restrictions on the use of certain substances that affect the recyclability of products and materials
- Energy consumption or energy efficiency of products
- Resource utilization or resource efficiency of products
- Minimum quotas for recyclates in products
- Easy disassembly and remanufacturing as well as easy recycling of products and materials
- Environmental impact of products throughout their life cycle, including their carbon dioxide (CO_2) footprint and their environmental footprint
- Prevention and reduction of waste, including packaging waste

The issue of reparability is also being pushed with the planned EU Right to Repair. The aim is to make it easier and cheaper to repair goods. In the future, the necessary repair and maintenance information must be available for each product (European Commission, 2023).

However, not only product-related legislation is relevant for a circular economy. Furthermore, relevant is EU waste legislation, which also takes a life-cycle approach. A key principle of waste legislation is Extended Producer Responsibility (EPR), under which the producer of a product is responsible for the entire life cycle of the product in accordance with the polluter pays principle. This responsibility begins with product design and extends specifically to the post-use phase, including collection, take-back, sorting, reuse, recycling, and final disposal of the product (CEID, 2021; Neligan et al., 2023). This approach creates incentives for manufacturers to design products to last longer, to be recyclable or reusable after their original use.

The product-specific and waste legislation requirements described above exemplify how the information requirements for products are increasing within the EU. However, the discussion regarding the DPP goes beyond the issues of sustainability and circularity, as it could also become relevant for all mandatory product information such as CE marking under the New Legislative Framework in relation to evidence of conformity or access to market surveillance (DIN/DKE/VDI, 2023). The DPP can play an important role in systematically holding and providing the necessary data and information. In addition, the systematic impact analysis of possible environmental effects over the entire life cycle (life cycle analysis) of products and production resources is becoming increasingly important in an industrial context. This requires standardized data structures of life cycle relevant data in the DPP (see also DIN/DKE/VDI, 2023). The DPP must therefore be indirectly designed to record certain characteristics, such as ecological or CO_2 footprints or material flows of products. However, it must also hold information that extends the life cycle, including information to facilitate repair, remanufacturing and/or recycling.

3.3.2 Technical requirements

For cross-sector and cross-system use as well as data provision by various actors, the DPP must meet diverse technical requirements. Central are both consistent basic elements and structures with essential information analogous to a passport and a user-centric, digital solution through uniform methods and tools as well as instructions for use suitable for the target group (DIN/DKE/VDI, 2023). At the same time, data integrity, data security and data protection must be ensured via standardized, secure digital identities and access rights. The European Commission (2022a) also refers to the important role of standards for DPPs in Article 9 of the proposed EU Ecodesign Regulation. The DPP must be associated with a unique product identifier. The data carrier must be placed on the product, its packaging or the documentation accompanying the product in accordance with the applicable delegated acts. The data carrier and unique product identifier shall comply with the ISO/IEC 15459:2015 standard. All information contained in the product passport shall be based on open interoperable standards and shall be machine-readable, structurable and searchable. Interoperability refers to the ability of different systems, techniques or organizations to interact. The specific access rights are decided at the level of the defined product groups in the delegated acts (see Chapter 2). The EU Commission thus already recognizes that open and interoperable standards are necessary to facilitate the technical interpretation of data and to avoid cost-intensive mappings at the interfaces.

Article 10 of the planned EU Ecodesign Regulation currently provides for the following data- or digitalization-specific requirements:

- Full technical, semantic and organizational interoperability for seamless collaboration between different systems
- Free access to the product passport for consumers, economic operators, for example various manufacturers, and other relevant stakeholders on the basis of their respective access rights set out in the delegated acts
- Secure data storage and data processing
- Ensuring the authenticity, reliability and integrity of the data
- Data security and data protection

Jansen et al. (2023) identify the following technical requirements (based on the ISO/IEC 25010:2011(en) standard on system and software quality requirements and assessment) in addition to regulatory compliance:

- Functional suitability in terms of completeness, correctness as well as appropriateness and suitability for the respective sector or industry
- Security, confidentiality, and intellectual property protection via the secure exchange of DPP data between value chain actors.
- Accessibility for companies also via digital end devices if no stationary IT system is available; access controls for confidentiality and protection of intellectual property
- Interoperability
- Modularity and adaptability of required data contained in a DPP
- Availability and timeliness of data
- Portability of unique product identifiers across different information systems

4 Readiness of companies for DPPs

This chapter presents the level of readiness of companies to implement a DPP to strengthen a circular economy, both from the perspective of new product requirements and digitalization.

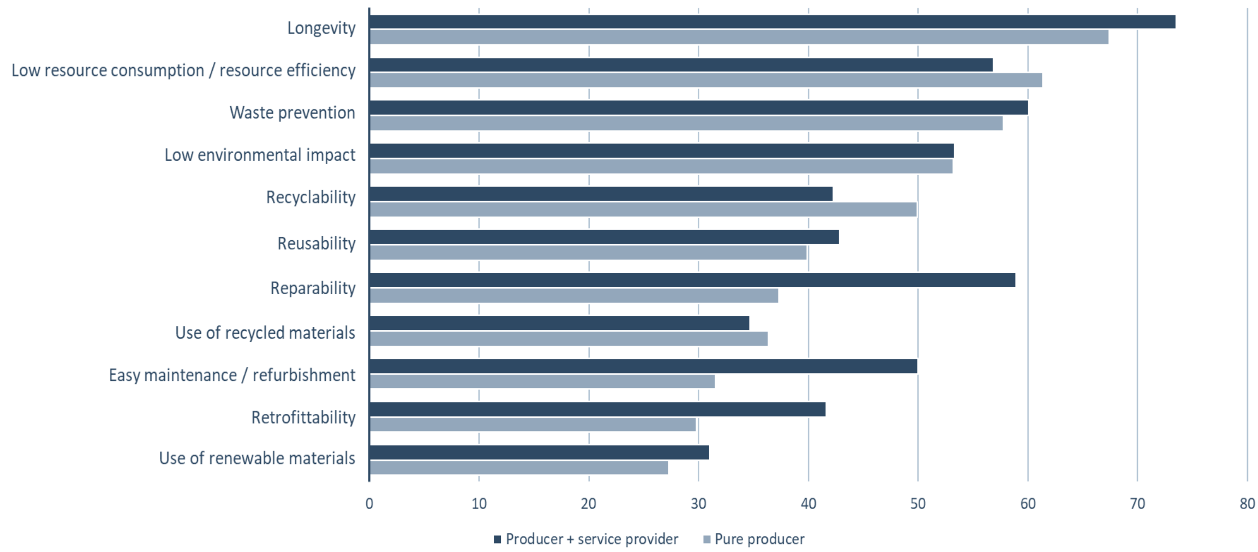
4.1 Prerequisites for the implementation of a circular product range

From a company perspective, a circular economy extends customer care throughout the entire product life cycle. Even after the sale and product use, it becomes more important for companies to return products to their value chain. Novel forms of products and services and new combinations of these are key to developing circular business models (Neligan et al., 2023). Few companies are comprehensively aligning their business model in a circular way, for example by looking at the entire life cycle, optimizing design, and/or developing new business models. The focus to date has been on energy and process optimization (Neligan et al., 2021). In addition, many companies are still in the early stages when it comes to circular business models. Neligan et al. (2022) show that so far only a few companies in the manufacturing sector are aiming for new business models, new markets or networking with players along the value chain. Yet, companies that already comprehensively pursue circular strategies are further along and more successful than companies without circular strategies (Lichtenthäler/Neligan,2023). In addition to the ecological effects, a circular economy also has economic potential. A study by Deloitte/BDI (2021) estimates the additional gross value added to be 12 billion euros per year by 2030.

Important product characteristics to improve recycling are a long durability, multiple use, reparability and a low and/or environmentally friendly use of raw materials. That is why these requirements are part of the future EU Ecodesign Regulation. As part of the 2022 summer wave of the IW-Zukunftspanel, a regular representative company survey, 1,200 companies in industry and industry-related services provided information on products and/or services that strengthen internal and cross-company circularity. Since a purely sectoral approach is insufficient, the companies were categorized based on their sales distribution into pure producers, pure service providers, or whether they produce goods and offer services (combined product-service providers). When asked about the relevance of circular product characteristics, Neligan et al. (2023) reveal a differentiated picture overall for producing companies (Figure 4-1): Some relevant product characteristics such as durability are already strongly pronounced, as they are part of the 'Made in Germany' quality promise[1] ; this is followed by aspects such as environmental impact and resource efficiency. Other characteristics such as reparability, ease of maintenance and refurbishment are not yet in focus as essential characteristics of products but are nevertheless necessary for the transformation to a true circular economy and will gain in importance in the context of the planned EU Right to Repair. Combined product-service providers also already classify these characteristics as more relevant than pure producers. They can play an important role here, as they can design products according to these criteria and at the same time offer the appropriate services.

Figure 4-1: Meeting ecodesign product requirements

Percentage of companies for which the following aspects of products are '(rather) important'



Source: IW-Zukunftspanel (2022), own calculations

[1] 'Made in Germany' which is considered synonymous with high quality, stands for products whose essential manufacturing steps take place in Germany (Salewski, 2016). The seal of approval of the 'Made in Germany' initiative is even stricter and specifies a share of the value chain (excluding raw materials) provided in Germany of 100 percent (Initiative Made in Germany, 2022).

The extension of customer support to the entire product life cycle has so far been realized primarily via product-oriented services to increase service life, such as maintenance and repair services. Usage- or result-oriented services that enable sharing and passing on have hardly played a role so far. A minority of companies are realigning or planning to realign their business model for circularity. Rather, existing products, services or their processes are being adapted in preparation for closed-loop management. About a quarter of both pure service providers and product-service providers are not only making minor adjustments to their product portfolio or processes to improve circularity but are also working on a new circular business model at the same time (Neligan et al., 2023).

Overall, the topic of the circular economy has not yet reached the mainstream of companies. Digitalization is an essential prerequisite for the circular economy, as it enables the collection, processing and evaluation of data to assess and measure the success of circularity and associated circular business models. Digital technologies make resource efficiency and circularity measurable and savings potentials usable. Greater resource efficiency can be achieved in companies through more digital efficiency measures. Few companies are adopting highly digital resource efficiency measures. Frequently used measures to optimize processes and energy consumption, as well as the use of new technologies in operations, are the most likely to exhibit a high degree of digitalization (Neligan et al., 2021). Neligan et al. (2022) also show that the introduction of additional services to a product (product-service systems) becomes easier the more data, digital networking are available and the higher the degree of digitalization of the business models. However, the use of efficiency-oriented and circular product-service systems is not yet very widespread, regardless of the business model.

4.2 Requirements for the implementation of the DPP in companies

This subsection shows that many companies in Germany do not meet the requirements for implementing the DPP yet. Companies must have a certain level of digitalization, hold and process data digitally, and also share it with other companies.

4.2.1 Degree of digitalization of the company

The level of digitalization of the company plays an important role in the implementation of the DPP, regardless of its position in the product lifecycle. Advanced in-house digitalization, reflected in particular in digital processes, is required to enable the efficient capture, storage and use of product information for the DPP. However, factors external to the company that form the framework conditions for in-house digitalization also play an important role. For example, the technical infrastructure outside the company (especially the availability of Internet with high bandwidths, but also the legal framework) should be designed in such a way that it favors the digitalization of companies.

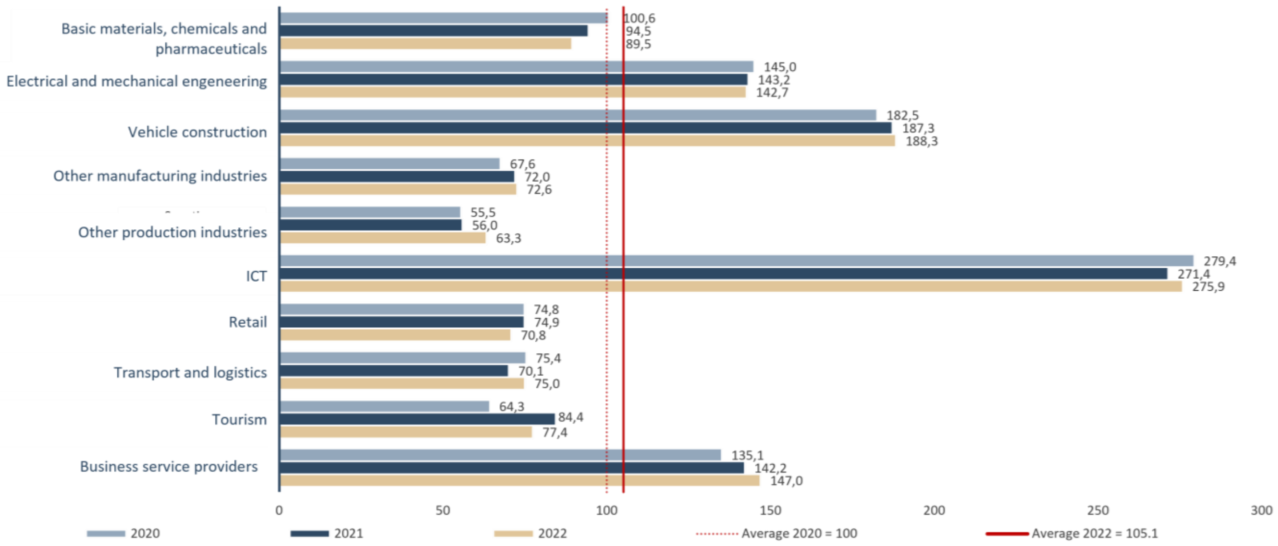
The Digitalization Index, which has been collected annually since 2020 on behalf of the German Federal Ministry for Economic Affairs and Climate Protection, demonstrates the development of digitalization at companies in ten different industry and service sector groups. To this end, it measures various digitalization indicators in five internal and five external categories. [2]

[2] Internal categories include processes, products, business models, qualification, and research and innovation activities. External categories include technical infrastructure, administrative-legal framework, society, human capital, and research and innovation landscape.

The results show that the sectors surveyed are very differently digitalized and are continuing to digitalize only gradually overall (Figure 4-2). The clear leader in all three survey years is the information and communications technology (ICT) sector, which reaches a score of 276 points in 2022 - more than 2.5 times the sector average. Vehicle construction holds its own in second place. In third place in 2022 are the business service providers, which outrank the electrical and mechanical engineering industry group. Business service providers include, for example, architecture and engineering firms, auditors and management consultants.

Figure 4-2: Digitalization of industries in Germany

Results of the Digitalization Index for the years 2022, 2021 and 2020; normalized average 2020 = 100



Source: Büchel/Engels (2022c)

The sectors of other production industries (including energy and water supply, wastewater and waste disposal, and construction), trade, other manufacturing, transport and logistics, and tourism are clearly below average. They score a maximum of 77 points. The difference with the leading industries is striking. To be able to implement DPPs, it is important that the digitalization of companies improves dynamically across all sectors and increasingly converges at a high level as far as possible. Especially for products with a high share of intermediate inputs, it is likely that companies from different industries are involved in the lifecycle of this product. If these companies have very different levels of digitalization, it is likely that the DPP cannot be filled, updated, and transmitted transparently, efficiently, and without errors.

A significant increase in the level of digitalization across all industries is not in sight so far. In some index categories, there is regression in some industries in 2022 compared with 2021. It is likely that this is due to the confluence of various crises, including the pandemic and the Ukraine war. Cost pressure and uncertainties facing companies in Germany are still particularly high. Exceptional political and economic developments are leading to exceptional behavior on the part of companies - for example, with regard to investment in digitalization. It is possible, for example, that digital advances ventured during the Corona pandemic - such as the development of a digital product - will be discontinued again due to the ongoing exceptional situation.

The European Commission's Digital Economy and Society Index (DESI) also provides information on the extent to which companies in Germany meet the requirements for implementing the DPP. Two indicators in the index category 'integration of digital technology' are particularly revealing. Only 38 percent of companies in Germany exchanged information electronically in 2021 (Electronic Information Exchange indicator; European Commission, 2022c). However, this electronic exchange of information is a key prerequisite for the DPP. The EU average is also only 38 percent. Solely 32 percent of companies in Germany (EU: 34 percent) use cloud technologies. However, these are important for storing DPP information efficiently and securely.

Overall, the data suggests that many companies in Germany are not yet digitally positioned to the extent that they could implement the DPP.

4.2.2 Handling data in the company

As part of the digitalization required to implement the DPP, it play a crucial role how companies handle data. Comprehensive data storage, efficient data management and intelligent data use are essential to collect, manage and update the information for the DPP. Companies must ensure that they have the necessary processes and technologies in place to collect, store, process, and retrieve product information as needed.

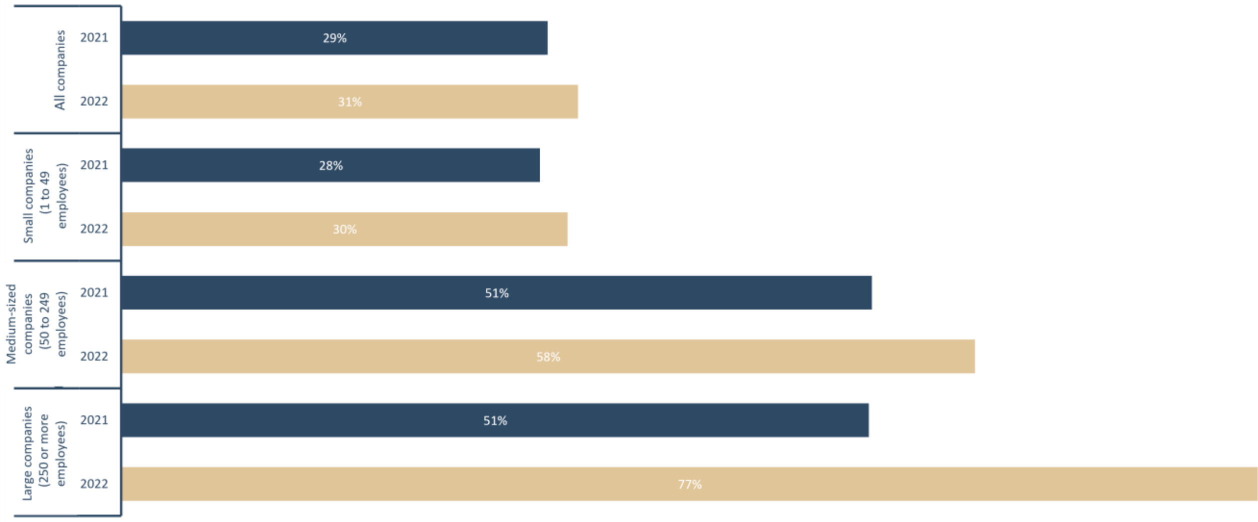
According to Büchel/Engels (2022a; 2022b), if a company is 'data economy ready', it fulfills the requirements for being able to manage data efficiently. Data economy readiness is thus an adequate indicator that can show whether companies meet the requirements for implementing the DPP. Data economy readiness therefore complements the digitalization indicators mentioned in the previous subsection.

More specifically, data economy readiness is about the extent of digital data storage, the way in which data is managed, and the diversity of data use.[3] In 2021 and 2022, more than 1,000 companies from the industrial and industry-related services sectors were representatively surveyed on their data economy readiness. In 2021, 29 percent, and in 2022, 31 percent of the companies were 'data economy ready' (Figure 4-3). It is more often the large companies with more than 250 employees that meet the requirements for being able to manage data efficiently. Among these, as many as 77 percent will be 'data economy ready' in 2022. Among companies with up to 49 employees, the figure is only 30 percent. To be able to implement the DPP in Germany, it will be necessary for many more companies to be data economy ready.

[3] Data storage is about the extent to which personnel data, product data, production and process data, customer master data, customer usage data, supplier data, financial data, and research and development data are stored digitally. Data management involves the use of data governance, the systematic and standardized collection and review of data, the existence of standardized and permanent interfaces for internal data exchange, the evaluation of data, the existence of consent management in accordance with data protection law, the existence of a data strategy, and the search for new data sources and opportunities for data use. Analysis is about the extent to which data is used for the following purposes: analysis, visualization and documentation, automation and control, forecasting of process and market developments, (further) development of products, services and business models, advertising and marketing, sale of data, and giving away data free of charge.

Figure 4-3: Data Economy Readiness

Percentage of companies in Germany that meet the requirements to manage data efficiently



Source: Büchel/Engels (2022b)

For example, a DPP cannot be implemented if some of the product data is still stored in analogue form. This is the case for 38 percent of the companies surveyed. The same applies to the establishment of data governance: Effective framework conditions are needed so that companies can manage and use data efficiently. The core task of data governance within a company is to ensure that data is made available in a controlled manner at the right time and in the right place exclusively for those authorized to access it and in the required data quality (Engels/Schäfer, 2020). In addition, data governance ensures that the company is 'compliant' regarding both external and internal specifications and guidelines for handling data. Hence, data governance is the basis for ensuring data quality and data integrity, which in turn are central to the implementation of the DPP.

To ensure a consistent and meaningful DPP, companies must ensure that their data is of high quality. This includes reviewing and cleansing existing data and using standards to capture new data. Product information must be consistent and comparable. Companies should implement mechanisms to verify data quality, for example through automated validation processes or regular audits.

In addition, data integrity is important. Companies often have various internal systems and databases in which product-relevant information is stored. To successfully implement a DPP, these data sources must be integrated. This may require the implementation of interfaces or the use of databases that bring together all relevant information. Companies must ensure that data integrity is maintained and that tampering, or falsification of product information is prevented. They must establish clear policies and procedures for accessing product information to ensure that only authorized individuals can access the data. At the same time, mechanisms for monitoring and logging data access should be implemented to ensure data security.

Ensuring data security - and also data protection - is particularly necessary because a DPP can be linked to sensitive product information. In addition to appropriate security measures, companies must comply with the legal requirements of data protection.

Data governance forms the framework for data quality, data integrity, data security and data protection. Data management puts these into practice. Accordingly, companies need clear guidelines on how to handle product information and how to record, update, store and delete it. To date many German companies are still a long way from comprehensive data governance. For example, only around 31 percent of companies in the data economy readiness survey in 2022 state that they have data governance in place (see also Büchel/Engels, 2023).

4.2.3 Data sharing with other companies

In addition to the efficient handling of data in one's own company, it is important for the implementation of the DPP that companies are able and willing to share data with other companies. So-called data sharing considers both the receipt of data from other companies or institutions and the provision of data to other companies or institutions. Both are relevant for the implementation of the DPP.

In many cases, various companies, such as suppliers, are involved in the manufacturing of a product. To implement a comprehensive DPP, it is important to work with these partners and establish a common data structure. Effective communication and coordination are essential to ensure that all relevant product information is captured, shared and updated. Companies must generally be willing to share their product information in a common data pool to enable a unified and interoperable product passport. At the same time, cross-company data sharing increases the speed of product design when pre-product characteristics are directly digitally integrated into computer-aided design and enterprise resource planning application systems without loss of information.

According to the unpublished results of the representative Data Economy Readiness survey conducted in the fall of 2022, which also forms the basis for Büchel/Engels (2023), companies in Germany that give away product data generated internally at all give away 47 percent of their product data to other companies. Conversely, companies that generally obtain product data from other companies receive an average of 52 percent of the product data used from other companies. Overall, however, only 21 percent of the 1,051 companies surveyed from industry and industry-related service providers hand over data to other companies at all (Büchel/Engels, 2023). 38 percent of companies receive data from other companies. To implement the DPP, almost all companies in Germany should share product data with other companies. Otherwise, it is not possible to implement a comprehensive DPP.

Legal concerns regarding data privacy, copyright and/or antitrust law are a reason for 64 percent of companies not to hand over any data, or not to hand over even more data. When it comes to receiving data, this plays a role for 51 percent of companies. In a similar survey of 1,002 industrial companies and industry-related service providers in fall 2021, 68 percent cited legal obstacles to sharing data in Germany (Büchel/Engels, 2022a). Of these, 88 percent had data protection concerns, and 77 percent feared unauthorized access by third parties. These concerns must be allayed by clear and also unambiguously communicated legal framework conditions if companies are to implement the DPP successfully. Data protection and security aspects play a key role, especially when data is transferred between companies. Companies must be able to ensure that they make appropriate legal and contractual arrangements to guarantee the security of the data and ensure compliance with the applicable data protection regulations (see also Fries/Scheufen, 2019, and Fries/Scheufen, 2023).

Technical obstacles to data sharing also need to be resolved. In the 2021 survey, 22 percent of companies cited technical barriers (Büchel/Engels, 2022a). Of these, 67 percent criticized a lack of standards for data sharing, 62 percent reported a lack of technical knowledge, and 47 percent saw a lack of scalability of the technical infrastructure as an obstacle. Technical concerns about data security were a reason for 46 percent of companies in the 2022 survey not to hand over data or to hand over even more data (Fraunhofer ISST, 2023). Implementation of the DPP requires interfaces between the players involved and the technical tools to enable everyone to populate and read out the DPP.

5 Possible structure of a DPP

This chapter addresses the possible structure of a DPP by presenting content-related and technical elements and standards available for their implementation. In addition, a technically directly implementable DPP prototype based on the ECLASS data standard in combination with the Asset Administration Shell (AAS) of the Industrial Digital Twin Association (IDTA) is illustrated.

5.1 General structure

The structure of a DPP must consider various content-related and technical aspects so that the Product Passport can provide information digitally along the value chain or the life cycle of products. Content aspects relate to what information is integrated into the DPP and technical aspects relate to how the whole thing is implemented.

Content structure

The content structure of the DPP must provide the framework to capture and structure all necessary information about the product. This information makes it possible to provide unique identification of the product, such as details of the manufacturer, serial number and model. In addition, the product itself and its characteristics, such as details of parts/components, appearance or functions, can be described using the information. Environmentally relevant information, such as details of the CO_2 footprint, can also be mapped transparently in this way. The scope of this information is flanked by legal requirements regarding the content requirements for the DPP (see Chapter 3.3.1). In particular, the different life cycle phases of a product result in different information and requirements for the structure of the DPP. This results in the following requirements:

- **Semantic information in the sense of master data:** The information to be recorded relates to various aspects and properties of the product and comes in part from different sources. Properties in this context are the necessary and relevant information for the product, which is required for identification, description and life cycle assessment.[4] Therefore, it is necessary to process the entire range of information, which represents, for example, numerical or alphabetical data with and without a reference quantity (for example, units).
- **Changing semantic information:** While information identifying the product is entered once and uniquely, other information changes with each production step. For example, the total weight of the product, which changes with each added part, or the total ecological footprint of the product, which changes with each production step and along the life cycle of the product.

[4] The exact definitions of characteristics or properties can be found in IEC 61360 (VDE-Verlag, 2017).

- **Growing information content:** The information content of a DPP grows along the value chain, as each manufacturer/marketer of a reportable product fills out a DPP and must take into account all information on all components of the product (for example the DPPs of the precursors).

Technical structure

Technically, the structure of the DPP is intended to support the transfer of information about a product between systems in the form of data. These are not transmitted as individual instances but bundled together. This is done in such a way that each instance has a meaning or a reference to the atomic component of the product; this is also referred to as semantic information. The DPP bundles data, transports it and thus functions as a so-called transport container from a technical point of view. The DPP should not only be viewed by people such as manufacturers, suppliers and consumers and processed according to their authorizations, but should also be readable by machines and application systems:

- **Exchange between/within companies:** Information exchange can take place between companies, but also occurs between successive production steps or areas within a company.
- **Exchange between technical systems:** The structure of the DPP must correspond to the necessary logic for communication between technical systems. This involves a variety of tasks ranging from physical bit transmission to representation of the information (Laudon et al., 2010).
- **Uniform and interoperable access:** As a transport container, the DPP is primarily responsible for segmenting the data stream, avoiding data backlog and ensuring error-free transmission (ibid.). As a result, the DPP provides uniform access to the information it contains. It is also interoperable between systems. However, information is recorded, structured and prepared differently. Technically, there are different transport containers and not everyone is suitable for transport for information structured in a certain way. Semantic information and transport containers must fit together technically, otherwise the information cannot be interpreted or can only be interpreted with effort.

Ideally, therefore, the DPP should be structured in such a way that the information that ensures clear identification of the product, a precise description of the product and its properties, and all environmentally relevant information can be entered in the DPP. In this way, the various details, changing information and growing information content can be tracked. Technically, this is favored if the DPP serves as a transport container, for example as a collection and transport object for all information, which receives, arranges and passes on the information from various internal and external transmitters.

Modular structure

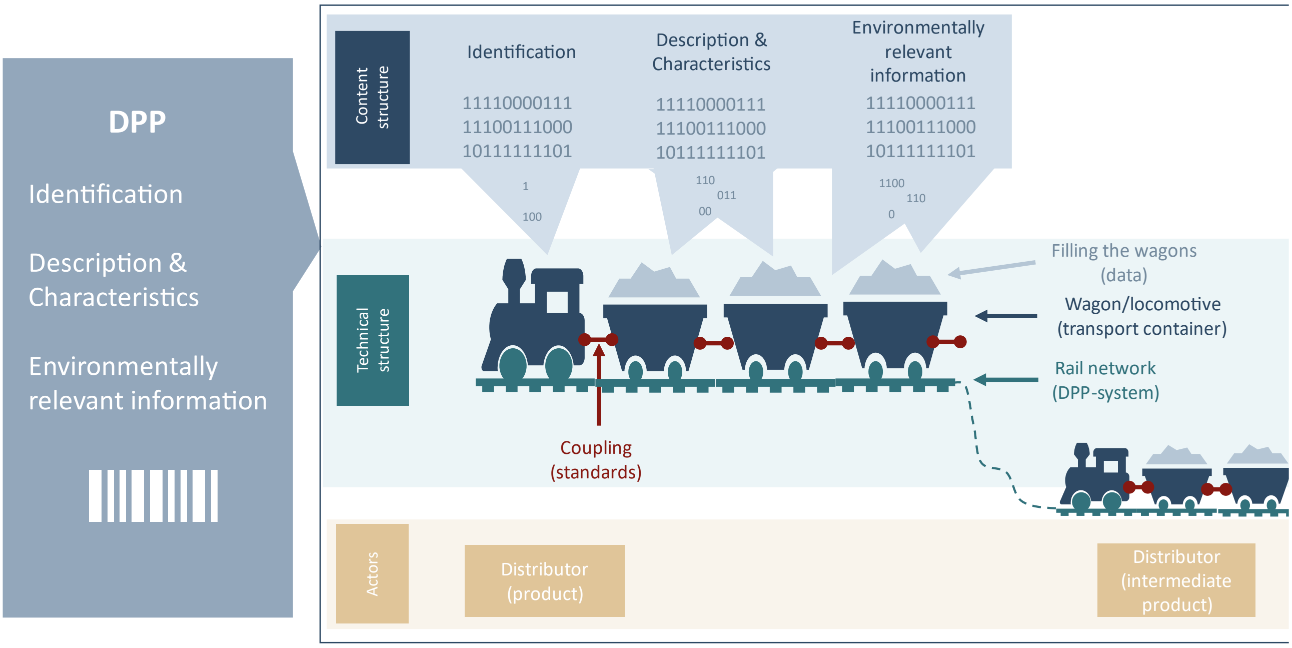
To meet the content-related and technical requirements of the DPP, a modular structure is expedient. Like a modular system, the required components can be brought together. It is essential that the individual components of the DPP also fit together. The structure of a DPP can be simplified by analogy with a train (Figure 5-1):

- **DPP:** A DPP for a product is represented by an entire train, including locomotive and wagons. This DPP is created by the distributor of the product or the train is put on the rails by him. The DPP consists of unchangeable information concerning only this one product and uniquely identifying it, represented by a locomotive and further information describing the product, its characteristics and functions, as well as information on environmentally relevant factors and the life cycle of the product, represented as wagons.

- **Transport container:** Suitable transport containers are required to be able to transport the information in the DPP. The following applies here: not every type of transport container is suitable for every type of information. Similar to the transport of goods by rail, not every wagon model is suitable for every content. For example, there are special wagons for the safe and best possible transport of gas, bulk goods or tree trunks. This logic can also be applied to the DPP.
- **DPP system:** The DPP system is represented by the rail network in this analogy. Without underlying infrastructure, no information can be transmitted.
- **Standards:** Standards form the missing link between recorded information and technical infrastructure. The information data must fit together and be able to be integrated by the distributor to be able to create a complete DPP at the end. Standards form the coupling, so to speak, between the locomotive and the individual rail cars, making the information compatible with each other and, above all, holding it together. But standards are also crucial for the DPP system: without a standardized track, the train cannot run. The analogy can be applied arbitrarily to the train in terms of standards.

Figure 5-1: Simplified representation of the structure of a DPP

What information should be stored and how can this be implemented?



Source: Own representation

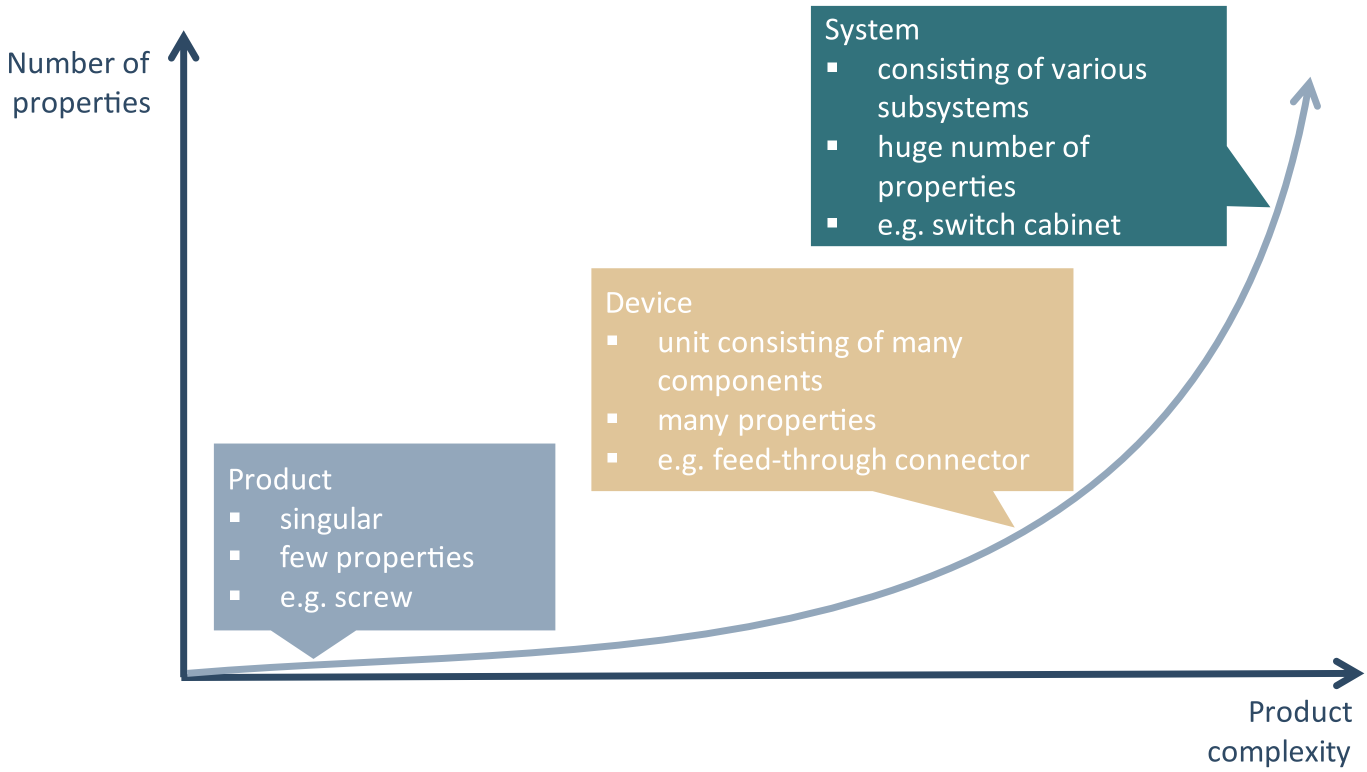
Standards for semantics and transport containers establish transparency, sustainable information and interoperability, so that interpretation costs are eliminated. They are also relevant when a distributor of a product sources precursors from other manufacturers. The information on these precursors is integrated from their DPPs into the DPP of the product. In the train analogy, this would mean that another train is integrated into the train.[5] However, this only works if the DPPs are compatible or interoperable, the trains in the analogy run with the same gauge and use the same coupling system. The DPP contains more information, or the train becomes longer, the higher the number of individual components or wagons.

Mastering complexity

The amount of information to be processed in a DPP for a product depends in particular on how complex its production is. In the case of a simple product such as a screw, it can be assumed that it consists of few components and undergoes only a few production steps. Thus, it is to be expected that the DPP of this product also contains only a few properties. As the complexity of a product increases, for example in the case of devices such as a fuse or systems such as a control cabinet, which in turn are made up of subproducts or subsystems, the number of components it consists of also increases. As a result, the DPP must capture more information and contains a large number of properties (Figure 5-2). In Chapter 5.3 provides an example of this based on the ECLASS data standard.

Figure 5-2: Number of properties of a product contained in the DPP

Number of properties increases with complexity of the product



Source: Own representation

In line with Germany's economic structure, local DPPs have to meet complex requirements. In terms of gross value added, the German economy is dominated by services (69 percent), but German industry, with its typically complex products, is still relatively important, especially in comparison with many other European

[5] In practice, whether this train is integrated including the locomotive or only the wagons depends on the process, the lifecycle phase and the product.

countries. The manufacturing industry (excluding construction) still plays an important role with 23 percent (2022). Every fifth euro in Germany is generated in the manufacturing sector alone (Destatis, 2023). The complexity of products increases when they consist of a large number of inputs (manufactured goods, services, raw materials and energy). In the manufacturing sector in Germany, the share of intermediate inputs was 69 percent in 2022 (Destatis, 2023; IW Consult, 2023). Interconnectedness via intermediate inputs means that the DPP of a final product consists of many individual DPPs.

Performance

Depending on the industry and the complexity of the products, there are different requirements for the DPP or the performance of the DPP system. More powerful systems and information models are important for industrial purposes and highly complex products, but are useless and too bureaucratic for other industries, as they become quite complex and require technical prerequisites that are not available everywhere. An example of a simple DPP system is a QR code-based label, which might suffice in certain industries, such as textiles, but is not suitable for data transport for more complex products. It can therefore be assumed that the structure of a DPP can vary from industry to industry, even if the same technical and content requirements exist.

5.2 Available standards

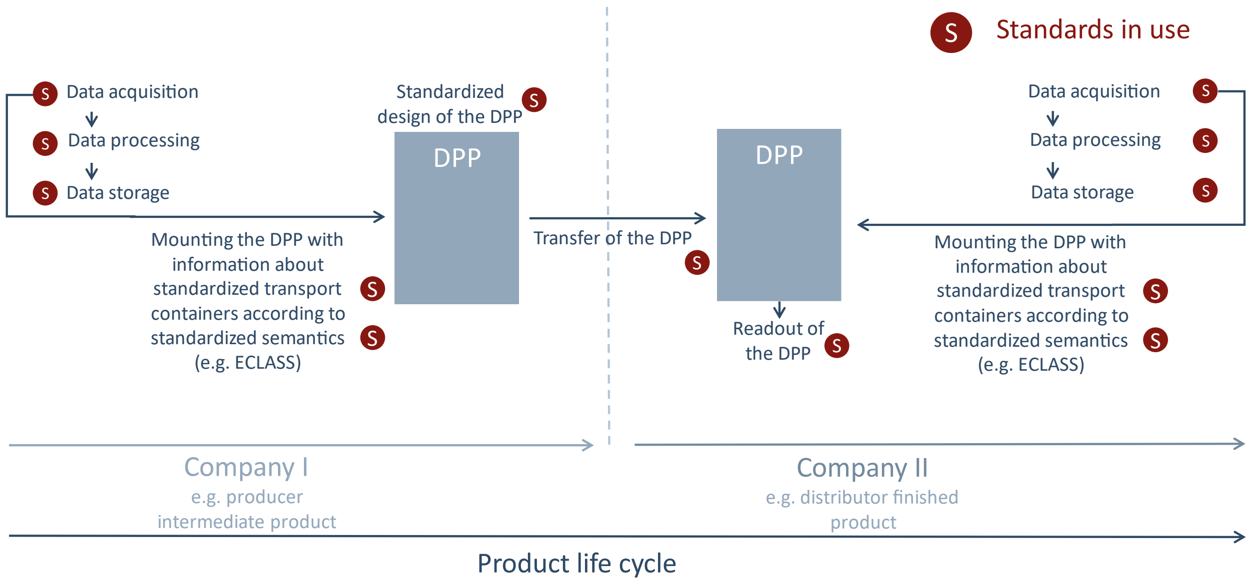
To ensure that all stakeholders involved can view and add to the necessary information about the product, it is imperative to have a structured and, above all, standardized way of collecting, storing and passing on information. A standard is a written statement that presents requirements, specifications, guidelines or characteristics. Its coherent application ensures that materials, products, processes and services are suitable for their intended use and can be applied accordingly (ISO, 2017). Therefore, data standards are an important basis for building DPPs. Global standards are a useful tool (GS1 Germany, 2023). Under the EU Ecodesign Regulation, the European Commission plans that all information contained in the DPP should be based on open standards in an interoperable format that must be machine-readable, structured, and searchable (European Commission, 2022a, Article 9d).

The complexity of the DPP concept is once again evident in the standards. The balancing act between cross-sector and cross-system, but nevertheless specific specifications requires a high degree of coordination (DIN/DE/VDI, 2023). Therefore, it is necessary to deal not only with the different requirements, but also with existing standards for the corresponding product groups or sector (groups). While industry-specific solutions can achieve faster standardization within the industry, comparability across different industries is no longer possible. Cross-industry standards offer the advantage of ensuring interoperability rather at the end of the value chain. It would therefore make sense for the DPP to implement standardized information collection across industries. In addition, the phase of the product life cycle as well as the process stage within the data transmission influence the required standards, since, for example, standards in connection with disposal only become relevant at the end of the product life cycle.

A schematic overview of the multitude of interfaces of standards with a DPP gives Figure 5-3. Standards are required at every step in the collection of information from acquisition, storage, processing, to assembly, appearance, transmission and readout of the DPP. Among other things, standards regulate the handling of product-related data in the DPP. They provide uniform designations and documentation requirements. In this way, information losses at the interfaces within and between companies can be avoided and a uniform understanding of the information can be ensured (Engels, 2017). Data standards above all facilitate the exchange of data between companies, which is essential in the context of the DPP. Predefined structures, such as those provided by the ECLASS data standard, optimize the business processes associated with data exchange by ensuring standardized semantics. All players along the value chain can benefit from this (ibid.).

Figure 5-3: Schematic illustration of the relevance of standards for the DPP.

Information collection along the life cycle axis of a product



Source: Own representation

(Data) standards are also important for the transformation to a circular economy. Thinking and doing business in cycles requires a much greater willingness to cooperate and communicate from all the players involved along the value chain than in a linear economy. Circular business models need networking and collaboration, because only through the combination of individual circular business models does an overall circular economy become established (Fluchs et al., 2022). To preserve the value of a product for as long as possible, not only manufacturers must take on more responsibility, but also the coordination between the actors must increase. The transition to a circular economy is therefore not only associated with a radical transformation of entire value chains, but also with increasing demands on the management of complexity. Standardized information collection is what makes it possible to implement repairs, recycling or resource conservation across the board in the first place. Norms and standards therefore not only simplify processes, but also have a positive effect on the economic efficiency of circular strategies (DIN/DKE/VDI, 2023). At the same time, competitive advantages can also be expected for companies operating in a circular manner compared to linear-oriented companies (see also Chapter 4.1).

For the implementation of the structure of a DPP described in this report (Chapter 5.1), standards from the following three areas are particularly relevant:

- **Data standards for identification**. They enable clear and overlap-free marking of products. For this purpose, type plates or QR codes already exist in industry that refer to identifying labels.

- **Data standards for classification and description**. They provide a uniform description of products and their characteristics for their comparison. The classification provides a kind of commodity group technical classification of the product. The description shows the product-specific characteristics and features of the product. Examples of this type of data standard are the ECLASS master data standard, ETIM[6] , a standard for the exchange of product data of electronic products or the United Nations Standard Products and Services Code (UNSPSC)[7] , a standard for e-procurement.

- **Standards for the collection of environmentally relevant information**. They enable reliable and uniform details of required environmental information. This includes the specification of comparable emissions such as CO_2 and other greenhouse gases along the product life cycle, which follow standardized calculation methods. In addition, information on disposal is described, which can be found in the product manuals. In Germany, for example, DIN ISO 14064-1 and the Corporate Standard of the Greenhouse Gas Protocol are widely used for the recording of greenhouse gases by companies (WBCSD/WRI, 2004).

The specific standards that must be met depend on the industry or the product. Formalized requirements are recorded in the form of standards. Standards are generally recognized and binding rules and benchmarks that are used to evaluate the quality, performance and safety of something. Since the DPP is discussed as an instrument for promoting a circular economy, the additional standardization requirements that arise with regard to meeting the demands of a circular economy are also examined. These are identified in Germany as part of the standardization roadmap for various sectors. To consider the entire product life cycle, this process is based on the strategies for a circular economy developed by Potting et al. (2017) and Kirchherr et al. (2017), the so-called 9R strategies[8] . Regarding the DPP, normative bases are generally required 'for the structure for grouping product-specific content and its presentation' (DIN/DKE/VDI, 2023). However, national and international standardization institutes such as DIN, DKE/VDE, CEN, CENELEC and ultimately ISO and IEC standards are being developed and published, but so far no digital standards to fulfill a DPP or digital data exchange.

The transformation to a circular economy brings with it many standardization needs. The implications that arise from this for the DPP are currently still undetermined. The requirements can nevertheless be implemented at an abstract level. By creating an infrastructure (DPP system) for the DPP that is flexible enough to accommodate cross-sector and cross-system information and at the same time specific enough to comply with concrete requirements for relevant sectors, standards and norms can be integrated into the structure of the DPP. In this regard, the proposal for the EU Ecodesign Regulation refers, among other things, to the GTIN (Global Trade Identification Number) according to the ISO/IEC 15459-6 standard or an equivalent identifier of products or parts thereof.

5.3 DPP prototype based on the ECLASS data standard

The present DPP prototype addresses the need of German industry to map complex interrelationships in the value creation of products in a DPP (see also Chapter 5.1). The presented DPP is therefore especially

---

[6] The ETIM standard is the international standard for the classification of technical products for B2B product data exchange. Originally, ETIM stood for "Electrotechnical Information Model". Today, the 'E' in ETIM no longer represents a concrete term, as it has been extended to other industries and is used worldwide. (ETIM Germany, n.d.)

[7] The UNSPSC is a classification system of merchandise management that is used especially in e-commerce in the American area (UNSPSC, 2023). However, UNSPSC lacks semantic features for description.

[8] R0 Refuse, R1 Rethink, R2 Reduce, R3 Reuse, R4 Repair, R5 Refurbish, R6 Remanufacture, R7 Repurpose, R8 Recycle, and R9 Recover (Potting et al., 2017; Kirchherr et al., 2017).

technically designed to have robust characteristics to capture required content and the given complexity of product properties. The design of the prototype is based in particular on matching the content and technical requirements with a suitable data standard. This iterative process requires addressing the following questions:

- Which **data standard** is both suitable for a uniform semantics of information collection in the DPP and for its technical implementation?
- What **content** needs to be captured to enable unique identification, description and life cycle assessment for the product?
- What is the **modular technical structure**, especially with regard to the transport container for data transport and access authorizations to information?

A concrete proposal for a technically directly implementable DPP prototype based on the ECLASS data standard in combination with the ASS explained:

Data standard

One data standard that meets the above requirements is ECLASS. It is a standard for the classification and unique description of products and services (ECLASS, 2023). Compared to other data standards such as the Common Procurement Vocabulary (CPV) of the EU[9] or the UNSPSC, ECLASS is applied globally. Moreover, ECLASS is applicable across industries, unlike, for example, the ETIM data standard, which has to be cut to the electrical industry. The use of such a data standard ensures the uniform preparation of product data, the possibility of translating the information into other languages and the digital exchange on an international level. The ECLASS Standard appears to be particularly suitable for meeting the requirements of the DPP, as it also provides a uniform data structure, the use of unique codes, the annual adaptation of the data standard to the requirements of different industries, markets and product innovations. In addition, human-readable standards from ISO and IEC are implemented in ECLASS in a semantically machine-interpretable way. This is important for the European manufacturing industry to ensure that their products placed on the market conform to the standards.

Contents

It has not yet been decided which properties a DPP must compulsorily record. However, the ECLASS Standard covers various industries as well as product and commodity groups. The prerequisite for a broad field of application is therefore given. The ECLASS Standard primarily provides a *structuring principle for* the information to be recorded in the DPP.

Properties capture the concrete product attributes, such as width, height, etc., some of which are very product-specific: For example, every product has a weight, but the rated voltage is not relevant for every product. As a result, certain attributes according to the ECLASS classification are only applicable for certain product groups. Depending on the product for which a DPP is created, the properties covered are therefore different and no standard catalog can be processed. For the definition of these attributes, standards, for example DIN,

---

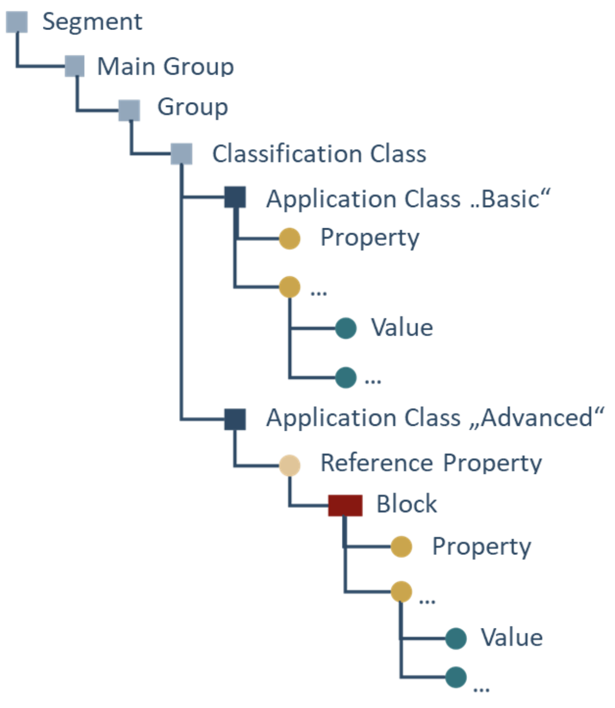
[9] The CPV standard is the basis for the EU's common vocabulary for public contracts and serves to provide a uniform description of contract items (European Commission, 2008).

CEN, ISO as well as DKE/IEC, provide orientation for users and thus also for the DPP. Furthermore, the industry knows which product-specific properties are relevant. Most recently, both European and Asian industry have developed further properties for accurate product descriptions directly from the product design and standardized them in ECLASS.

The ECLASS Standard is hierarchically structured and comprises various elements (Figure 5-4). The classes or product groups allow an initial product grouping and lead to a first order. This order ranges from the coarse, for example the assignment of an industry, to the fine, for example the designation of a specific product. The classification initially assigns products via the four levels of subject area, main group, group and classification class, before the actual properties of the product are listed.

Figure 5-4: Structure of the ECLASS Standard

Hierarchical structure with four classification levels



Source: ECLASS e.V., 2023

Modular technical structure

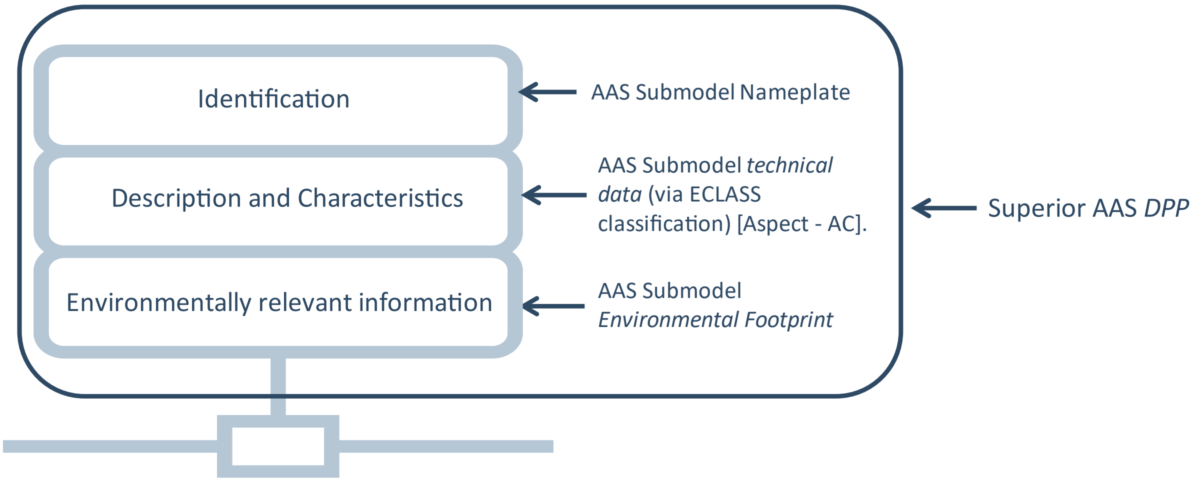
The choice of transport container has a decisive influence on the design of the modular structure of the DPP. The required scope of the DPP (identification, description, life cycle assessment) can be fulfilled with ECLASS, but can only be implemented technically if open transport containers are used for data exchange.

Transport containers: Experience has shown that robust transport containers such as the Asset Administration Shell (AAS) are ideal for the digital image of complex products in industrial sectors, especially when large volumes of data have to be transported. The AAS is standardized by the Industrial Digital Twin Association (IDTA); it is a consortium standard (IDTA, n.d.). This means that it is currently still being developed by a limited group of contributors and has not yet been transferred to standards organizations. Basically, the AAS enables the implementation of a 'digital twin' for Industry 4.0, for example a digital image of the product. In addition to the AAS, many proprietary containers from individual software manufacturers exist. The AAS is suitable for the present DPP prototype because it is an open transport container and allows a modular structure. In addition, the entire life cycle of products, devices, and machines can be covered, and the interoperability that is important in the DPP can be established across companies (BMWK, 2022; Plattform Industrie 4.0, 2019). The structure of an AAS is based on DIN EN IEC 63278-1 (structure of the Asset Administration Shell for industrial applications) and functions similarly to a modular system. An overarching AAS contains various submodels, which in turn bundle the properties for a specific aspect of the product.

A DPP could be designed using the ECLASS Standard as follows (Figure 5-5). A higher-level AAS is created for the DPP. This is filled with three submodels that bundle and provide the information required and relevant for the product for identification, description and life cycle assessment.

Figure 5-5: Modular structure of the DPP with ECLASS

DPP with three submodels of an AAS



Source: Own representation based on ECLASS e.V. (2023)

Depending on the product group, the submodels comprise a predefined catalogue of properties that contains the information that must be recorded for a complete DPP for a product, but the specific attributes differ from product to product. Table 5-1 provides an overview of possible properties that submodels can capture for a product.

Table 5-1: Possible contents of a DPP with ECLASS semantics

Identification, description and properties as well as environmentally relevant information as submodels of the AAS.

Submodel	ECLASS Designation Submodel	Properties
Identification	AAS Submodel Nameplate	Manufacturer name
		Address
		Serial number
		Year of manufacture
		Markings
		Number of markings
		Markings
		Label name
		...
Description and characteristics	AAS Submodel *technical data* (via ECLASS classification) [Aspect - AC].	Size
		Form
		Material
		Functions
		...
Environmentally relevant information	AAS Submodel *Environmental Footprint*	Carbon footprint
		Number of PCF methods
		Number of TCF methods
		Product Carbon Footprint (PCF)
		PCF calculation method
		PCF CO2eq
		PCF reference value for the calculation
		PCF quantity specification for the calculation
		PCF life cycle phase
		...

TCF: Transport Carbon Footprint; PCF: Product Carbon Footprint

Source: ECLASS e.V. (2023)

Access authorizations

In addition, the access authorization to the information (private/public) can be defined via the submodels (BMWK, 2022; VDE Verlag, 2022). Table 5-2 indicates which allocation underlies the presented DPP prototype. In particular, the aim is to protect competition-relevant information and trade secrets, while at the same time making all necessary information available to actors along the value chain of products.

Table 5-2: Access authorizations of the DPP prototype

Overview of the access authorizations of the submodels

	Public (open to the public)	**Private** (protected, by authorization)
Identification	Information for the unique identification of the product (manufacturer, product, year of manufacture, location)	
Description and characteristics of a product	Properties describing shape, size and function	Properties containing information relevant to competition (e.g. patent information, prescriptions, consumption data)
Environmentally relevant information on the product life cycle	Regulatory information	Industry-requested information (e.g. information on data quality, internal scorings)

Source: Own representation

Visual examples

To illustrate the extent of the complexity and scope of the properties to be captured, two illustrative examples based on ECLASS follow (see also Table 7-1 and Table 7-2 in the appendix):

- **Screw:** A commercially available screw serves as an example of a product with few properties. Table 7-1 contains an excerpt of the properties to be recorded. The *nameplate* submodel records all information about the manufacturer of the product. For the description of the screw and the representation of its characteristics, mainly appearance, size and material are described. This is captured in the *technical data* submodel via the existing ECLASS application class. In this example, the collection of environmentally relevant information represents a CO_2 footprint calculated on the basis of ISO 14044. The calculation is performed for the life cycle stage ‘manufacturing’.
- **Feed-through terminal block:** The second example shows a DPP for a feed-through terminal block (also known as a ‘fuse’). A feed-through modular terminal is a product that, unlike the screw, is made up of many components with different characteristics. This results in a large number of properties that must be recorded in a DPP. The properties themselves are determined according to the industrial requirements intended for this product class and, in parts, according to the standards (DIN, EN, ISO, DKE/IEC). Table 7-2 contains an excerpt from the prototype of the DPP for a feed-through modular terminal block, which illustrates the scope of the properties to be recorded.

Challenges

Currently, the properties contained in the submodels are not yet free of overlaps. Parts of the environmentally relevant information are already included in the submodel that captures the description and characteristics of the product. However, because of new obligations for products under the proposed EU Ecodesign Regulation, the information, including material characteristics, will take on a new significance and will require its own submodel. This does not initially pose a problem in the first phase of a prototype development, but it does reveal relevant starting points for further development.

According to the Circular Economy Standardization Roadmap of DIN/DKE/VDI (2023), it is not clear how data that is already publicly accessible in databases is to be integrated or linked in the DPP so that multiple provision of information at different points is avoided. Clarification is also needed on how to integrate more extensive information from upstream products or downstream data that arise during the life cycle. ECLASS can bundle information in such a way that multiple provision can be avoided and the growing need for information in the life cycle can be considered. Currently, there are various public databases for product information, some of which contain overlapping information. The public sector has a duty to better bundle this information.

Product information can be exchanged along the value chain, as ECLASS data can be used compatibly with most product management systems in companies, for example SAP. Key advantages of ECLASS are:

- Interoperability between companies and systems is given.
- The modular system allows different transport container formats to be selected and submodels to be tailored to a DPP.
- The requirements of the European industry are met.
- Conformity with standards is given and semantically implemented.
- The very broad, but at the same time detailed and specific set-up of the information structuring in relation to the application fields and the simple handling enable a practical solution.
- The regular updates provide an advantage over other systems.

6 Conclusion

The planned EU Ecodesign Regulation for sustainable products will set the course for products to be more closely aligned with circular economy principles in the future. Knowledge of both the upstream stages of the value chain and the effects of one's own actions on downstream stages of the value chain is essential for this. The DPP is an important enabler, as it provides the necessary data and networking opportunities. The aim of the DPP is to ensure better transparency along the industrial value chain by digitally storing product-specific information. However, the DPP as such does not ensure lower environmental impacts from products. These depend primarily on their design and the choice of materials (European Court of Auditors, 2023).

The current debate lacks a concrete proposal for the implementation of a DPP, although proposals exist regarding the requirements for products (ecodesign) as well as data standards for the collection of information about the products.

Many companies in Germany also do not meet the requirements for implementing a DPP yet, including sufficient digitalization and comprehensive data management within the company. With this sobering corporate reality, the task is to find an implementable solution for a DPP. It is important to keep in mind that manufacturers are the primary source of information for DPPs, and therefore they should perceive a DPP approach as a benefit rather than a burden (Plociennika et al., 2022). This report outlines a DPP based on the ECLASS data standard, taking into account the already known elementary building blocks for the envisaged European solution.

Implementing a DPP is an iterative process. Companies should establish a feedback system to collect customer and user experiences and incorporate them into the further development of the DPP. They should also continuously monitor technological developments and regulatory requirements and adapt the DPP accordingly. ECLASS can do this as well via its regular updates. For successful implementation, however, not only must the technical requirements be met, but employees must have the necessary skills and knowledge. Organizations should provide training to ensure employees are familiar with the necessary tools, processes and best practices. These can include, for example, training on data management, data protection guidelines or the use of specific software solutions.

One of the new mandatory and fundamental requirements is that European DPPs should be fully interoperable regarding the technical, semantic and organizational aspects of end-to-end communication and data transmission. The net benefit of a DPP will strongly depend on the implementation costs. From a macro perspective, the DPP will bring far-reaching benefits by increasing market transparency, improving efficiency, enabling new business models, and providing greater product and counterfeit security (Deloitte, 2022). Existing global open data standards for supply chains provide a good foundation for DPP implementation, as it minimizes costs and enables rapid time to market. At the same time, manufacturers and industrial users of DPPs are familiar with known standards and there are opportunities for increased transparency for consumers, potential for data integration, and data interoperability. In contrast, competing proprietary standards would result in significantly higher costs for development and maintenance as well as integration of different data. IW Consult is presently calculating the cost reduction potential and macroeconomic impact of an established standard such as ECLASS in a typical lifecycle process. This study will be published in the fall of 2023.

7 Appendix

Table 7-1: Example DPP for a screw

Extract from the DPP for a screw with ECLASS (example data without authenticity reference)

Submodel	Properties	Value	Unit
Identification AAS Submodel *Nameplate*	Manufacturer name	*IW Köln*	
	Manufacturer product designation	*Example screw*	
	▶Address	*Address*	
	Serial number	*12345*	
	Year of manufacture	*2023*	
	▼Markings		
	Number of markings	*1*	
	▼Marking		
	Marking name	*TÜV sign*	
	...		
Description and Characteristics AAS Submodel *technical data* (via ECLASS classification) [Aspect - AC].	Width of head (fastener)	*12,0*	*Millimeter*
	Length of head (fastener)	*12,0*	*Millimeter*
	Head diameter	*12,0*	*Millimeter*
	Head details	*Milling ribs*	*Millimeter*
	Flange/collar diameter	*3,0*	*Millimeter*
	Sphere radius	*2,0*	*Millimeter*
	Height of head over all	*7,0*	*Millimeter*
	Head form	*Hexagon*	*Millimeter*
	Thread length of nut size	*80,0*	*Millimeter*
	Thread length of screw side	*77,0*	*Millimeter*
	Nominal length (inch)	*314*	*Inch*
	...		
Environmentally relevant information AAS Submodel *Environmental Footprint*	▼Carbon Footprint		
	Number of PCF methods	*1*	
	▼Carbon Footprint (PCF)		
	PCF calculation method	*ISO 14044*	
	PCF CO2eq	*8,0*	*Kilogram*
	PCF reference value for the calculation	*Kg*	
	PCF quantity specification for the calculation	*10,0*	
	PCF life cycle phase	*A3 - Production*	
	...		

PCF: Product Carbon Footprint

Source: ECLASS e.V. (2023)

Table 7-2: Example DPP for a through terminal block (fuse)

Excerpt from the DPP for a through terminal block with ECLASS (example data without authenticity reference)

Submodel	Properties	Value	Unit
Identification AAS Submodel *Nameplate* [nameplate]	Manufacturer name	*IW Cologne*	
	Manufacturer product designation	*Exampleterminal block*	
	▶Address	*Address*	
	Serial number	*12345*	
	Year of manufacture	*2023*	
	...		
Description and Characteristics AAS Submodel *technical data* (via ECLASS classification) [Aspect - AC].	Rated voltage	*800*	*Volt*
	Rated current [In] for power loss indication	*32*	*Amps*
	Min. line cross section, rigid	*0,2*	*Square millimeter*
	Number of contact points per level	*2*	
	Number of levels	*1*	
	Combustibility class	*V2*	
	Levels internally bridged	*No*	
	Closing plate required	*No*	
	Material of insulation	*Polyamide*	
	Connection type	*Screw connection*	
	Connection type 2	*Screw connection*	
	Min. connectable conductor cross-section fine wire with conductor end sleeve	*0,25*	*Square millimeter*
	min. Operating temperature	*-60*	*Degree Celsius*
	max. operating temperature	*105*	*Degree Celsius*
	Width of spacing	*6,20*	*Millimeter*
	height at lowest possible mounting	*47*	*Millimeter*
	Color	*Black-white-green*	
	Length	*42,5*	*Millimeter*
	Assembly type	*Top-hat rail TH35G rail G32*	
	Mechanical and electrical design (s)	*Mechanical and electrical design (s)*	
	Construction general	*Construction general*	
	Size dimension	*Size Dimension*	
	type of enveloping body	*Envelope cuboid*	
	Width	*6,15*	*Millimeter*
	Height	*42,5*	*Millimeter*
	Depth	*45,8*	*Millimeter*
	Net weight	*0,0103*	*Kilogram*
	Mounting design	*Assembly*	
	Number of versions of the housing parts	*0*	
	Max. connectable conductor cross-section fine wire with conductor end sleeve	*4*	*Square millimeter*
	Min. connectable conductor cross-section multiple wire	*2,50*	*Square millimeter*
	...		
Environmentally relevant information AAS Submodel *Environmental Footprint*	▼Carbon Footprint		
	...		

CAx: all computer aided application systems and processes such as Computer Aided Design (CAD), Manufacturing (CAM), Engineering (CAE), EVM: Electromagnetic Compatibility, among others.

Source: ECLASS e.V., 2023

List of tables

List of Figures

Bibliography

Büchel, Jan / Engels, Barbara, 2023, Data Sharing in Deutschland, IW Trends, Nr. 2, Köln

Büchel, Jan / Engels, Barbara, 2022a, Datenbewirtschaftung von Unternehmen in Deutschland, IW-Trends, Nr. 1, Köln

Büchel, Jan / Engels, Barbara, 2022b, Viele Unternehmen sind nicht bereit für die Datenwirtschaft, IW-Kurzbericht Nr. 96, Köln

Büchel, Jan / Engels, Barbara, 2022c, Digitalisierung der Wirtschaft in Deutschland – Digitalisierungsindex 2022, Kurzfassung der Ergebnisse des Digitalisierungsindex im Rahmen des Projekts „Entwicklung und Messung der Digitalisierung der Wirtschaft am Standort Deutschland“, https://www.de.digital/DIGITAL/Redaktion/DE/Digitalisierungsindex/Publikationen/publikation-digitalisierungsindex-2022-kurzfassung.pdf?__blob=publicationFile&v=1 [1.9.2023]

BMUV, o. J. Auf einen Klick: Produktpass, Lückenloser Lebenslauf, https://www.bmuv.de/digitalagenda/auf-einen-klick [14.7.2023]

BMUV, 2023a, EU-Staaten stimmen für Digitalen Produktpass und gegen Vernichtung von Neuwaren, Pressemitteilung, 22.05.2023, https://www.bmuv.de/pressemitteilung/eu-staaten-stimmen-fuer-digitalen-produktpass-und-gegen-vernichtung-von-neuwaren [24.7.2023]

BMUV, 2023b, Die Nationale Kreislaufwirtschaftsstrategie, Grundlagen für einen Prozess zur Transformation hin zu einer zirkulären Wirtschaft, https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/nkws_grundlagen_bf.pdf [24.7.2023]

BMUV, 2023c, Aus der Praxis: EPD, Gläserner Beton, https://www.bmuv.de/digitalagenda/aus-der-praxis [24.7.2023]

BMUV – Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, 2022, Smartphones und Tablets sind zukünftig leichter reparierbar, Pressemitteilung am 18.11.2022, https://www.bmuv.de/pressemitteilung/smartphones-und-tablets-sind-zukuenftig-leichter-reparierbar [30.11.2022]

BMUV – Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, 2020, Umweltpolitische Digitalagenda, https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Digitalisierung/digitalagenda_bf.pdf [14.7.2023]

BMWK – Bundesministerium für Wirtschaft und Klimaschutz, 2022, Plattform Industrie 4.0, Specification: Details of the Asset Administration Shell, Part 1 – The exchange of information between partners in the value chain of Industrie 4.0 (Version 3.0RC02), https://www.plattform-i40.de/IP/Redaktion/DE/Downloads/Publikation/Details_of_the_Asset_Administration_Shell_Part1_V3.pdf?__blob=publicationFile&v=1 [31.7.2023]

BDI – Bundesverband der Deutscher Industrie e.V, 2023. 9 CE Policy Update, Internes Dokument

Circle Economy, 2023, The circularity gap report 2023, Amsterdam, https://www.circularity-gap.world/2023# [14.7.2023]

Cirpass, 2022, The Digital Product Passport as defined in the Proposal for Eco-design for Sustainable Product Regulation (ESPR), https://cirpassproject.eu/wp-content/uploads/2023/03/ESPR-short-summary-Final.pdf [14.7.2023]

Deloitte / BDI – Bundesverband der Deutscher Industrie e.V., 2021, Zirkuläre Wirtschaft. Herausforderungen und Chancen für den Industriestandort Deutschland, Studie, https://www2.deloitte.com/de/de/pages/sustainability1/articles/zirkulaere-wirtschaft-studie.html [9.5.2022]

Deloitte, 2022. Impact of international, open standards on circularity in Europe, https://www2.deloitte.com/pl/pl/pages/zarzadzania-procesami-i-strategiczne/articles/Impact-of-GS1-standards-on-circularity-in-Europe.html [30.7.2023]

Demary, Vera, 2022, Der Data Act: Welchen Rahmen Unternehmen für Data Sharing wirklich brauchen, IW-Policy Paper, Nr. 2, Köln

Destatis, 2023, Volkswirtschaftliche Gesamtrechnungen, Inlandsproduktionsberechnung, detaillierte Jahresergebnisse, 2022, Stand: 8. März 2023

DGNP - Deutsche Gesellschaft für Nachhaltiges Bauen, 2023, Der Gebäuderessourcenpass der DGNB, https://www.dgnb.de/de/nachhaltiges-bauen/zirkulaeres-bauen/gebaeuderessourcenpass [14.7.2023]

DIN – DIN e.V. / DKE – Deutsche Kommission Elektrotechnik, Elektronik und Informationstechnik / VDI – Verein Deutscher Ingenieure, 2023, Deutsche Normungsroadmap Circular Economy, https://www.din.de/resource/blob/892606/06b0b608640aaddd63e5dae105ca77d8/normungsroadmap-circular-economy-data.pdf [14.7.2023]

ECLASS e.V., 2023, Guidelines and Basic Principles, https://eclass.eu/fileadmin/Redaktion/pdf-Dateien/Wiki/Guidelines_and_basic_principles/Guidelines_and_Basic_Principles_ECLASS.pdf [10.8.2023]

Engels, Barbara / Schäfer, Christin, 2020, Data Governance in deutschen Unternehmen, Gutachten im Rahmen des Projektes DEMAND-DATA ECONOMICS AND MANAGEMENT OF DATA-DRIVEN BUSINESS, Köln

Engels, Barbara, 2017, Bedeutung von Standards für die digitale Transformation – Befunde auf Basis des IW-Zukunftspanels, IW-Trends, Nr. 2, Köln

ETIM Deutschland e. V., o. J., ETIM – der internationale Standard für den B2B-Produktdaten-Austausch https://etim.de/ [7.9.2023]

Europäische Kommission, 2023, Kampf gegen Wegwerfgesellschaft: Kommission will Recht auf Reparatur, Pressmitteilung, 22. März 2023, https://germany.representation.ec.europa.eu/news/kampf-gegen-wegwerfgesellschaft-kommission-will-recht-auf-reparatur-2023-03-22_de [26.7.2023]

Europäische Kommission, 2022a, Vorschlag für eine Verordnung des Europäischen Parlaments und des Rates zur Schaffung eines Rahmens für die Festlegung von Ökodesign-Anforderungen für nachhaltige Produkte und zur Aufhebung der Richtlinie 2009/125/EG, 30.03.2022, COM(2022) 142 final, https://eur-lex.europa.eu/resource.html?uri=cellar:bb8539b7-b1b5-11ec-9d96-01aa75ed71a1.0003.02/DOC_1&format=PDF [24.7.2023]

Europäische Kommission, 2022b, EU-Strategie für nachhaltige und kreislauffähige Textilien, Mitteilung der Kommission an das Europäische Parlament, den Rat, den europäischen Wirtschafts- und Sozialausschuss und den Ausschuss der Regionen, COM(2022) 141 final, https://eur-lex.europa.eu/resource.html?uri=cellar:9d2e47d1-b0f3-11ec-83e1-01aa75ed71a1.0013.02/DOC_1&format=PDF [26.7.2023]

Europäische Kommission, 2022c, Index für die digitale Wirtschaft und Gesellschaft (DESI) 2022 – Deutschland, https://ec.europa.eu/newsroom/dae/redirection/document/88748 [1.9.2023]

Europäische Kommission, 2020a, Ein neuer Aktionsplan für die Kreislaufwirtschaft. Für ein saubereres und wettbewerbsfähigeres Europa, Mitteilung der Kommission an das Europäische Parlament, den Europäischen Rat, den Rat, den Europäischen Wirtschafts- und Sozialausschuss und den Ausschuss der Regionen, 11.3.2020, COM(2020) 98 final, https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0016.02/DOC_1&format=PDF [24.07.2023]

Europäische Kommission, 2020b, Green Deal: Sustainable batteries for a circular and climate neutral economy, Press release, 10 December 2020, https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2312 [26.7.2023]

Europäische Kommission, 2019, Der europäische Grüne Deal, Mitteilung der Kommission an das Europäische Parlament, den Europäischen Rat, den Rat, den Europäischen Wirtschafts- und Sozialausschuss und den Ausschuss der Regionen, 11.12.2019, COM(2019) 640 final, https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0021.02/DOC_1&format=PDF [24.07.2023]

Europäische Kommission, 2008, Verordnung (EG) Nr. 213/2008 Der Kommission vom 28. November 2007 zur Änderung der Verordnung (EG) Nr. 2195/2002 des Europäischen Parlaments und des Rates über das Gemeinsame Vokabular für öffentliche Aufträge (CPV) und der Vergaberichtlinien des Europäischen Parlaments und des Rates 2004/17/EG und 2004/18/EG im Hinblick auf die Überarbeitung des Vokabulars, https://www.beschaa.bund.de/SharedDocs/Downloads/Rechtsgrundlagen/NormenUndRechtsvorschriften/EUVerordnungen/verordnung_EG_213_2008.pdf?__blob=publicationFile&v=1 [28.08.2023]

Europäisches Parlament, 2023, Neue EU-Vorschriften für nachhaltigere und ethisch bedenkenlose Batterien, https://www.europarl.europa.eu/news/de/headlines/economy/20220228STO24218/neue-eu-vorschriften-fur-nachhaltigere-und-ethisch-bedenkenlose-batterien?xtor=AD-78-%5bSocial_share_buttons%5d-%5blinkedin%5d-%5bde%5d-%5bnews%5d-%5beconomy%5d-%5bbatteries%5d& [26.7.2023]

Europäisches Parlament /Europäischer Rat, 2017, Verordnung (EU) 2017/1369 des europäischen Parlaments und des Rates vom 4. Juli 2017 zur Festlegung eines Rahmens für die Energieverbrauchskennzeichnung und zur Aufhebung der Richtlinie 2010/30/EU, https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32017R1369 [26.7.2023]

Europäischer Rechnungshof, 2023, Kreislaufwirtschaft: Langsame Umsetzung in den Mitgliedstaaten trotz EU-Maßnahmen, Sonderbericht https://www.eca.europa.eu/ECAPublications/SR-2023-17/SR-2023-17_DE.pdf [27.7.2023]

Eurostat, 2023, Nutzungsrate wiederverwendbarer Stoffe, https://ec.europa.eu/eurostat/databrowser/view/cei_srm030/default/table?lang=de [14.7.2023]

Fraunhofer Institut für Software und Systemtechnik ISST (Hrsg.), 2023, Anreizsysteme und Ökonomie des Data Sharing – Status Quo der deutschen Datenwirtschaft und Anwendung von unternehmensübergreifende Datenaustausch, Dortmund

Fries, Martin/ Scheufen, Marc, 2023, Vertragsgestaltung beim Data Sharing: Empirie und Best Practice, in: RDI - Recht Digital, 4. Jg., Nr. 9, S. 419-425

Fries, Martin/ Scheufen, Marc, 2019, Märkte für Maschinendaten: Eine rechtliche und rechtsökonomische Standortbestimmung, in: MMR – MultiMedia und Recht, Jg. 22, Nr. 11, S. 721-726

Fluchs, Sarah / Neligan, Adriana / Schleicher / Carmen / Schmitz, Edgar, 2022, Zirkuläre Geschäftsmodelle: Wie zirkulär sind Unternehmen?, IW-Report, Nr. 27, Berlin / Köln

Geissdoerfer, Martin / Savaget, Paulo / Bocken, Nancy M. P. / Hultink, Erik Jan, 2017, The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production, 143. Jg., S. 757–768 https://doi.org/10.1016/j.jclepro.2016.12.048 [9.5.2022]

Götz Thomas / Adisorn, Thomas / Tholen, Lena, 2021, Der Digitale Produktpass als Politik-Konzept, Wuppertal Report Nr. 20, https://epub.wupperinst.org/frontdoor/deliver/index/docId/7694/file/WR20.pdf [25.07.2023]

GS1 Germany, 2023 Digitaler Produktpass: mehr Transparenz über Nachhaltigkeitsinformationen, https://www.gs1-germany.de/service/gs1-newsroom/meldung/digitaler-produktpass-mehr-transparenz-ueber-nachhaltigkeitsinformationen/ [14.7.2023]

IDTA, o. J. Asset Administration Shell: die Verwaltungsschale für den Digitalen Zwilling, https://industrialdigitaltwin.org/ [10.8.2023]

ISO – International Organization for Standardization, 2017, Standards, https://www.iso.org/standards.html [17.8.2023]

ISO, 2023, – ISO/WD 59040 – Circular Economy – Product Circularity Data Sheet, https://www.iso.org/standard/82339.html [26.7.2023]

IW Consult, 2023, Neunter Strukturbericht für die M+E-Industrie in Deutschland mit den Schwerpunktthemen „Wirtschaftliche Verflechtungen der M+E-Industrie in Deutschland“ und „Weltweite Entwicklung der Investitionstätigkeit“, Berichtsstand 2022, Gutachten im Auftrag des Arbeitgeberverbands GESAMTMETALL, Köln

Jansen, Maike / Meisen, Tobias / Plociennik, Christiane / Berg, Holger / Pomp, André / Windholz, Waldemar, 2023, Stop Guessing in the Dark: Identified Requirements for Digital Product Passport Systems in: Systems 11, 123. https://doi.org/10.3390/systems11030123 [30.7.2023]

Kirchherr, Julian / Reike, Denise / Hekkert, Marko (2017) Conceptualizing the circular economy: An analysis of 114 definitions, Resources, Conservation and Recycling, 127. Jg., S. 221–232, https://www.sciencedirect.com/science/article/pii/S0921344917302835 [30.7.2023]

Laudon, Kenneth C. / Laudon, Jane P. / Schoder, Detlef, 2010, Wirtschaftsinformatik – Eine Einführung, Pearson Studium, München

Lichtenthäler, Sarah / Neligan, Adriana, 2023, How Circular Are Businesses in Germany? in: Intereconomics: Rethinking Resource Efficiency: Europe's Transition to a Circular Economy, Volume 58, Nr. 2, S. 79–86 https://www.intereconomics.eu/contents/year/2023/number/2/article/how-circular-are-businesses-in-germany.html [14.7.2023]

Neligan, Adriana / Engels, Barbara / Schaefer, Thilo / Schleicher, Carmen / Fritsch, Manuel / Schmitz, Edgar / Wiegand, Ralf, 2021, Digitalisierung als Enabler für Ressourceneffizienz in Unternehmen, Gutachten im Auftrag des Bundesministeriums für Wirtschaft und Energie, Berlin

Neligan, Adriana / Baumgartner, Rupert J. / Geissdoerfer, Martin / Schögg, Josef-Peter, 2022, Circular disruption. Digitalisation as a driver of circular economy business models, in: Business Strategy and the Environment, S. 1–14

Neligan, Adriana / Lichtenthäler, Sarah / Schmitz, Edgar, 2023, Produkte und Dienste für eine zirkuläre Wirtschaft, IW-Report, Nr. 16, Berlin / Köln

Piétron, Dominik / Staab, Philipp / Hofmann, Florian, 2022, Daten für die Circular Economy – Wie zirkuläre Daten-Governance nachhaltiges Wirtschaften ermöglicht, FES Impuls, https://library.fes.de/pdf-files/a-p-b/19831-20221219.pdf [14.7.2023]

Plattform Industrie 4.0, Details of the Asset Administration Shell – from idea to implementation, presentation, https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/vws-in-detail-presentation.pdf?__blob=publicationFile&v=12 [31.7.2023]

Plociennik, Christiane et al., 2022 Towards a Digital Lifecycle Passport for the Circular Economy, in: Procedia CIRP, Jg. 5, S.122–127, https://www.sciencedirect.com/science/article/pii/S221282712200021X [26.7.2023]

Potting, José / Hekkert, Marko /Worrell, Ernst / Hanemaaijer, Aldert, 2017, Circular Economy: Measuring innovation in product chains. PBL Netherlands Environmental Assessment Agency, https://www.pbl.nl/sites/default/files/downloads/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf [30.7.2023]

PSQR, 2023, All about DPP, https://psqr.eu/publications-resources/all-about-dpp/ [10.8.2023]

Salewski, Phil, 2016, Made in Germany - oder doch nicht? Die Zulässigkeitskriterien für die Herkunftsangabe nach der Rechtsprechung, News vom 20.10.2016, https://www.it-recht-kanzlei.de/made-in-germany.html#abschnitt_17 [11.01.2023]

Sipka, Stefan, 2022, Digital product passports: What does the Sustainable Products Initiative bring?, Commentary, European Policy Centre, https://epc.eu/en/publications/Digital-product-passports-What-does-the-Sustainable-Products-Initiati~484018 [27.6.2023]

SPD / Bündnis 90 / Die Grünen / FDP, 2021, Mehr Fortschritt wagen – Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit, Koalitionsvertrag 2021-2025, https://www.spd.de/fileadmin/Dokumente/Koalitionsvertrag/Koalitionsvertrag_2021-2025.pdf [29.9.2022]

Stretton, Chris, 2022, Digital product passports (DPP): what, how, and why?, https://www.circularise.com/blogs/digital-product-passports-dpp-what-how-and-why [14.7.2023]

UNSPSC – United Nations Standard Products and Services Code, 2023, Welcome, https://www.unspsc.org/ [01.09.2023]

VDE-Verlag, 2017, EC 61360-1:2017, Standard data element types with associated classification scheme - Part 1: Definitions - Principles and methods, https://www.vde-verlag.de/iec-normen/224719/iec-61360-1-2017.html [10.8.2023]

VDE-Verlag, 2022, E DIN EN IEC 63278-1 VDE 0810-781:2022-07, Verwaltungsschale für industrielle Anwendungen, Teil 1: Struktur der Verwaltungsschale, https://www.vde-verlag.de/normen/1800748/e-din-en-iec-63278-1-vde-0810-781-2022-07.html [31.7.2023]

WBCSD – World Business Council for Sustainable Development / WRI - World Resources Institute, 2004, The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standards, https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf [25.08.2023]