D5.1

DPP Prototypes

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Abstract:	This report gives a high-level view of the DPP, situating it in a wider technological and international context. The importance of semantic interoperability for the DPP is also stressed and a non-exhaustive list of potentially useful data models and ontologies are provided. Four illustrative videos related to the DPP are also described.
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22	SyncForce BV	SyncForce	NL
23	ASOCIACION DE EMPRESAS TECNOLOGICAS ES INNOVALIA	INNOVALIA	ES
24	Textile Exchange	TextileExchange	US
25	Responsible Business Alliance	RBA	US
26	WORLDLINE FRANCE	WORLDLINE	FR
27	RISE RESEARCH INSTITUTES OF SWEDEN AB	RISE	SE
28	IPOINT-SYSTEMS GMBH	iPoint	DE
29	Global Electronics Council	GEC	US/NL
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Preparing the ground for the gradual piloting and deployment of DPPs from 2023 onwards, focusing on developing a roadmap for prototypes in three value chains: electronics, batteries and textiles.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms	
CE	Circular Economy
URI	Unique Resource Identifier
EPC	Electronic Product Code
LCSA	Life Cycle Sustainability Analysis
SW	Semantic Web
LOD	Linked Open Data
REO	Responsible economic operator
DID	Distributed identifier
UID	Unique product identifier
ESG	Environmental, Social & Governance

Executive Summary

The purpose of this document is to present a consolidated vision of the cross-sectoral Digital Product Passport (DPP) and the DPP system - the technical framework required to deliver DPP data. This conceptual 'prototype' is a description of a DPP that is accessible to a wide audience and that has achieved a high level of consensus by relevant stakeholders and which concerns all of the components of the DPP: informational, technical, governance rules and required standards. Thus, this report heavily relies on the results provided by other CIRPASS reports, namely:

Informational:

- *Deriving an initial set of information requirements to serve as a basis for future discussions*
- *Exploring possible DPP use cases in battery, electronics and textile value chains*
- *Stakeholder consultation on key-data*

Technical:

- *Benchmark of existing DPP-oriented reference architectures*
- *Identification schemes*
- *DPP system architecture*
- *DPP system roadmap*

Governance rules:

- *Recommendations*
- *A study on DPP costs and benefits for SMEs*
- *Cross-sector and sector-specific DPP roadmaps*

Standards:

- *Report on current standards landscape and interoperability requirements*
- *DPP user stories*
- *Standardisation gaps and roadmap*

To this end, Chapter 1 presents a high-level view of the DPP and the DPP system, providing a vision of the problems that must be solved when designing a DPP system capable **not only of ensuring regulatory compliance but also of integrating smoothly into the Data Economy and allowing for further digitisation of the EU Industry.** This chapter also addresses the international context in which the EU DPP will operate. This includes a comparison of the EU DPP with the UNTP DPP proposed by the recent UNECE Recommendation 49 and which focuses on international supply chains.

Chapter 2 provides background information on semantic interoperability. It explains the difference between data models and ontologies, which are very similar concepts but with important differences. It also offers basic background knowledge on Linked Open Data and the Semantic Web. Finally, it explains **why semantic interoperability is crucial for the DPP and the DPP system**, in particular in view of the need for cross-sectoral interoperability of data for the Circular Economy.

Chapter 3 digs deeper into the topic of “ontologies” which are data models with standardised technical representations and their use in the DPP system. A useful working example from the European Commission, the EPREL database, is provided to help readers understand the notions of “upper-level” and “domain specific” ontologies. After also defining the concepts of “DPP system ontologies” and “Regulatory ontologies”, it provides a list of potentially useful existing ontologies for the DPP.

Finally, Chapter 4 presents the four video demos that were developed during the project with the aim of illustrating a **specific feature of the DPP system** as proposed by CIRPASS. Each video was designed for a specific purpose while remaining short, concise and with wording remaining at a **low technical level** in order to be easily understood by all.

1 A high-level view of the DPP and the DPP system

This chapter presents a high-level view of the DPP and the DPP system, providing a vision of the problems that must be solved when designing a DPP system capable not only of ensuring regulatory compliance but also able to connect the EU Internal Market to the Data Economy. This chapter also addresses the international context in which the EU DPP will operate.

1.1 What is the problem that we are trying to solve?

The design of the DPP system architecture must provide solutions to the following problems:

Problem #1:

> How can **all industrial sectors** agree on a common DPP system that is compliant to the requirements of upcoming EU regulations (Ecodesign for Sustainable Products Regulation, Battery Regulation, Toys Regulation, Detergents Regulations, Construction Products Regulation, Critical Raw Materials Act, Packaging and Packaging Waste Regulation) and that is capable of supporting the massive issuing of DPPs as of 2027?"

Problem #2:

> How can all industries agree on an **extensible and flexible** DPP system capable of supporting beyond-mandatory data exchanges to enable new circular business models? Indeed, allowing the DPP to support non mandatory data exchanges allows companies to use it also to develop data-enhanced activities.

Problem #3:

> How can the system be designed to support the **future activities** of a Circular Economy which is still in the making and whose inner workings are still largely unknown?

In a Circular Economy, where waste is minimized and material resources are constantly reemployed, the concept of "upstream" and "downstream", historically defined for linear value chains, must be redefined. In CIRPASS, "upstream" and "downstream" are always defined with respect to the "responsible economic operator" (REO) that has the legal obligation to issue a DPP for their product, as illustrated below. In this figure, "raw materials" can refer to either virgin or recovered or recycled materials.

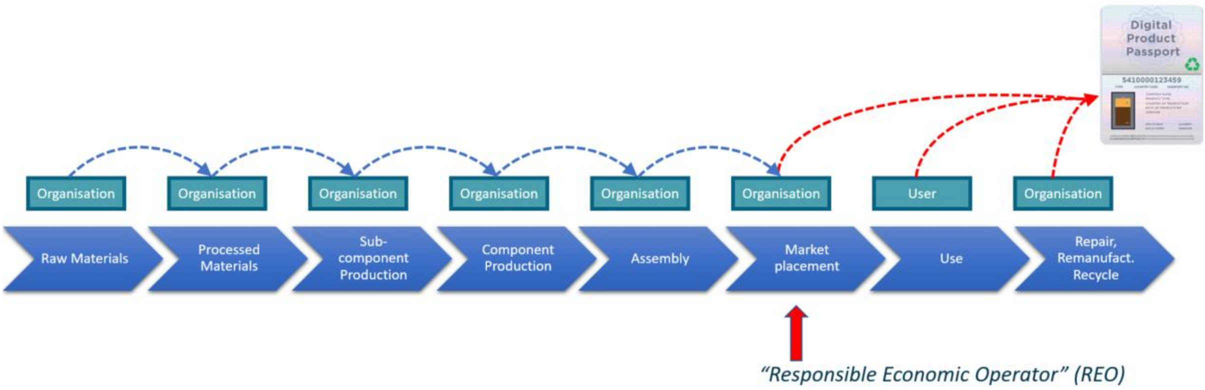


Figure 1. Position of the "Responsible Economic Operator" in the circular value chain

Problem #4:

While the DPP is not a traceability tool and is intended primarily as a tool to promote circular value retention for products after they have been placed on the market, the crucial need to facilitate data sharing for both reasons of traceability and transparency over international supply-chains will necessarily affect the DPP, at minimum because this data will be required to produce the mandatory information for the DPP. How can the DPP system support the **connection of upstream and downstream actors**?

The CIRPASS proposal for the DPP system, described in the following documents, is designed to address the 4 above challenges.

- *Identification schemes*
- *DPP system architecture*
- *DPP user stories*

This proposal is designed for maximum acceptability by economic actors, thanks to the possibility to reuse legacy systems and data models, has the capacity to accommodate both regulatory and non-mandatory (business-model-specific) and evolving information requirements, and is built using state-of-the-art but sufficiently mature technologies to support the massive issuing of DPPs as of 2027. This makes the system both easy to deploy and future-proof.

1.2 The DPP in its wider technological ecosystem

The CIRPASS vision for the DPP system is that it should not only support the issuing of mandatory DPPs but is should also provide a crucial link between the EU internal market and the burgeonning data economy. Because the DPP is a mandatory regulatory obligation for companies and the also because the DPP system will require standardised data exchange protocols built to enable semantic interoperable of data across sectors, the DPP becomes the mandatory core that enables a wider technological and informational ecosystem, as illustrated below.

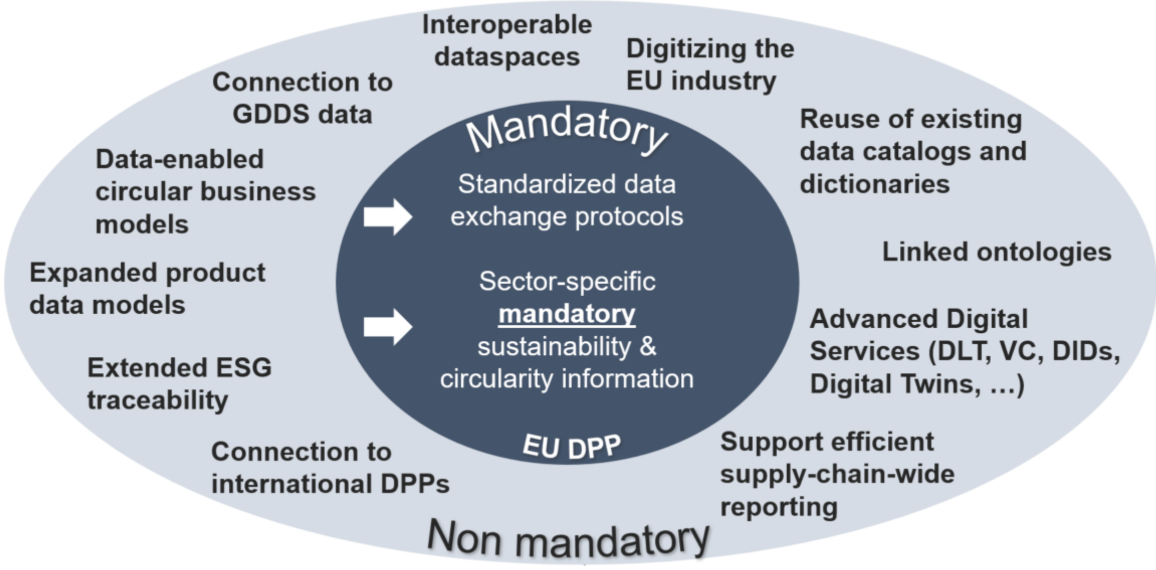


Figure 2. The complementary mandatory and non-mandatory aspects related to DPP system

Because of the possible yet desirable confusion created by the attachment of non-mandatory information to the same unique product identifier, CIRPASS defines the Digital Product Passport (DPP) as "*a structured collection of mandatory, machine-readable, product-related data with pre-defined scope and agreed data management and access rights extracted from a standardized product dataspace thanks to a unique product identifier and that is accessible via electronic means through a data carrier. The intended scope of the DPP is information related to sustainability and circularity, e.g., value retention from repair, re-sell, re-use, reconditioning, remanufacturing, and recycling*."

1.3 The EU DPP in an international context

While the Digital Product Passport is an initiative of the European Union, similar and related ones are underway in other regions of the world. For example, in the **United States of America**, the U.S. Inflation Reduction Act (IRA) requires manufacturers to disclose where critical materials in batteries such as lithium are sourced for tax credit eligibility. The SAE has created a Global Battery Traceability Standards Committee (TVVBC11) to establish a standard for this information.

During the G7 Digital and Technical Ministerial Conference that was held on April 30th, 2023, Europe and **Japan** agreed to work on ensuring international interoperability of digital infrastructure for enhanced data collaboration across companies and industries. During this conference, there was a general recognition that the Japanese (Ouranos Ecosystem) and European (Gaia-X) visions both looked in the same direction. And while the Japanese government does not envisage using the DPP as a regulatory tool, this vision also includes the DPP (figure below).

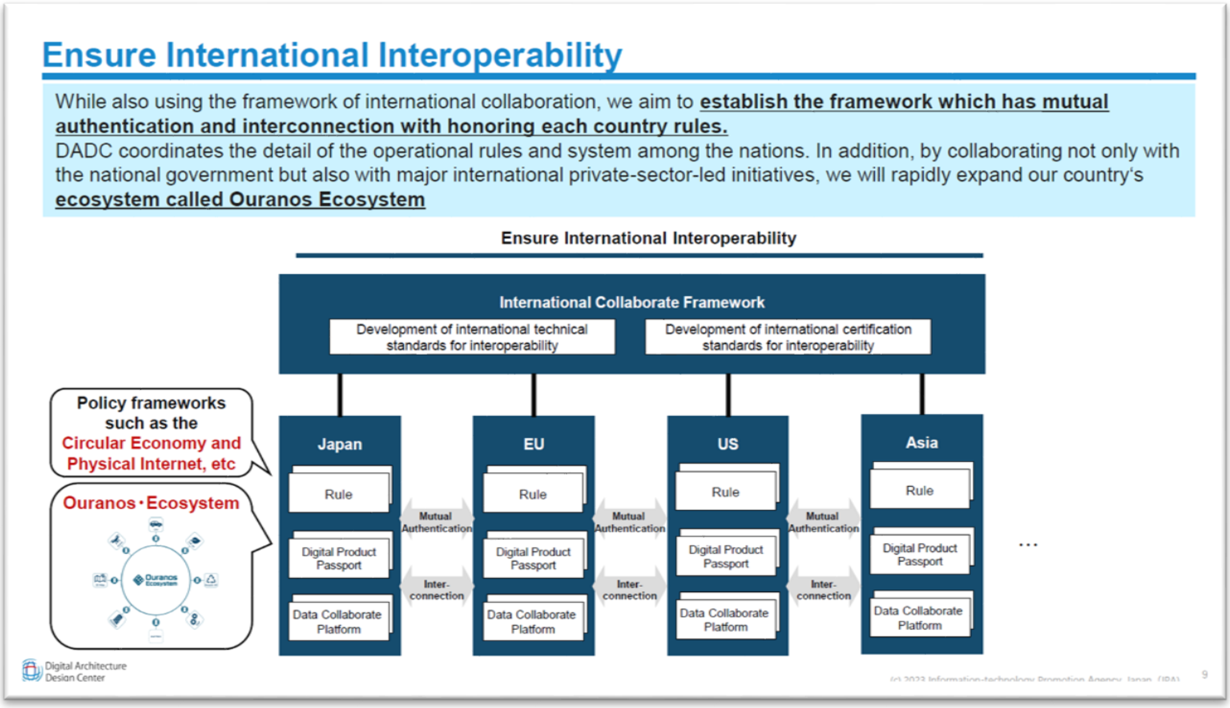


Figure 3. Presentation slide from the Digital Architecture Design Center (Japan)

The "Ouranos Ecosystem" is an initiative of the Digital Architecture Design Center (DADC) of the Information technology Promotion Agency[1] (IPA) that aims to realize data collaboration across companies, industries, and borders. The DADC was established in May 2020 as a public-private Task Force to study the basic design and operational infrastructure of a cross industry Data Space related to business-to-business transactions from the supply chain to the value chain for cross industry use.

Korea, through its Korea Internet & Security Agency (KISA), is actively promoting the use of blockchain technologies for a number of applications (online voting, digital badge, waste battery remaining life certification, and waste cooking oil distribution history management). In this context, it is planning on building a blockchain-based DPP platform as a public institution starting in 2025.

While for the time being, and to the best of our knowledge, only the European Union has envisaged using the DPP as a regulatory tool, it is not unlikely that another country may also wish to issue DPPs, perhaps with **different mandatory information requirements**. As products are simultaneously distributed and sold in many regions of the world, it would be desirable that both systems are built using the semantic interoperability layer and the same set of standards as the European DPP system. In this way, both passports would be interoperable, both technically and semantically. Similarly, the mandatory content of both passports could be validated using different templates (e.g., different SHACL scripts). This would considerably lower implementation costs to global economic operators.

[1] https://www.ipa.go.jp/dadc

1.4 The EU DPP in relation to international efforts in transparency

In recent years, the need for transparency over global supply chains has spurned the development of hundreds of traceability platforms and solution providers[2] leading many actors with a number of questions:

- How to choose among the different platform providers?
- How to manage delivering data in the different formats required by these traceability platforms?
- How are these upstream traceability schemes are related to the DPP?

To address the challenge related to the first two questions and because increasing regulatory demands will unfortunately also necessarily create increasing incentives for greenwashing, the UNECE Recommendation 49 – Transparency at scale, introduced the UN Transparency Protocol (UNTP)[3].

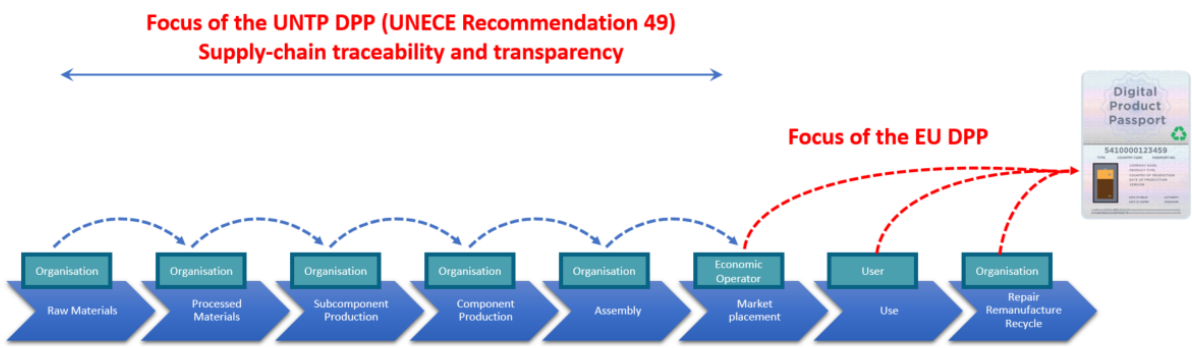


Figure 4. Comparing the focus of the EU DPP and the UNTP DPP

Similarly to the EU DPP, the UNTP defines a product-centric, decentralized information system and architecture where data is linked to the physical shipped product. It provides a simple vocabulary, separating data from the assessment of data (conformity credentials) and linking to traceability events. The UNTP is designed to work with product identification systems that are already deployed and in wide use. The only constraint on the choice of identification system is that the issuer of the identifiers should provide a service on their registry to host a pointer to where the data is located.

Recognizing that an architecture that depends on full digitalisation of all data will be costly and complex to implement, inhibiting uptake, the UNTP uses a balanced approach that defines just the key data elements needed for automated processing and allows more complex information that support human audits to remain as un-structured PDFs. Thus, facts about products are separated from the conformity assessment of those facts against dozens of different compliance criteria. The UNTP DPP is therefore a B2B digital product passport that acts as a "semantic waist" by including just the ESG metrics needed for the next actor to assess its supply chain inputs. Implementation of the UNTP has been demonstrated to be trivial and low cost. Any traceability solution provider can expose their clients' data in conformity to the UNTP, facilitating interoperability. The table below provides a more detailed comparison of the UNTP DPP and the EU DPP.

[2] Refer to CIRPASS report "Benchmark of existing DPP-oriented reference architectures" available at https://cirpassproject.eu/project-results/

[3] https://www.youtube.com/watch?v=dJFryZS2UII

Table 1. Comparison between the EU DPP and the UNTP DPP

	EU DPP System	UNTP DPP
Architecture	(Mostly) decentralized (EU-operated registry for product IDs); Product centric	Decentralized ; Product centric
Mandatory	Yes, for regulated products	No
Conformity Credentials	No, but could be linked to DPP data in the future	Yes
Verifiable traceability events	No, but could be linked to DPP data in the future	Yes
System integration	agnostic	agnostic
Interoperability standards	CEN CENELEC standardisation request for DPP system standards in 8 areas of standardisation	W3C VC & DID standards, product & entity identifier schemes, vocabularies such as vocabulary.uncefact.org, GS1 EPCIS-LD
Are “system” aspects clearly distinguished from “data” (payload) ?	Yes. “DPP System” will be standardised through CEN/CENELEC standardisation request. “DPP Data” will be defined through ESPR delegated acts.	Yes. “System” aspects are the resolution protocol and the VC envelope (issuer, date, id, signature, etc). The “Data” aspects (ie the payload of the VC) are one of three types: a UN DPP, a Conformity credential, a traceability event.
Does the standard or recommendation cover « system » only?	Yes	No.
Payload format	Linked data	Linked data
Selective privacy mechanisms	Yes	Yes
Implementation support	Digital Europe and Horizon Europe Pilot projects. Other support mechanisms will be provided by EU and member states.	Supporting materials such as schema, vocabularies, and test services https://github.com/uncefact https://uncefact.github.io/spec-untp/docs/specification
Is there an identifier for the DPP itself?	Optionally yes	Yes, URI
DPP issuer	Economic operator responsible for placing the product on the EU market	Any actor in the supply chain
(Backup) Resolver with links to the data	In case provided links go stale (e.g., bankruptcy), links to backup data will be available in the EU registry.	The issuer of IDs should provide a service on their registry to host a pointer to where the data is.
Does the Data carrier on the product contain an URI?	Not necessarily	Not necessarily

2 DPP and semantic interoperability

This chapter provides background information on semantic interoperability. It explains the difference between data models and ontologies, which are very similar concepts but with important differences. It also offers basic background knowledge on Linked Open Data and the Semantic Web. Finally, it explains why semantic interoperability is crucial for the DPP and the DPP system, in particular in view of the need for cross-sectoral interoperability of data for the Circular Economy.

2.1 European Commission definition of semantic interoperability

Since 2014, **semantic interoperability** has been increasingly promoted by the European Commission to help European public administrations perform seamless and meaningful cross-border and cross-domain data exchanges. In their published Semantic Interoperability Courses[4], semantic interoperability is defined as the preservation of precise meaning of semantic information. Semantic interoperability is achieved when social agreements are reached on vocabularies (common specifications for naming things) and on structural meta data (data models and reference data).

Metadata is data that defines and describes other data (ISO/IEC 11179-1).

Structural metadata: data that gives meaning to data and indicates how it is structured:

- A **data model** is a collection of entities, their properties and the relationships among them, which aims at representing a domain, a concept or a real-world thing.
- **Reference data** is a small, discrete set of values that are not updated as part of business transactions but are usually used to impose consistent classification. Reference data normally has a low update frequency.

As shown below, semantic interoperability also implies syntactical interoperability.

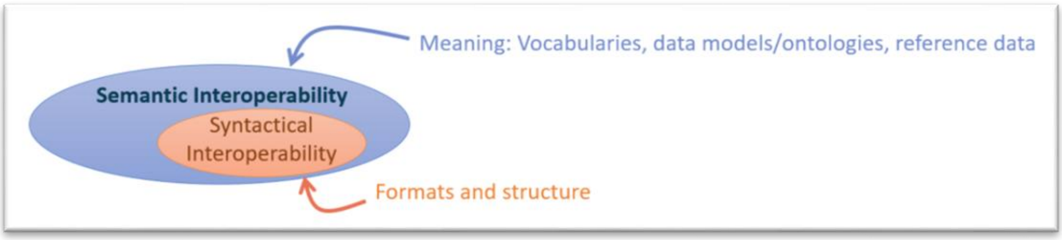


Figure 5. Semantic and syntactical interoperability

2.2 From data models to ontologies

This section explains the difference between data models and ontologies, very similar concepts but with important differences.

2.2.1 Data models

As stated above, a **data model** is a collection of entities, their properties and the relationships among them, which aims at the representation of a domain, a concept or a real-world thing.

[4] Module 1 – Introduction and overview of existing initiatives, ISA Programme, Action 1.1 [EU_Semantic_Interoperability]

A data model contains:

Classes: the distinct types of things that exist in our data, typically organized in a class hierarchy.

Relationships or Object properties: properties that connect two classes, typically organized in a property hierarchy.

Data properties (or attributes): properties that describe an individual class and are thus relations between a class and a literal.

Data models are typically designed for a specific application. There is a vast choice of tools that can be used to design a data model, from the simplest (a spreadsheet) to the most complex (an industrial digital twin).

2.2.2 Ontologies

Ontologies are **formal data models** designed for greater generality and expressivity. Similarly to data models, ontologies define the types of things that exist in a given domain and the properties that can be used to describe them. When classes and properties are combined, the ontology can be viewed in a graph format. Because they are generalized data models, ontologies only model general types of things that share certain properties but don't include information about specific instances. Ontology-based approaches guarantee the structuring of data and the effective use of derived knowledge, which includes tasks like reasoning over data.

Differently from data models which can be implemented with a vast choice of tools, **ontologies are data models with a standardized technical representation**.

2.3 Features of ontologies

The term "ontology" roots from philosophy as the science of being qua being and was first used in the field of computer science by Hayes to develop a domain-specific ontology of liquids [Hayes 1985]. Further detailed discussions for clarifying the term "ontology" led to Studer et al.'s definition of an ontology as "a formal and explicit specification of a shared conceptualization" [Studer 1998]. A conceptualization refers to the abstract representation of knowledge, existing in the mind of a person or community, that can be used to make decisions, reason, and solve problems. In order for the conceptualization to be documented, communicated and analysed, a language is necessary to concretize it in an explicit and formal manner. This is by identifying "the entities that are assumed to exist and the relationships that hold among them" in a certain reality and defining them as "concepts and relations" using some vocabulary to serve as modelling primitives and a formal language to build a logical rendering. For example, the conceptualization of "a person sits on the chair" can be concretized using the primitives "chair", "person", and "sits-on" and some choice of an explicit and formal language.

In this context, ontologies provide advantageous features for intelligent systems, as well as for knowledge representation and engineering [Gaševic 2009]. These are:

-The vocabulary: the syntactic and semantic notations of the entities and relationships of the conceptualization. They provide logical statements describing terms and specify rules for combining some. As such, the vocabulary of an ontology is not just a syntactic notation, but also the semantic common understanding of the terms using some formalization. However, it is not the vocabulary that qualifies as the ontology, but the conceptualizations that the terms of the vocabulary are intended to capture [Chandrasekaran 1999]. This results in ontologies being both human-understandable and machine-readable.

-A taxonomy: the hierarchical categorization/classification of entities and their relationships within a domain. These hierarchies help in generalizing (using super-classes and super-properties) and specializing (using sub-classes and sub-properties) the concepts and relations of a domain. Both the taxonomy and the vocabulary of the ontology provide a conceptual framework for discussing, analyzing and retrieving information in a domain.

-The content theory: the logical theory behind the classes and properties using some ontology representation language, according to which we restrict what can and/or cannot be an instance of the corresponding class or property. Some classes/properties require complex representations such as in the case of foundational ontological relations e.g. location, parthood, membership, etc. which require an elaborate specification within an ontology representation language that can well capture the intended semantics [Danash 2022]. Being recognized as theories, this allows for performing consistency checking to verify that the axiomatic structures are consistent, enhancing interoperability between different applications.

-Knowledge sharing and reuse: the formal specification of an ontology allows for its sharing and reuse among other intelligent systems because of its characteristic of being human understandable and machine-readable.

For these reasons, ontologies are used in numerous domains for enhancing collaboration, interoperability, education, and modeling [Fikes 2007]. A tool to support collaboration is mostly needed in interdisciplinary projects where specialists from multiple and different background domains have different views of the same problem or issue. Ontologies play an important role in providing a common understanding and representation of the domain in a consensual manner that is independent from a specific point of view. Additionally, interoperability is achieved by the syntactic and semantic integration of information from different and disparate sources i.e. data conversion and information integration become easier to automatize in the case of a common ontology shared between different data sources.

2.4 Linked Open Data and the Semantic Web

Open data is data that anyone can access, use and share [Kitchin 2014]. Different degrees of data openness exist depending on the format of data chosen by institutions, which in turn determines the capability of linking this data on the Web.

Tim Berners-Lee, renowned as the inventor of the Web and initiator of Linked Data, has proposed a deployment scheme for Open Data (refer to Figure below). This scheme begins with the publication of data, initially as PDF on the Web. In the second stage, the data evolves into a structured format, such as within an Excel file, rather than an image scan of a table, which enables computer programs to extract values from each cell. The third stage involves making data available in a non-proprietary format, like comma-separated values instead of Excel. Data achieves a 4-star rating when each unit (e.g., each cell in a table) can be uniquely identified using a Unique Resource Identifier (URI), allowing individuals to point at data through these URIs. The Open Data process is completed when each URI, uniquely identifying a cell's data, is connected to other or same data on the Web using a link, also identified by a URI. The linking of two resources on the Web is termed a "triple" (subject-predicateobject). Typically, the Resource Description Framework (RDF) standard syntax is employed to represent graphically and write formally these triples which are referred to as RDF triples.

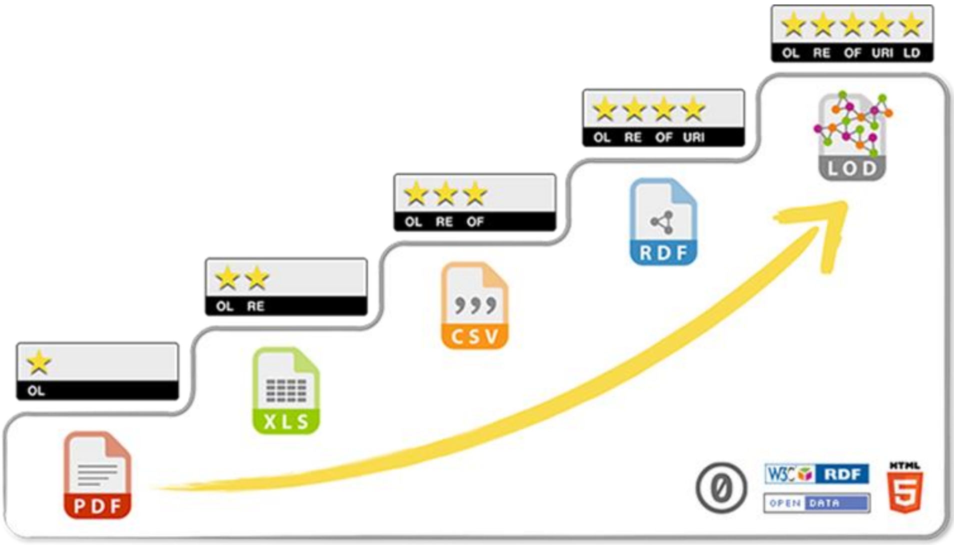


Figure 6. A 5-star deployment scheme for Open Data[5]

Such a paradigm of data is referred to as the Linked Open Data (LOD) paradigm. LOD emphasizes the publication and interlinking of structured data on the web, creating a vast network of interconnected resources. Using the LOD paradigm means assigning a URI to every data set accessible on the Web, as a resource node within the distributed Web graph database. In this paradigm, the data sets and each individual indicator, data point, and associated metadata function as resource nodes, creating an embedded and interconnected web graph. Additionally, LOD technologies facilitate both syntactic and semantic interoperability among systems. Indeed, each data point published on the LOD Web requires linkage to a concept that defines its association with some other data points as belonging to the same categorization—whether objects, events, situations, or abstract notions. This practice enhances the contextual understanding and meaningful connections within the LOD framework.

Moreover, it is at this point, where ontologies play a fundamental role in defining the structure of data using concepts and relations [Berners-Lee 2001]. They help both people and machines to communicate, supporting the sharing of semantics and not only syntax [Maedche 2001]. By employing RDF triples, the syntax of data becomes standardized, facilitating seamless transferability from one system to another i.e. syntactic interoperability. The explicit semantic nature of RDF triples, due to complying with some ontology, enables machines to "understand" and "exchange" the received data i.e. semantic interoperability.

Consequently, the term Semantic Web (SW), which is the next step in the evolution of the World Wide Web (WWW), is used to describe datasets, ontologies, and technologies within the LOD Web. Technical recommendations for related technologies (Figure below) are widely documented and standardized by the World Wide Web Consortium (W3C). These include the Resource Description Framework (RDF) as a graph model for data, the RDF Schema (RDFS) and the Web Ontology Language

[5] Suggested by Tim Berners-Lee, the inventor of the Web and Linked Data initiator, available from https://5stardata.info/en/

(OWL) for defining vocabularies and ontologies, the SPARQL Protocol And RDF Query Language (SPARQL) as a query language dedicated to RDF, in addition to other supported services for inferences and graph validation.

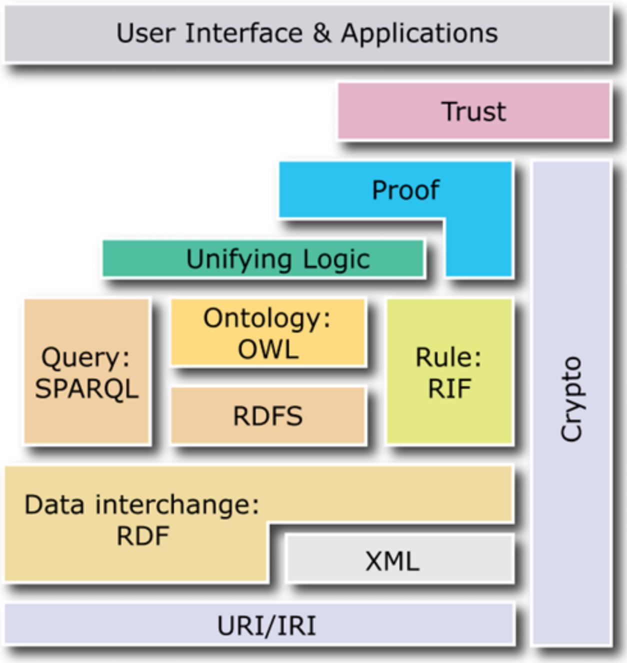


Figure 7. The Semantic Web layer cake diagram[6]

More recently, the term "knowledge graphs" has surfaced to characterize graphs on the LOD Web that encompass both datasets and ontologies with formal semantics. These knowledge graphs can be instrumental in interpreting data and deducing new facts [Ontotext]. Conceptually, a knowledge graph can be envisioned as a network comprising various datasets and ontologies relevant to a specific domain. By applying a reasoner, one can derive new knowledge from this interconnected network of information [Ehrlinger 2016].

2.5 Why is semantic interoperability needed for the DPP system?

As explained in the CIRPASS report “DPP system architecture” (D3.2), a vision of two parallel methods for accessing DPP data is proposed, one relying on unique product identifiers (UID) embedded into HTTP URIs and one relying on the use of DIDs as unique product identifiers. Both methods make it possible to resolve to the DPP data starting from an UID embedded into a data carrier. Whatever the method used to reach the DPP data, this data is stored in a multitude of decentralized DPP data repositories under the responsibility of the REO, i.e. the ‘responsible economic operator’ who is legally responsible for issuing the DPP for the products they are placing on the market. The use of standardised technical representations and formats used to express this data makes it possible to create a light, top-level semantic interoperability layer necessary to facilitate data sharing and reuse. This is summarized in Figure 8.

[6] Source: https://www.w3.org/2007/03/layerCake.png, available from https://www.w3.org/2001/sw/, consulted on January 19, 2024

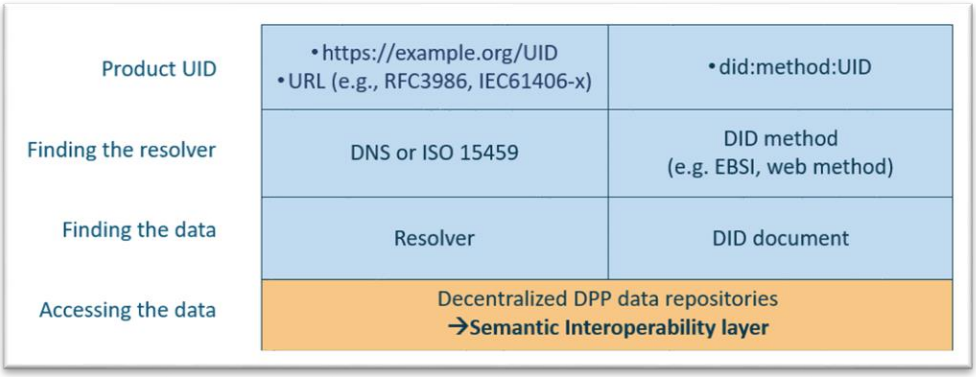


Figure 8. CIRPASS proposal for the DPP system: Two architectures for accessing DPP data[7]

There are several reasons why semantic interoperability is a must for the DPP system:

Reuse of legacy data and legacy systems: Semantic interoperability allows actors to continue using their existing vocabularies, data models and ontologies while creating mappings or alignments between different vocabularies when terms are equivalent. Indeed, as exemplified in the table below, developing data models, ontologies, vocabularies and classification systems is a complex endeavour as social agreements (consensus) must be achieved to obtain high levels of adoption. However, converting these to machine readable formats and making this machine-readable data semantically interoperable represent much less effort. In addition, the Linked Data tools available in the market today allow an easy connection to legacy systems (which contain these legacy data models). Thus, very pragmatically, the interoperability layer on top helps these legacy systems integrate seamlessly into the DPP system.

Table 2. A comparison of the effort required to develop and deploy elements of a data sharing system

	Effort (time)
Developing a data model	+ +
Developing a domain ontology	+ + +
Developing dictionaries and classifications systems	+ + +
Developing standards for information points (product carbon footprint, durability, …)	+ + + +
Developing regulatory information requirements per sector	+ + + +
Converting the above into machine readable data	+
Making machine readable data semantically interoperable	+

Once data models are transformed into ontologies, these can be reused wholly or in part, as illustrated in Figure 9. In this figure, we see that Ontology 2 reuses and expands on Ontology 1, while Ontology 3 reuses only parts of Ontologies 1 and 2. This makes it possible to continuously build new knowledge based on widely accepted, previously defined and consensus-based expert knowledge.

[7] Figure reproduced from CIRPASS report D3.2 « DPP system architecture »

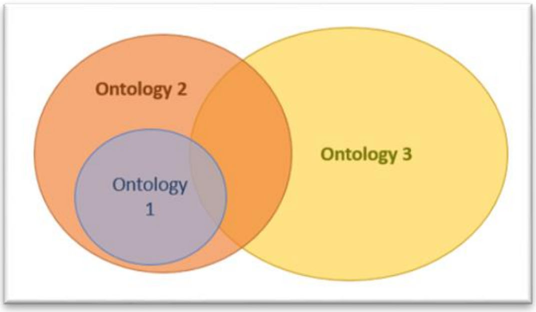


Figure 9. Ontology reuse options

Support vocabulary diversity: It is a useless hope that the entire world will align to the use of a single, common vocabulary. This is identical to the idea that the entire world should use a single common language. Semantic interoperability allows us not only to build semantic mappings between different vocabularies but also to link structured knowledge to each concept. This in turn makes it possible to support automated reasoners. This is illustrated in the figure below where we see that two colours, each defined in a specific colour system, are identified as “the same”. (More precisely, in this context, the two colours would be rather identified as “highly similar”, as each colours system describes different characteristics of a colour.)

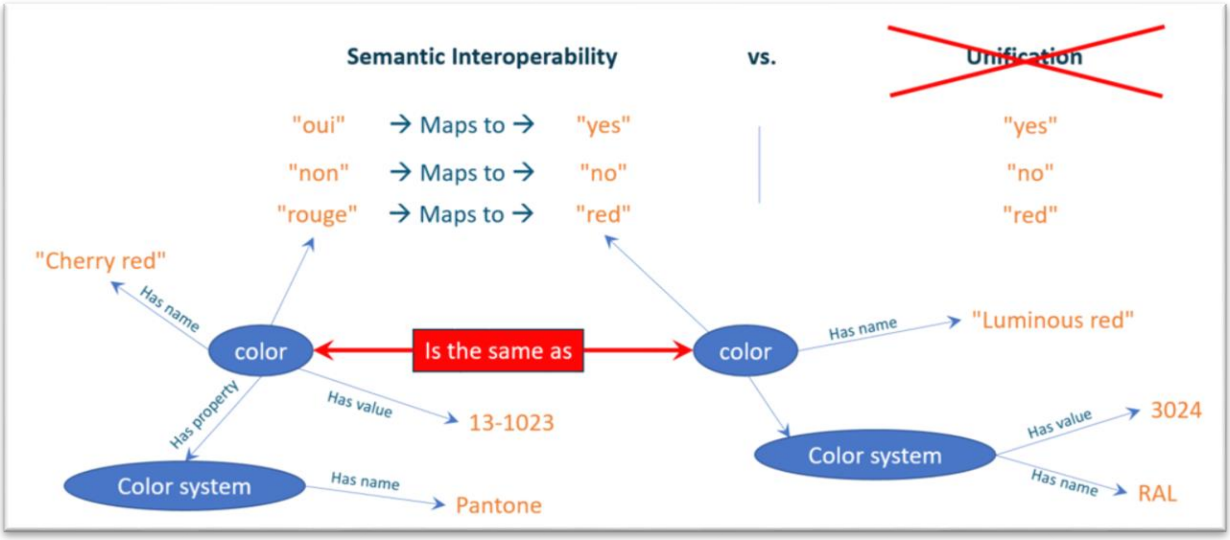


Figure 10. Semantic interoperability versus unification

Remove information barriers in the Circular Economy: The Circular Economy is cross-sectoral by nature. Since most products are composite products with subcomponents sourced from many different sectors, lifting information barriers in the Circular Economy requires that data originating from one sector must be clearly understood and interpretable when it is used by another sector. Thus the semantic interoperability layer must support this data reuse.

Support data space interoperability: The availability of semantically interoperable machine-readable data makes it easier to connect to and reuse data from different data spaces: manufacturing data spaces[8], Green Deal data spaces[9], etc. in a manner compatible with the recommendations of the European Data Space Support Center[10].

Flexibility: Since semantic web technologies allow dynamic interpretation and transformation, data can easily be selected and presented differently depending on the needs of different stakeholders (e.g., consumers, life-cycle actors, regulators, etc.), and a changing regulatory environment.

Combinability: Semantically interoperable data models make it easy to combine data from multiple sources. This can be done to assemble the DPP data itself from multiple repositories but also to support acquiring data from upstream suppliers. This means that a manufacturer can more easily combine data sources from their different suppliers, for example. If needed, this process can be supported by ontology alignment tools such as exemplified in the demo described in section 4.3 below.

Extensibility: Semantically interoperable data models make it easy to flexibly extend data systems. If concepts change, e.g. new rules or new relations are needed, those can just be added to the Linked Data system without having to roll out a new version of the data model or new database tables. Information can be piled on to the information stack as long as the relation to the existing information is given. For example, suppose that an energy class "A+++" is defined for a given product group. In an ontology, a label "better than A+++" can be easily created as a new class. An example where the extensibility properties of the DPP system are demonstrated is the flexible customs query system capable of embedding new sources of data described in section 4.3 below.

3 Ontologies for the DPP and the DPP system

In this chapter, we define the concepts of "upper-level" and "domain-specific" ontologies. To help illustrate this concept, we use an example from the EPREL database of the European Commission. We then explain how these two concepts are related to the DPP system. Finally, we provide a list of potentially useful ontologies for the DPP.

3.1 An example from the European Commission – The EPREL database

The European Product Registry for Energy Labelling (EPREL) is a mandatory, centralised database of product data for the following product categories : dishwashers, washing machines, washer-dryers, displays, household refrigeration, commercial refrigeration, tyres, light sources, air conditioners, domestic ovens, range hoods, household tumble driers, local space and combination heaters, professional refrigerated storage cabinets, residential ventilation units, solid fuel boilers, water heaters, hot water storage tanks and related solar devices (https://eprel.ec.europa.eu/). The data model from the EPREL database, which applies to all products regulated under the Energy Labelling Regulation, includes the following 4 mandatory types of information:

- General information
- Product information sheet
- Product availability

[8] https://manufacturingdataspace-csa.eu/
[9] https://www.greatproject.eu/
[10] https://dssc.eu/

- Supplier contact

Within each of these categories, the mandatory data points differ widely between product categories. For example, the data required for Tyres differs from the data required for Washing machines (see snapshots below). We observe that the EPREL data model template for each product category clearly defines each information point and corresponding data format (text, real or integer numbers, Yes/No options, etc.) and unit, when applicable. For example, the recent Energy Labelling Regulation Delegated Act for household washing machines and household washer-dryers[11] provides clear requirements regarding EPREL (including the QR code on the label and very clear instructions on information display formats.) Internally, the EPREL database defines the character encoding formats for the data (e.g., UTF-x).

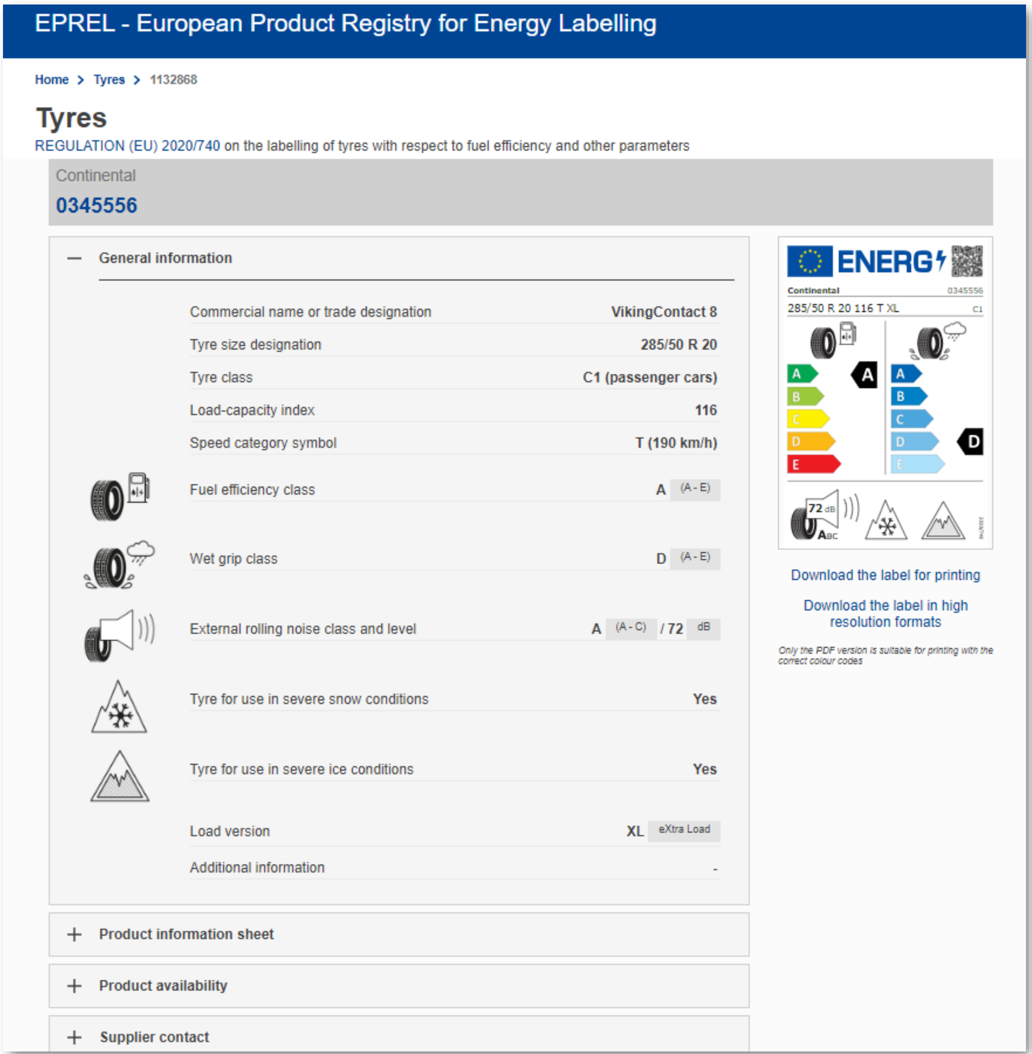
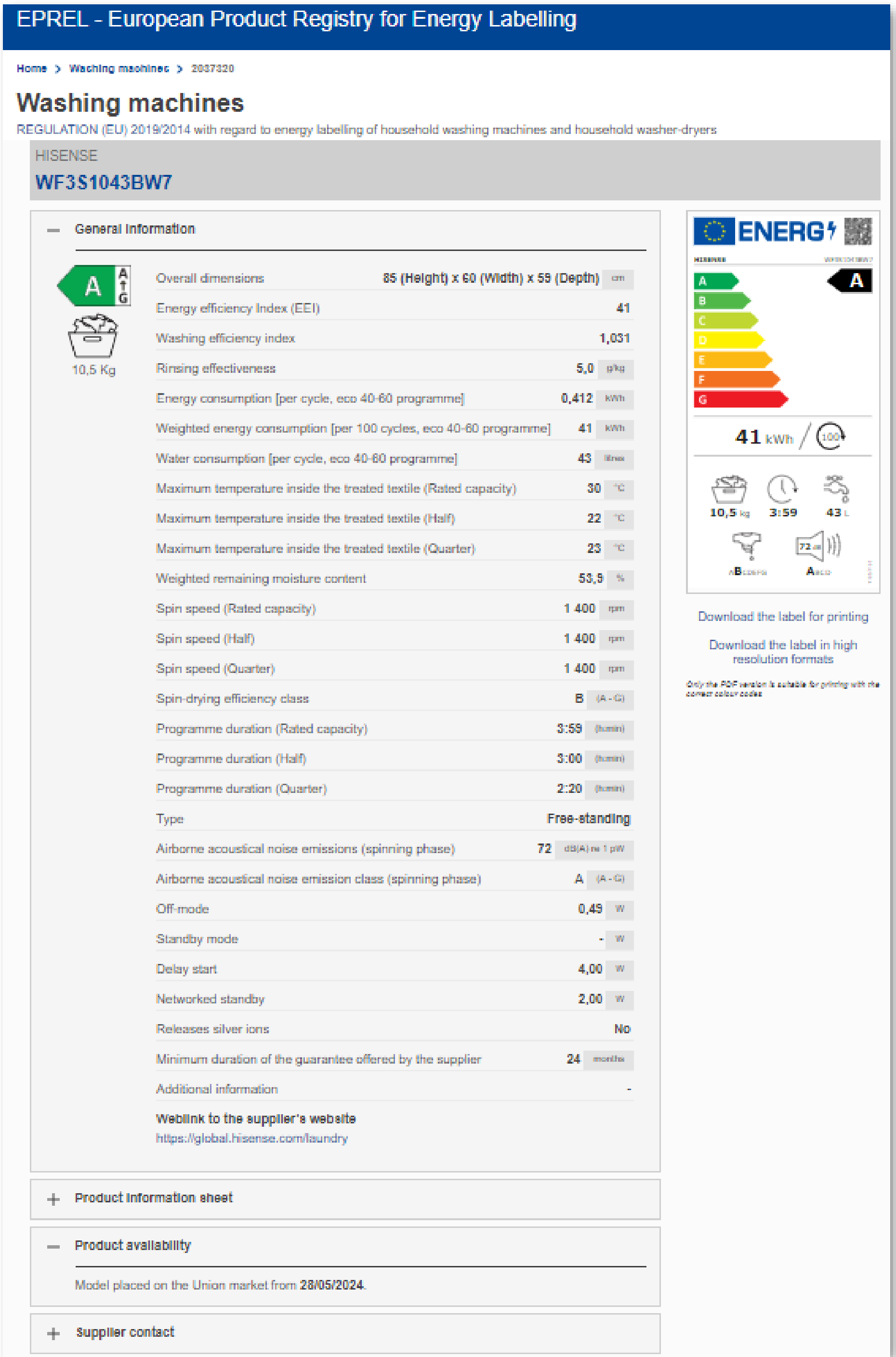


Figure 11. Snapshot from the EPREL database

[11] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02019R2014-20210501



EPREL - European Product Registry for Energy Labelling

Home > Washing machines > 2037320

Washing machines

REGULATION (EU) 2019/2014 with regard to energy labelling of household washing machines and household washer-dryers

HISENSE

WF3S1043BW7

General information

10,5 Kg

Overall dimensions	85 (Height) x 60 (Width) x 59 (Depth)	cm
Energy efficiency Index (EEI)	41	
Washing efficiency index	1,031	
Rinsing effectiveness	5,0	g/kg
Energy consumption [per cycle, eco 40-60 programme]	0,412	kWh
Weighted energy consumption [per 100 cycles, eco 40-60 programme]	41	kWh
Water consumption [per cycle, eco 40-60 programme]	43	litres
Maximum temperature inside the treated textile (Rated capacity)	30	°C
Maximum temperature inside the treated textile (Half)	22	°C
Maximum temperature inside the treated textile (Quarter)	23	°C
Weighted remaining moisture content	53,9	%
Spin speed (Rated capacity)	1 400	rpm
Spin speed (Half)	1 400	rpm
Spin speed (Quarter)	1 400	rpm
Spin-drying efficiency class	B	(A - G)
Programme duration (Rated capacity)	3:59	(h:min)
Programme duration (Half)	3:00	(h:min)
Programme duration (Quarter)	2:20	(h:min)
Type	Free-standing	
Airborne acoustical noise emissions (spinning phase)	72	dB(A) re 1 pW
Airborne acoustical noise emission class (spinning phase)	A	(A - G)
Off-mode	0,49	W
Standby mode	-	W
Delay start	4,00	W
Networked standby	2,00	W
Releases silver ions	No	
Minimum duration of the guarantee offered by the supplier	24	months
Additional information	-	

Weblink to the supplier's website
https://global.hisense.com/laundry

Download the label for printing

Download the label in high resolution formats

Only the PDF version is suitable for printing with the correct colour codes

Product information sheet

Product availability

Model placed on the Union market from 28/05/2024.

Supplier contact

Figure 12. Snapshot from the EPREL database

3.2 An ontology world view for the DPP system

Let us define the elements of the above described EPREL data model that applies to all products (limited to those regulated by the Energy Labelling Regulation) as the "upper-level" data model or ontology. Similarly, the product-group specific elements are defined as the "domain-specific" data model or ontology. Similarly to EPREL, the DPP will require an upper-level cross-sectoral data model or ontology to define concepts that apply to all products for which the DPP will become mandatory. This is referred to as the "DPP system ontologies" below. Similarly to EPREL, the DPP will require product-group specific data model templates. This is referred to as “Regulatory ontologies” below. These regulatory ontologies are the technical translation of the mandatory information requirements that will be defined in upcoming ESPR Delegated Acts. This comparison is summarized in the table below.

Table 3. Comparing EPREL and the DPP system on the general and specific elements of their data models

	EPREL	DPP system
Upper-level	4 information categories: •General information •Product information sheet •Product availability •Supplier contact	DPP system ontologies
Domain specific	Product-group specific data model template	Regulatory ontologies for sector-specific mandatory information requirements

For the DPP system, this relation is illustrated in the figure below:

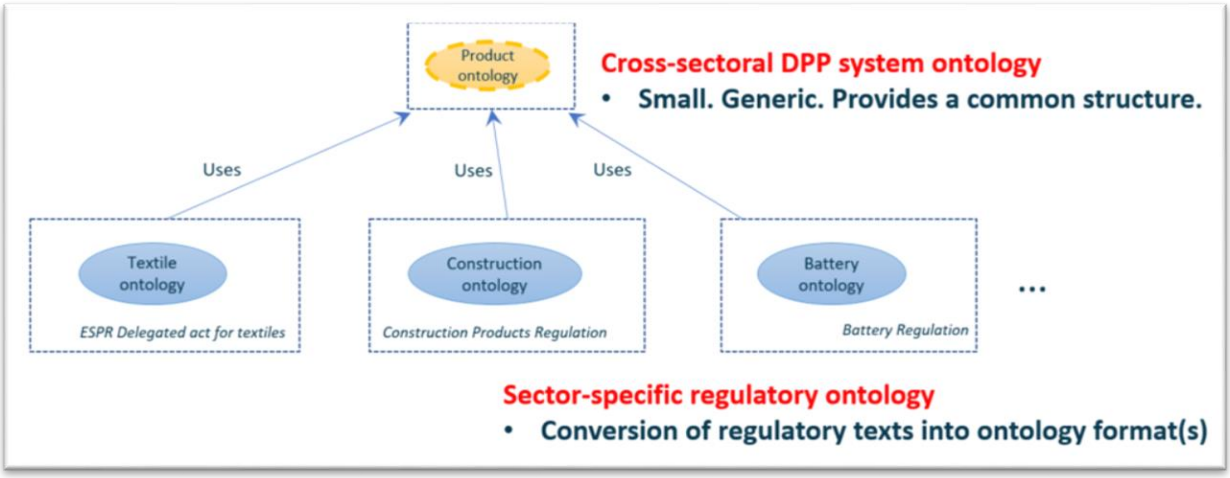


Figure 13. Relation between the DPP system product ontology and the Regulatory ontologies

The cross-sectoral “product ontology” illustrated above should provide the generic concepts that are applicable to all product groups.

Differently from the EPREL example where stakeholders must upload data to a centralized database, in the DPP system, the data remains stored under the responsibility of the REO, either by the economic operators themselves (“do-it-yourself DPP”) or by a party to which this task is delegated. This last might be a DPP-as-a-Service operator or an industry association. This is illustrated below.

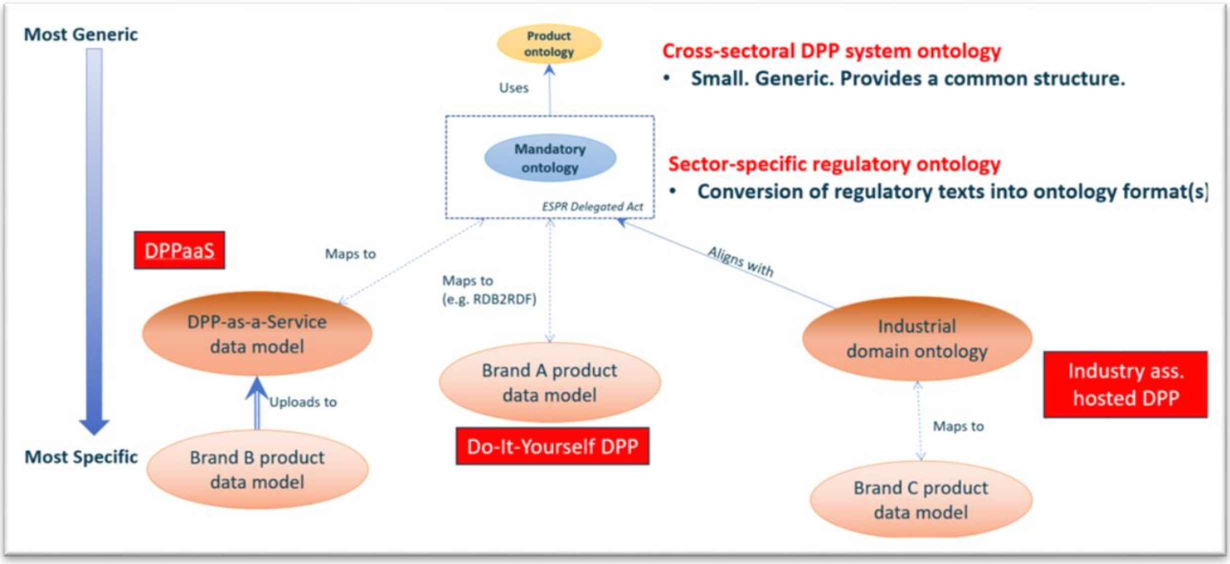


Figure 14. Mapping data towards the Regulatory ontologies

Finally, there are many ways to build semantic mappings to expose data in the correct formats. Transforms can be used to perform mappings between a data model and an ontology. Ontology bridges can be used to perform mappings between two ontologies. Whether mapping or alignment tools will be necessary to expose data in the correct formats will depend on the legacy systems used by the parties sharing this data. These may hold legacy company data models or use full-blown, complex industry ontologies, a small part of which is reused to expose mandatory DPP data.

3.3 DPP system ontologies

As explained above, the term ‘DPP system ontologies’ refers to ontologies covering commonly used concepts that can be applied in a cross-sectoral manner, irrespective of a specific delegated act or product group. This section describes an number of possible cross-sectoral ontologies for the DPP system, several of which potentially go further than the needs for upcoming European regulations.

3.3.1 Product ontology

By providing a common structure for the generic description of products that can be used across sectors, the ‘product’ ontology, from which all regulatory ontologies can inherit, makes it easier to reuse data from one sector in another. The alternative approach, which would consist in defining sector-to-sector mappings for each pair of regulatory ontologies, would require exponentially increasing effort as the number of regulatory ontologies increases. This exponentially increasing work is avoided by offering the possibility to align each regulatory ontology with a single upper-level ontology. Thus, the ‘product’ ontology is what will make cross-sectoral semantic interoperability easier in the future by allowing for easy reuse and alignment.

While there is a huge body of work dedicated to the design of cross-sectoral data models or ontologies for products, a non-exhaustive review of which is provided in section 3.4.1, in the case of the DPP system, this ‘product’ ontology should focus essentially on the modelling needs of upcoming regulatory ontologies. Existing data models and ontologies, which are all widely deployed in industry, should all be able to easily map data towards these regulatory ontologies. As cross-sectoral information requirements related to ESPR will certainly evolve over the coming decades, the DPP system ‘product ontology’ can grow and adapt as required.

3.3.2 Event ontologies and data models

Event ontologies are formal representations of events in a particular domain, capturing their essential attributes, relationships, and semantics. These ontologies provide a framework for describing and understanding events, facilitating interoperability, data integration, and reasoning across diverse applications and domains. The Event Ontology[12] [Raimond 2007], a W3C recommendation, provides a general-purpose framework for modeling events across different domains. It defines foundational concepts and properties related to events, such as event types, participants, temporal aspects, causal relationships, and spatial locations. It serves as a basis for developing more specialized event ontologies tailored to specific application areas, promoting semantic interoperability and knowledge sharing. Another generic event ontology is the Linking Open Descriptions of Events (LODE) [Shaw 2009] focusing on aspects of events.

In the product-modeling domain, event ontologies help in representing the lifecycle of products, including manufacturing processes, supply chain operations, and consumer interactions. For example, the ontology presented in [Solanki2014] focuses on representing supply chain events using Semantic Web technologies. In this work, the authors propose an ontological model for representing EPCIS[13] (Electronic Product Code Information Service) events on the Web of data. EPCIS 1.2 was approved as ISO/IEC 19987:2017. EPCIS events, recorded and registered against EPC tagged artifacts, encapsulate the "what", "when", "where", "why" and "how" of these artifacts as they flow through the supply chain. The ontology provides a scalable approach for the representation, integration, and sharing of EPCIS events, with the aim to provide a standardized vocabulary for describing various types of supply chain events, such as shipment arrivals, order placements, and inventory updates. By leveraging linked data principles, it enables the integration of supply-chain event data across heterogeneous sources thereby facilitating interoperability, collaboration and exchange of EPC related data across enterprises on a Web scale. Later, in [Solanki2015], the authors propose a provenance-aware framework driven by the Semantic Web and linked data principles for representing and sharing EPCIS data on the web. Traceability is at the core of the framework, implemented through the automated generation and validation of linked pedigrees using data from the pharmaceutical domain. By incorporating provenance information into supply chain events, transparency, accountability, and quality control, supporting regulatory compliance and risk management are enhanced.

In 2022 GS1 published the EPCIS 2.0 standard, including a data model for visibility event data in which the XML, JSON and JSON-LD syntaxes are supported, as well as capabilities of sharing sensor data (the "how" dimension), certification details, and the ability to use product identifiers encoded as GS1 Digital Link, or the equivalent draft standard ISO/IEC DIS 18975. EPCIS 2.0 is intended to be used in conjunction with the Core Business Vocabularies (CBV) 2.0 standard which provides definitions of data values that may be used to populate the data structures defined in the EPCIS standard. EPCIS 2.0 and CBV 2.0 are also known as ISO/IEC 19987:2024 and ISO/IEC 19988:2024.

3.3.3 DPP stakeholder ontology

The ESPR Article 8, 2.(f) lists "*the actors that are to have access to information in the product passport and to what information they are to have access, such as customers, manufacturers, importers and*

[12] https://semanticweb.cs.vu.nl/2009/11/sem/.

[13] The Electronic Product Code Information Service (EPCIS) is an EPC global standard, that aims to bridge the gap between the physical world of RFID –a generic term for all methods of tagged product identification- tagged artifacts, and information systems that enable their tracking and tracing via the Electronic Product Code (EPC).

distributors, dealers, professional repairers, independent operators, refurbishers, remanufacturers, recyclers, market surveillance and customs authorities, civil society organisations, researchers, trade unions, and the Commission, or any organisation acting on their behalf;"

There is clearly a need to provide clear definitions of the different parties that should be granted access rights to specific data element of the DPP in both read and write modes, even if these definitions will likely have sector-specific variations. Further, as the European Commission is actively preparing the adoption of ESPR implementing acts setting out procedures to issue and verify the digital credentials of economic operators and other relevant actors that shall have access rights to information included in the product passport, these definitions will certainly play an important role in these procedures.

3.3.4 Other cross-sectoral ontologies

In this section, we list a number of other potential ontologies that could be used, in the future, across the different sectors targeted by the different ESPR Delegated Acts.

3.3.4.1 LCA ontology

Several groups have proposed ontologies for life-cycle assessment (LCA). Earthster, an open-source software tailored for LCA linked data applications, firstly introduced the Earthster Core Ontology (ECO) [Epimorphics 2010, Sayan 2011]. Despite its development, Earthster encountered limited community support, leading to its cessation in 2011. Concurrently, independent efforts resulted in a semantic representation around the US Life Cycle Inventory database [Bertin 2012], a refined model of refinery operations [Takhom 2013], and an ontology dedicated to product manufacturing [Zhang 2015]. However, these initiatives lack a unified formal foundation, which is crucial for ensuring interoperability [Janowicz2014]. Later in [Janowicz 2015, Yan 2015], the authors proposed an ontology design pattern for the semantic description of the key elements of a life cycle inventory, namely the LCA ODP, coupled with the representation of an LCI spatiotemporal scopes, namely STscopes ontology. This work continued until 2016, during which both ontologies were employed at the core of a consensus model for LCA semantic catalogs in [Kuczenski 2016]. The consensus model was used to derive, from a group of diverse inventory data from difference data sources such as Ecoinvent and Gabi, "semantic catalogs" as linked open data (LOD) in the semantic web. Although this has resulted in the translation of a large number of datasets found across well-known databases into linked graph data, however, neither the ontology nor the source codes are available for the public for replication, beside the fact that the work has stopped after 2016. Later, in [Ghose2019], a Danish team built upon the work in [Janowicz2015, Yan 2015] with the purpose of facilitating and promoting the integration of diverse LCSA sources. Their work proposed the BONSAI (big open network of sustainability assessment information) ontology as an extension of both the LCA pattern ontology, and the STscopes ontology. This was followed by contributing with a data integration workflow for the translation of some LCSA datasets, e.g. the Exiobase[14], into RDF graphs and Input/output models compliant to BONSAI [Hansen 2020]. The work continues to add value to the LCA community towards the Semantic Web and Linked Open Data in which discussions on the status and opportunities for FAIR data sharing of LCSA data take place in [Ghose 2024]. Indeed, additional ontologies have emerged focusing on the semantic representation of LCI/LCA, exemplified by works from researchers such as [Blomqvist 2023] and [Matsokis 2010].

[14] https://www.exiobase.eu/.

3.3.4.2 CSR ontology

Similarly to LCA data, emerging Corporate Sustainability Reporting (CSR) requirements (e.g., EU CSRD) may require the exchange of interoperable data in standardised formats. In the future, this data may potentially be linked to the DPP.

Ontologies could indeed be a useful tool to address the current lack of a common accounting understanding of regulations about social and environmental performance disclosure. In addition, there is no generally accepted accounting standard and reporting framework for reporting CSR information. This difficulty is multiplied by the fact that CSR requirements vary in different parts of the world. According to [Yaldo 2014], ontologies can be used to resolve these issues: firstly, the ontology can be used as a shared vocabulary to disambiguate terminology for sustainability reporting among multiple organizations; secondly, the ontology can be used as a knowledge base to enable computer software to automatically generate sustainability reports. To this end, the authors have developed an ontology for CSR reporting based on the Global Reporting initiative (GRI) G4 Sustainability Reporting Guidelines[15]. The conceptual model has been formalized using Unified Modeling Language (UML) and encoded using OWL. Interested readers are referred to the systematic literature review on conceptual models for CSR performed by [Sousa Santos 2019].

3.3.4.3 D-SI meta data model

In 2019, a meta data model for the secure, unambiguous and unified exchange of metrological data was defined by the European EMPIR project in which all physical processes are described using only seven base units (second, metre, kilogram, ampere, kelvin, mole, candala) [Hutzschenreuter 2019]. These base units are themselves defined using only seven physical constants (speed of light, Planck constant, electron charge, Boltzmann constant, Avogadro constant, caesium frequency, luminous efficacy of monochromatic radiation of frequency 540×1012 Hz, K_{cd})[16] with fixed numerical values and on other base units that are derived from the same set of constants. These definitions lead to unprecedented clarity in the transmission of measurement data according to the specifications of the Système International d'Unités (SI), a crucial requirement in the context of automated machine-to-machine interfaces.

3.4 Potentially useful ontologies for the DPP

This section presents a non-exhaustive list of existing data models and ontologies which may be used in the context of the DPP, either in a cross-sectoral manner or for specific sectors. The authors welcome all input which could be used to improve this section.

3.4.1 Data models and ontologies related to products

Many collaborating organizations, or even different departments within an organization, frequently develop and maintain their own product models. This situation leads to (a) information duplication and its associated problems, (b) the inability of traditional models to handle the multitude of variants in today's markets, and (c) the need for an integrated product model to be shared by all participating organizations in global supply chains (SCs) or within an organization's different departments. One direction towards addressing such a problematic is by means of an ontology approach providing a common upper-level model according to which the different product models can be integrated.

[15] https://www.globalreporting.org/
[16] https://en.wikipedia.org/wiki/SI_base_unit

There is a large body of work dedicated to the design of generic or cross-sectoral data models or ontologies for products. Typically, each of these works focus on modelling different facets of a product:

- the product's supply-chain,
- the product's design parameters including its links to production information,
- how the product is assembled from its subcomponents,
- business processes for placing the product on the market, including logistics information,
- downstream activities potentially related to circular economy.

These data models often rely on specific classification systems which again are related to the part of the value chain which is the focus of the model. Thus the semantic model that is proposed and that includes the product attributes will highly depend on the product class and the focus in the value chain. Below, we provide a glimpse of existing data models and ontologies related to products. The authors welcome input on any missing data model or ontology of high relevance to the DPP.

The TOVE (Toronto Virtual Enterprise) project [Belli 1992] defined a set of ontologies for the representation of enterprises, among which one ontology described product related concepts. This ontology adopted traditional representations of variants and specifically considered products obtained as assembled components. In [Patil 2005], an ontology-based framework for enabling semantic interoperability among product data was proposed assuming that a product's data semantics are defined by any interacting application or dataset. Another formally specified domain ontology for product modeling is the PRoduct ONTOlogy (PRONTO) which represents a product's information via two hierarchical levels: the abstraction hierarchy and the structural hierarchy [Vegetti 2011].

GoodRelations: The popular Schema.org vocabularies offer an entry for 'Product' which can be used liberally to describe any offered product or service[17]. For example: a pair of shoes; a concert ticket; the rental of a car; a haircut; or an episode of a TV show streamed online. This term uses terminology from the GoodRelations ontology for E-Commerce, created by Martin Hepp [Hepp 2008]. GoodRelations is a vocabulary for publishing machine readable data about the details of a product and/or service in a way easily reused by search engines, mobile applications, and browser extensions. GoodRelations is being used by 10,000+ small and large shops world-wide.

GS1 Global Data Model (GDM): Published since 2020, GDM defines a consistent set of product attributes needed to list and sell products in a given market [GDM 2024]. It is most frequently used in the fast-moving consumer-packaged goods and food and beverage sectors between brand owners and retailers, wholesalers, e-tailers and consumers. Both global and regional attributes are defined to address the fragmentation of global commerce and specific data needs. The GDM also includes the Business Names, Business Definitions, Examples and Usage Statements that have been developed within the Attribute Definitions for Business (ADB) Standard. This data is closely aligned with the GDM, the ADB is a separate standard and not part of the GDM Standard. In 2023, the GDM was augmented by a complementary standard on market stages which addresses the problem of data completeness and accuracy over the various phases of the product lifecycle (or market stages) such as listing, ordering, moving, storing, and selling the products to consumers.

Asset Administration Shell: Since 2017, a Plattform Industrie 4.0 Working Group has developed the Asset Administration Shell (AAS) standard for the digital representation of assets to facilitate the interoperability of Industrie 4.0 components and digital twins [I4.0 2022]. The AAS is the logical

[17] https://schema.org/Product which is reused by the GS1 web vocabularies https://www.gs1.org/voc/Product

representation of a simple component, a machine or a plant at any level of the equipment hierarchy or supply chain along the whole lifecycle of assets. AAS models can be created both for asset types and asset instances. AAS users, both humans and machines and including the asset itself, can update the information of the AAS during the lifetime of the asset until its disposal. The structural principles of the AAS are defined in the AAS formal UML metamodel (see Figure below). Optionally, an AAS can refer to existing dictionaries of semantic properties (e.g., ECLASS, IEC 61360 series). These standardised ontologies propose views which are a defined set of elements selected for a specific stakeholder, e.g. for a machine operator. Several different formats for exchanging the AAS are provided: XML, JSON, RDF, AutomationML as well as an OPC-UA information model. AAS models are exchanged either through standardised file(s) exchange or via a standardized API. The IEC 63278-series describes the specification of AAS.

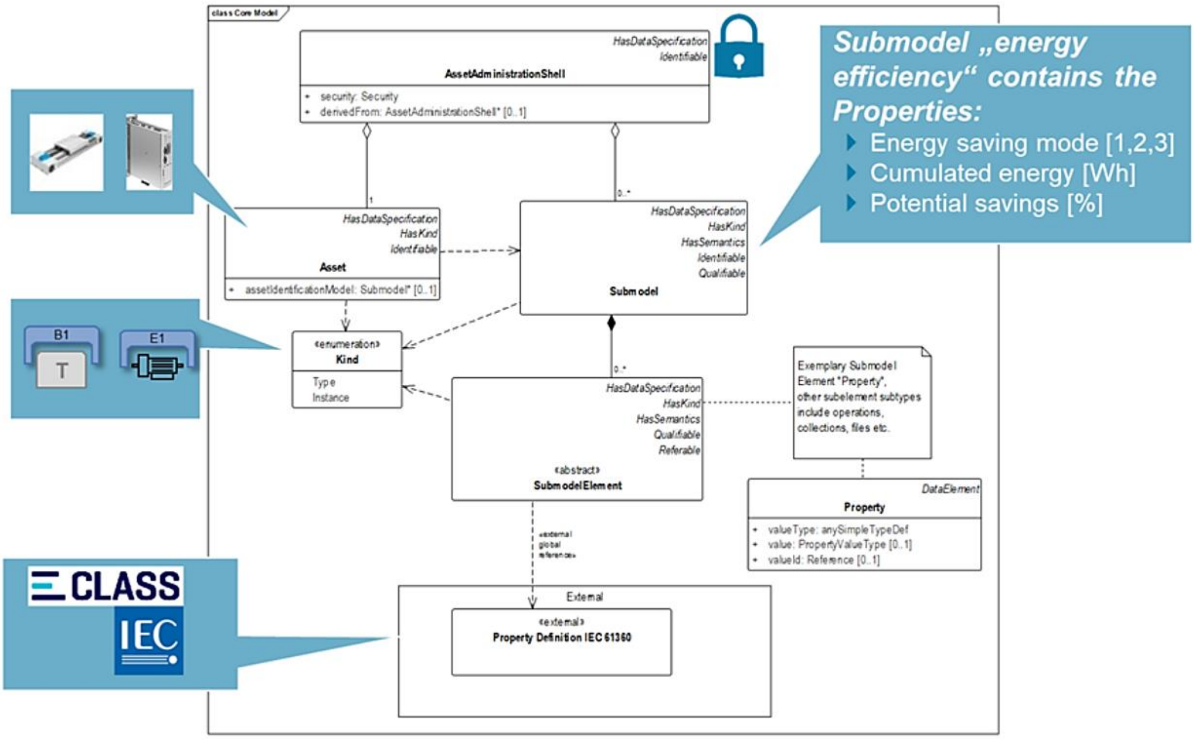


Figure 15. AAS metamodel overview (Source: [OPC Foundation 2024])

FEDeRATED: Launched in 2019, the FEDeRATED project has developed a semantic data sharing architecture to enable data sharing among various pre-existing logistics platforms and stakeholders [FEDeRATED 2024]. The aim is to constitute a so-called ‘federated network of platforms’ or Mobility Data Space (for freight) in which government authorities (customs) are also potential users. At the heart of the architecture is the semantic model, which consists of an upper-level ontology that is used for alignment of existing transport mode, cargo, document, and/or physical infrastructure data models and ontologies. It allows parties to share information using common semantics as defined by these aligned ontologies without any prior agreement on which data to share (‘plug and play’). The data-sharing architecture is developed and validated with various Living Labs in different EU Member States. The results of the FEDeRATED project are to be adopted as recommendations to the European Commission Directorate-General (DG) MOVE for the Mobility Data Space by the Digital Transport and Logistics Forum (DTLF), an expert group of Member State authorities, Industry Associations, standardization bodies, data-sharing platforms, and individual enterprises chaired by DG MOVE[18]. The FEDeRATED core semantic model (also called upper ontology) can be used beyond the mobility domain to address other domains related to physical objects (e.g. retail, wholesale, production). An alignment and demonstrator for Digital Product Passports has already been made (see section 4.3).

Consumer Goods Forum: Launched in 2020, the Product Data Coalition of Action of the Consumer Goods Forum aims to address weaknesses faced in today's data exchange processes[19]. To this end, one of its work streams focuses on new ways to exchange data. In this context, it is developing a foundational Global Data Model which is called the Interoperable Modular Data Exchange Framework (https://imde.io/). The framework will enable machine–to-machine data exchange across the entire value network, allowing economic operators to exchange data with both upstream and downstream business partners, and aims to minimize the cost for collecting, using and distributing data while at the same time improving data quality (consistency, relevance, completeness, accuracy and timeliness).

3.4.2 Data models and ontologies related to circular economy

Started in 2018 by the Ministry of Economy of Luxembourg and +ImpaKT, the Product Circularity Data Sheet (PCDS) initiative addresses the difficulty for industry actors to obtain reliable data on the circular economy properties (e.g. recycled content in %, presence of harmful chemicals, design-for-repairability, etc.) of a product [Mulhall 2022]. Here the term product can be understood at any level of a supply-chain. Indeed, faced with the complexity of real-world supply-chains, where each economic actor has a large number of suppliers and clients, achieving transparency along the supply-chain is a major challenge. The aim of the PCDS is to develop into an international standardized dataset of auditable statements which might serve as a basic data source for determining how 'circular' a product is. To this end, the PCDS standard is under development in the ISO/TC 323 – Circular Economy (see ISO 59040) and is expected to be published in 2024.

The PCDS is designed as a set of standardized statements associated to true/false values stored in a machine-readable format [PCDS 2022]. Inspired by the well-established Material Safety Data Sheet system (MSDS), the true/false statement format helps to resolve the conflict between confidentiality and the need for transparency since each statement can be transparently stated as true or false without having to disclose to every party the manufacturer's trade secrets[20]. In addition, it helps to reduce work and facilitate automation of document creation, exchange and reading. The IT system supporting the PCDS, while currently under design, will ensure the accessibility of the PCDS data by all relevant stakeholders (e.g. platforms, suppliers & customers in the supply chain, third-party verifiers) and focus on PCDS data integrity and exchange efficiency. While unique PCDS identifiers will be issued by a mandated organization, no central PCDS repository will be created, although other platforms might elect to develop repositories for their own markets. Thus, each economic actor generating a PCDS will be responsible for storing the PCDS on its own premise, making it securely accessible by other stakeholders, and ensuring the data integrity for its own PCDS. Several protocols are currently

[18] https://commission.europa.eu/about-european-commission/departments-and-executive-agen-cies/mobility-and-transport_en

[19] https://www.theconsumergoodsforum.com/end-to-end-value-chain/product-data/

[20] The standard PCDs allows each statement to be accompanied by a persistent identifier, linking to relevant offsheet free-form information that provides further details and supports the statement, including, but not limited to, applicable regulations, standards and assessment methods.

under development: an efficient data exchange protocol (including the data format for the exchange, e.g. XML and JSON), a methodology for creating a PCDS from data contained in multiple PCDS sheets and finally mechanisms for informing relevant stakeholders when a PCDS revision is available.

In [Li2023], the authors aim to provide an overview of general ontologies applicable on the cross-industry domain of circular economy (CE). For their study, out of the multiple factors to take into account in the study of CE is a product's life cycle as a necessary step to design and enable a CE model. As such, they investigate some ontologies of product life cycles. For example, the Coordinated Holistic Alignment of Manufacturing Processes (CHAMP) ontology [Smith 2018] represents knowledge of product life cycles, and uses a number of existing ontologies such as BFO [Arp 2015] and the Common Core Ontologies [Rudnicki 2019]. Other ontologies that allow for the representation of a product life cycle are the Additive Manufacturing Ontology (AMO) [Ali 2019], the BONSAI-core ontology [Ghose 2022], the Building Product Ontology (BPO) [Wagner 2019], etc. Following this review work, the authors develop a network of core ontologies for the CE in [Blomqvist 2023].

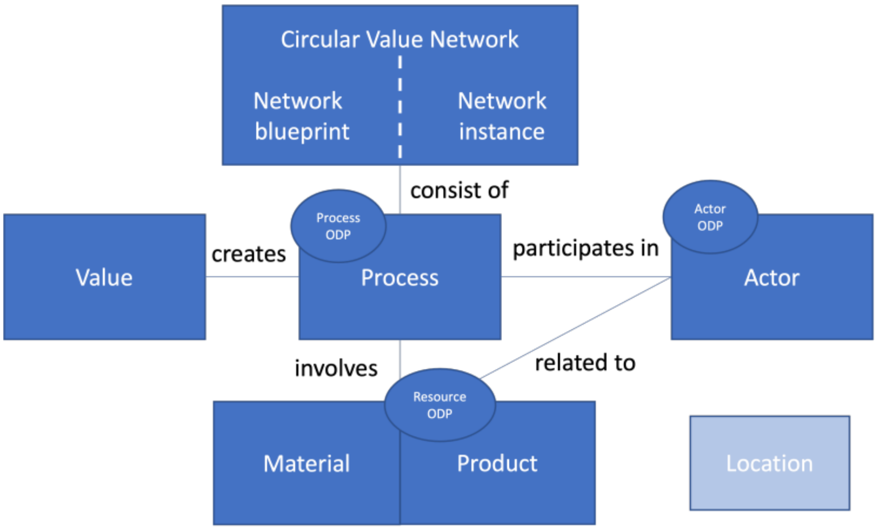


Figure 16. Core topics of the ontology network proposed by [Blomqvist 2023]. Source: [Blomqvist 2023]

This network of ontologies is used to illustrate a use case from the textiles sector. In the figure below, we see that the Product Circularity Data Sheet (PCDS) presented above, has been embedded as an information source attached to a product, here a specific shoe model, both of which being conceptualized as "resources". These resources are linked to an actor, here a footwear brand, which has a specific role, here issuer.

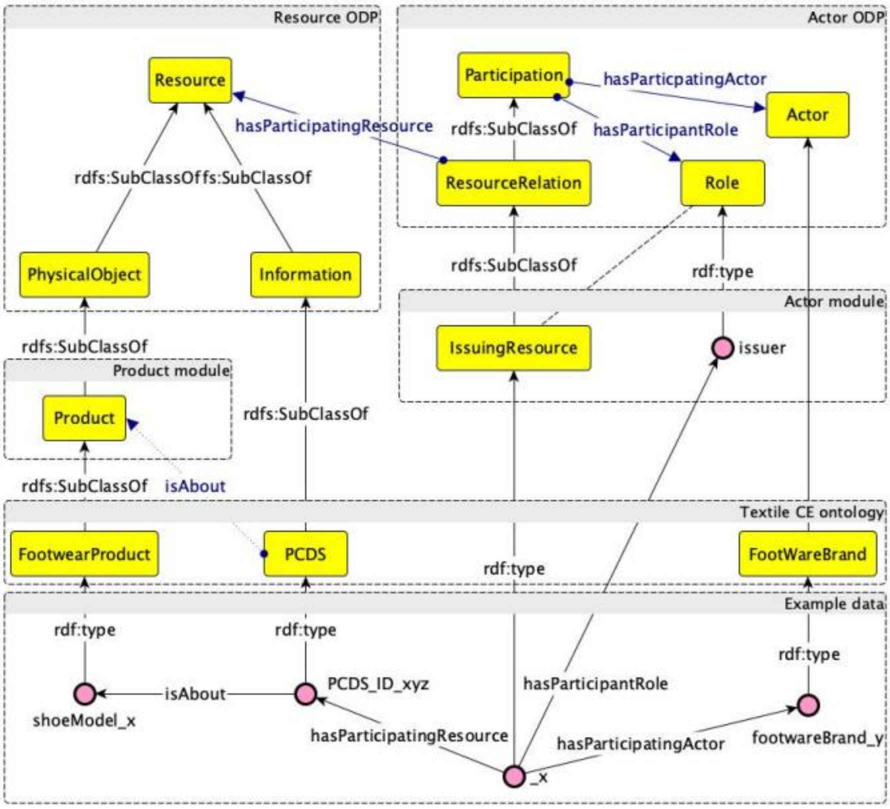


Figure 17. Example use of the ontology network modules in a textile use case. Source [Blomqvist 2023].

We observe that the root node of this graph is the token "_x". A similar graph could be drawn for a product DPP where the root node would be replaced by the reference to the unique product identifier.

3.4.3 Data models and ontologies related to batteries

BattINFO is an ontology of batteries and their interfaces developed by the BIG-MAP project, a Horizon 2020 project which ran from 1st September 2020 to 29th February 2024 [Clark 2021, Clark 2022]. BIG-MAP is part of the EU research initiative BATTERY 2030+, which aims to support the transition towards sustainable batteries. BattINFO has defined a common battery language to describe a range of battery chemistries, not only Li-ion, to support interoperability of data in battery research. BattINFO is itself based on the top-level European Materials and Modelling Ontology (EMMO), a multidisciplinary top-level ontology for applied sciences. The definitions included in BattINFO are based as far as possible on accepted standards defined by the International Union of Pure and Applied Chemistry (IUPAC) and aim towards the highest standards of scientific rigor and accuracy while reflecting current battery orthodoxy and dominant jargon.

Catena-X is part of Gaia-X, a European initiative that aims to establish an ecosystem in which data is shared in a trustworthy environment. Catena-X is Gaia-X's first implementation project. The goal of Catena-X is to provide an open data ecosystem for the automotive industry designed to create data chains that will enhance its members' value chains. Catena-X published in 2023 a draft Standard (CX – 0034) for a data model of a battery passport, aligned with the requirements of the Battery Regulation. The Catena-X model is expected to become very relevant in the automotive industry. An RDF interpretation of the Catena-X Battery Pass 3.0.1 Aspect Meta Model[21] was used as source ontology for the demonstration presented in section 4.3.

The **Battery Pass** project has published a Data Attribute Longlist for a battery passport aligned with the requirements of the Battery regulation [Battery Pass 2023]. This list has been transformed into an ontology and heuristic data model that is described in their recently published technical guidance report [Battery Pass 2024] and specified in their ongoing software demonstrator. A platform independent machine-readable version of this model is currently being designed. This work is closely aligned with that of Catena-X to ensure interoperability of these two similar initiatives.

The **International Material Data System (IMDS)** is the automobile industry's material data declaration system launched in 2000 in order to ensure compliance with the European End-of-Life Vehicle (ELV) Directive of OEMs and their suppliers. IMDS is a centrally managed system which collects data on all materials in the automotive production supply chain. It enables the participating companies to comply with worldwide ELV directives, REACH SVHC, Relative Risk Reduction (RRR), and similar regulations. The data quality standard achieved in IMDS could facilitate compliance with DPP data requirements by REOs in the EV battery sector.

The **BVCO** (Battery Value Chain Ontology) is being developed in Fraunhofer Institut für Silicatforschung (ISC) and implements knowledge in the battery production area, from raw material mining to battery manufacturing and battery recycling [Stier 2024]. Differently from BattINFO which focuses on the internal components and chemical processes, BVCO is dedicated to the higher-level process chains for material processing and manufacturing. The battery value chain is modelled as production steps and the battery itself is modelled as a system, as described in Figure 18. . The ontology also based on EMMO.

[21] https://github.com/eclipse-tractusx/sldt-semantic-models/tree/main/io.catenax.battery.battery_pass/3.0.1

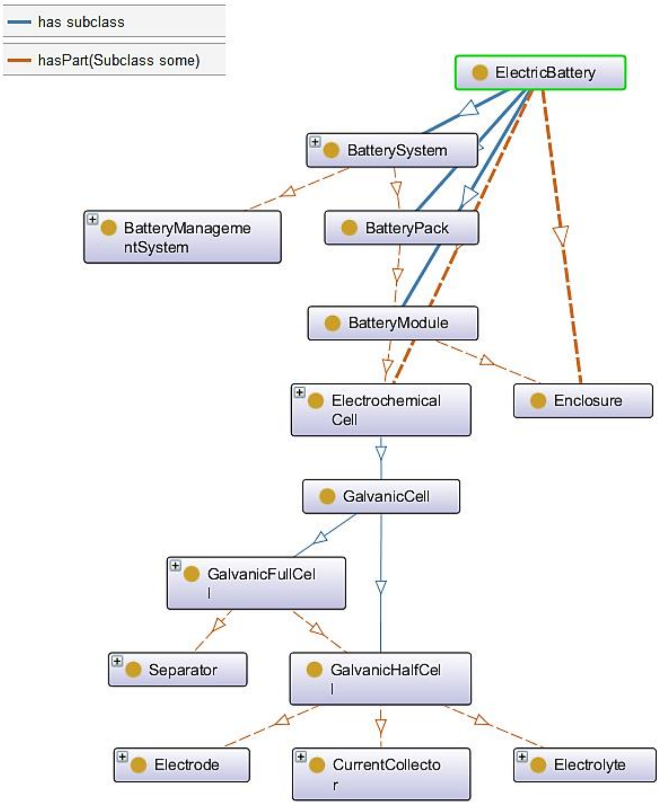


Figure 18. BVCO system view of an electric vehicle battery[22].

The **ProZell** battery ontology, proposed by the German battery research cluster ProZell, targets the modeling of lithium-ion battery materials and electrode-to-cell production process data [Mutz 2022]. By connecting chains of unit processes to raw materials and intermediate products (defined as 'items') related to battery cell production, the ontology enables the linking of analytical characterization methods to items, facilitating visualization, correlation, and predictions during battery production. The ontology has been designed to be mapped to the terms used in higher-level ontologies such as BattINFO, EMMO, and BVCO.

3.4.4 Data models and ontologies related to textiles

The EU-funded **TRICK** project, which is defining a traceability platform to enable verifiable claims related to textiles circularity and other sectors, recently published a review of data models and ontologies related to the textiles sector [TRICK 2022, Chapter 4.2.1]. From this survey, they have published an ontology, based on the eBIZ specification framework, adapted to their needs and which may have considerable synergies with the DPP [TRICK 2022b].

To date, the most comprehensive overview of data standards and classifications used within the textile industry is the Reference Guide on Code Lists and Identifiers in the Textile and Leather Value Chains published by UNECE in October 2022[23]. Its purpose "is to identify and describe code lists and identification schemes supporting the business processes and transactions for traceability and transparency in the textile and leather value chains." The UNECE Reference Guide shows that there is considerable coverage and overlap, but, given the publication date and the speed of change in the industry, standards focusing e.g., on circularity are missing. Furthermore, several sustainability-

[22] Source : https://github.com/Battery-Value-Chain-Ontology/ontology (accessed March 30, 2024)
[23] https://unece.org/sites/default/files/2023-10/Guidelines-ECE_TRADE_C_CEFACT_2022_INF1E.pdf

focused standard and certification systems which have means of identifying and storing data of certified products, facilities or processes, are not publicly available and are therefore not included.

Most of the standards that are publicly available have either machine-readable code list (short code with term) or are organized in formal data structures (e.g., XML, HTML, spreadsheet). Many have both. However, many of the largest and most widely used standards are kept behind a paywall, and so are not readily accessible to all users. Finally, often the term "classification system" is used instead of "data model" or "ontology" which creates uncertainty as to whether the approach is actually used to describe the properties of products or to simply to classify them. However, even product classification schemes provide general descriptions of eligible items for each category, even if this is in an unstructured form. For this reason, a number of them are included below, an unfortunately far from exhaustive list which focuses on Western Europe.

The **EAS** (European Article System) is used for shoes by most of the shoe industry and retailers. It is maintained by associations and paid by membership fees.

The **FEDAS** classification system is widely used for sporting goods and is accepted by BTE (Bundesverband des Deutschen Textil-, Schuh- und Lederwareneinzelhandels – Federal Association of the German Textile, Shoe and Leather Goods Retailers). A revision is planned in 2024.

The **BTE** classification system is used by many retailers for fashion retail mainly in German-speaking countries.

Refashion, the French textile industry's eco-organisation for clothing, household linen and footwear, has a classification of product categories.[24]

The **LCECAT** classification system is provided by the product data platform provider of the same name for different articles including fashion in the Netherlands.

Textile Exchange has a material classification system (ASR-2013), which aims to provide standardized codes for raw materials, processes, product categories and product details for the textile supply chain.[25]

GOTS (Global Organic Textile Standard) and Textile Exchange jointly developed a classification on materials, processes, and products for the harmonized application of their policies for scope and transaction certificates.[26]

The **GINETEX** care label standard is a material classification scheme.

The **circularity.ID** Open Data Standard and ontology for textiles and fashion, Version 4.0 (soon V5.0) was developed by circular.fashion for circularity in textiles and fashion in collaboration with a wide group of industry stakeholders. It provides a data protocol and ontology to make product data available for circularity checks and for textile sorting, reuse, and recycling.

[24] Refashion classification of product categories, URL: https://refashion.fr/pro/sites/default/files/fichiers/Product Classification File - textile-EN_V2.xlsx

[25] Textile Exchange, Materials, Processes, & Products Classification — ASR-213-V1.1-2021.05.01, URL https://textileexchange.org/app/uploads/2020/10/ASR-213-V1.1-Materials-Processes-and-Products-Classification.pdf

[26] Global Standard gGmbH & Textile Exchange: Materials, processes & products classification, version 1.0, May 2021, URL: https://global-standard.org/images/resource-library/documents/certificate-policies-and-templates/Materials_Processes_and_Products_Classification_v_1.0.pdf

The **Circular Product Data Protocol** (CPDP) was developed by a large consortium of industry stakeholders under the leadership of EON and proposes a circularity-focused data model for product and material-level data. The CPDP calls upon and leverages existing standards from GS1, Sustainable Apparel Coalition, Open Supply Hub, UNECE, etc.

The **Global Textile Scheme** (GTS) classification system and meta-standard has been available since summer 2023. It includes a data model with well-defined semantics and applies to all sectors of the textiles value chain. Its main use it the translation of existing product data of a data sender into a machine readable format which can be decoded by the data receiver into their own natural language and mapped to their own data formats. GTS integrates several classification systems such as EAS, FEDAS, BTE, and DTB. The raw material classification of GTS is aligned to the raw material classes of Textile Exchange and GINETEX. GTS covers components, demand data (between brands and suppliers) and offers the management of a broad range of product-related certificates.

The **CISUTAC** project has recently published a decision support tool[27] providing recommendations on necessary datapoints for textile sorting. The tool uses various post-consumer textile product attributes such as condition, construction, chemical content, etc. to comprehensively evaluate the optimal route to either reuse, repair or recycling for the post-consumer product.

The **UNECE-UN/CEFACT**, through its recent "Product Circularity Data Use Case for textiles and leather – Garments and footwear products" project, has defined a Conceptual Product Circularity Data Model focusing on tracking and tracing for circularity. [UNECE 2024] The focus of the information model is on data supporting circular business models for a circular economy. It is meant to be seamlessly integrated into the scope of the DPP, as shown in Figure 19. It is also meant to be used over the full value chain, from cradle to grave, with the exchange of product circularity data over the pre product-consumption phase of the supply chain to the post product-consumption phase.

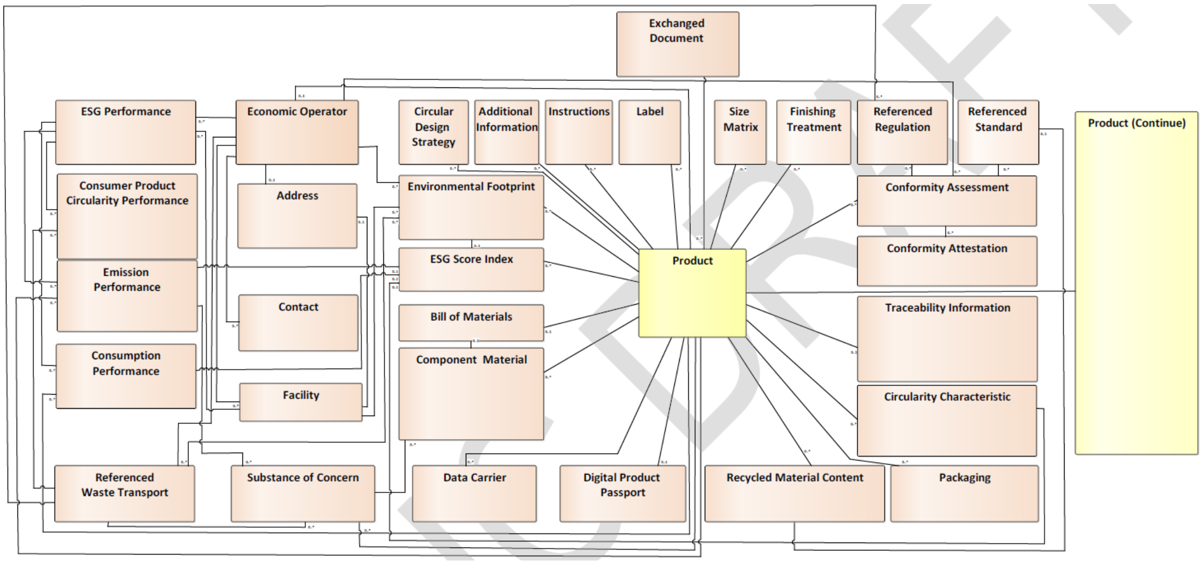


Figure 19. Conceptual Product Circularity Data Model. Reproduced from [UNECE 2024]

This model includes the definition of many circular economy actor roles, as shown in the table below, but only 2 business process roles for the actual data exchange, the Requestor and the Responder:

[27] https://www.cisutac.eu/solution-post-consumer-textile-waste (accessed April 9, 2024)

Business Process Role	Product Circularity Data Requestor Product Circularity Data Responder
Supporting Role	Farmer, Breeder, Spinner, Weaver, Designer, Manufacturer, Subcontractor, Brand Owner, Retailer, Trader, Wholesaler, Waste Exporter, Waste Importer, Governmental Authority, Recycler, Waste Collector, Waste Aggregator, Finishing provider, Tanner, Raw fibre treatments provider, Slaughterhouse, Warehouser, Transporter, Third Party Reseller, Product Identity Platform, Repair Provider, Retailer, Online Market Place, Agent, Consumer, Waste Sorter, Refurbishment Centre / Refurbisher, Collection Centre, Waste Disposal Provider, Third Party Manufacturer, Waste Sorter, Waste Incineration Facility, Landfill Site, Industrial Composting Facility, Waste Pre-Processor, Other Supplier, Tier-1-n Supplier/Manufacturer , Provider of IDs, Customer-Consumer

Figure 20. Circular Economy actor roles defined in [UNECE 2024]

3.4.5 Data models and ontologies related to electronic products

ETIM[28] is an international classification standard for technical products which also includes electronics finished goods. The ETIM product classification model provides the structure for standardized (technical) product data exchange between parties. The standard facilitates the listing and publishing of complete product data with the aim of making it easier to identify the technical products required by the user. ETIM has a flat organizational structure and the main focus is the definition of product classes and their features which are structured according to their importance as well as key aspects. A feature is clearly described by description, feature type, unit and/or value.

ECLASS[29] is a standard for the hierarchical classification and grouping of products and services designed to support their unambiguous description and the digital exchange of product master data. ECLASS develops different standards from industries such as electrical engineering, automation, process control engineering, food, automotive and office supplies. The ECLASS Standard currently offers about 48,000 product classes and more than 23,000 unique properties that can be collectively categorized with only four levels of classification: Segment, Main Group, Group and Subgroup. ECLASS will soon publish an ECLASS as RDF specification, which will be the first official ECLASS as RDF specification including all ECLASS Structural Elements. This allows the usage of ECLASS in, e.g., W3C Web of Things (WoT) Thing Description (TD) and AAS as RDF.

IEC Common Data Dictionary (IEC CDD) is an International series of Standards for semantic properties in the form of structured descriptions or online databases (IEC 61360-4 DB, IEC 61987 series, IEC 62720, IEC 62683, IEC 63213) of concepts for all industrial/technical domains (electrotechnical and non-electrotechnical; e.g. industry, building, energy, healthcare, …) based on the information model of IEC 61360-2. This dictionary may be used to define ontologies for use in the field of electrotechnology, electronics and related domains. This dictionary is currently being revised to provide additional properties needed for the evaluation and improvement of the environmental impact of products throughout the supply chain (IEC TS 63058:2021).

RePlanIT is an ontology for the sharing of ICT product data between manufacturers, sustainability experts and technology providers for the circular economy in view of future DPPs for ICT devices [Kurteva 2024]. The RePlanIT ontology for ICT DPPs captures knowledge on several levels - ICT device, hardware components, materials and the circular economy itself. RePlanIT's specification is based on

[28] https://www.etim-international.com/classification/model-information/

[29] https://eclass.eu

a literature survey, interviews and inputs from domain experts from both industry and academia. The use of the ontology has been successfully validated in a real-world scenario.

The **ITU-T/ETSI L. L.D4PI**[30] work group is currently elaborating a draft recommendation "An information model for digital product information on sustainability and circularity". The proposed Recommendation will provide a collection of information items organised to represent circularity, environmental sustainability and health information about ICT products and inform any actor during the product lifespan: design, manufacturing, usage phases including changes over the lifespan, until final recycling as e-waste. This work will determine the information items, to be represented in digital format, about ICT product information, either as individual products or grouped by model, batch, etc., common to all ICT products or specific to certain product categories. The objective is that this standard is technically aligned with corresponding work at ETSI. This standard will undoubtedly be linked to the ITU-T L.1023 standard on "Assessment method for circular scoring" which proposes criteria for the assessment of circularity and definitions of margins of improvement levels of ICT goods.

eReuse.org, a program originally funded by the European Union with the goal of improving the circularity of electronic devices, proposes an ontology developed by UPC in collaboration with social ICT refurbishers and recyclers in Catalonia [Talavera 2016]. This ontology is used in a software architecture that supports the management of second hand devices (such as desktops, laptops, and smartphones) and creates a global traceability standard for ICT devices.

The **CE-RISE (**Circular Economy Resource Information System)[31] Horizon Europe project aims to create an information system and integrate digital product passports to share detailed information on electronic products. The purpose is to provide stakeholders, including consumers, with a better understanding of the green credentials of electronic products and how to preserve critical raw materials through the reuse, repair and recycling of these items. To this end, the project is actively developing a vocabulary in order to create a common language to specify the circular properties and circular strategies for products.

4 DPP system video demos

Four video demos were developed during the project with the aim of illustrating a **specific feature of the DPP system** as proposed by CIRPASS. Each video was designed to be short, concise and to carry a clear message with wording remaining at a **low technical level.** While specific solutions were shown for example, wording was adapted to avoid giving the impression that the consortium is endorsing specific solutions. Each video script clearly explained that the video is provided for demonstration purposes and that many alternative solutions are possible.

4.1 DPP consumer app video

The DPP system architecture proposed by CIRPASS offers the possibility of enriching the product information data model with limitless content. This offers the possibility to not only link both mandatory and non-mandatory information to the same product identifier, but also to progressively enrich both the mandatory and non-mandatory content when either regulatory or business needs evolve. The DPP consumer app video was created for the following reasons:

[30] https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=18559
[31] https://ce-rise.eu/

- show a key feature of the DPP system which includes this flexible data model;
- show the complementarity of mandatory DPP data and non-mandatory product information, both before and after sale;
- explore how this information will create valuable services for consumers;
- explore how consumers may want to interact with the DPP in the future.

This video is available on the CIRPASS youtube channel:
https://www.youtube.com/watch?feature=shared&v=sLwVL4KbDJM

Figure 21. Extract from the DPP Consumer App video demo

About the demo:
The video shows a consumer interacting with an illustrative mock-up Customer efficiency App for Product Life Cycle & Circularity[32] which can read and display DPPs for products both before and after the sale of the item. The App has 3 main sub-domains:

1. The "Consumer" domain where a user can add and manage product information.
2. The "Mandatory public DPP consumer data" domain which shows structured product information according to mandatory DPP requirements.
3. The "Brand/Producer Product" domain where a responsible economic operator issuing the DPP can link more structured and/or unstructured product information (e.g., product website).

The app serves as a wallet and organizer for products and makes it easier for the consumer to perform precise product information searches and make responsible purchasing decisions and, after purchase, upload receipts, photos, files, and notes. The app shows that, irrespective of the data sources, moving from mandatory DPP data to the brand's additional information is seamless.

Key concepts illustrated:

- The App shows that mandatory DPP data remains even after brand product information has disappeared, as commonly happens when brands place newer products on the market. This shows the clear value of the DPP in a circular economy. Structured product data in

[32] Video footage kindly provided by https://www.mindworks.industries/project/dpp/

standardized formats will support consumers decades after the product has stopped being sold.

- The video shows that mandatory DPP data (structured; product lifecycle support) and the brand's product information (creative; sales support) can coexist in harmony and are highly complementary, both before and after sale.
- To limit confusion between mandatory and non-mandatory product information, there is likely a need to define structured data displays for mandatory product information.
- The DPP, through the App, makes it easy to share product information with maintenance personnel, online secondary marketplaces, and friends and family, all activities which are crucial in a circular economy.
- A combination of the brand's product information, mandatory DPP data and the consumer's personal information creates a sense of unity and empowers DPP usage.
- The App facilitates the interactions between the consumer and the brand and can support producer extended responsibility schemes by helping consumers with easier and more comfortable self-service, accessing repair services, reuse and recycle.

4.2 DPP resolver video

The DPP system architecture proposed by CIRPASS makes heavy use of "*resolvers*". A "resolver" is a commonly used web service that receives incoming requests, formulated in the form of a URI, and then redirects the request, in the sense of RFC9110, to the appropriate target (another URI) or targets (a list of URIs). The DPP resolver video was created for the following reasons:

- Illustrate the resolver concept in the context of the DPP system;
- Introduce the concept of "link types" that are used by the resolver and their potential use in the context of the DPP system;
- Show that the DPP system response to the reading of a data carrier can differ depending on the tool used to read the data carrier;
- Provide testimonials on the ease of implementation.

This video is available on the CIRPASS youtube channel:
https://www.youtube.com/watch?feature=shared&v=vYE0UXtixuo

Figure 22. Extract from the DPP resolver video demo

About the demo:

This video makes ample use of the results from the ProPare project which is described at https://www.axfoundation.se/en/propare-a-global-standard-for-digital-product-passports.

The technical implementation details of the Propare prototype are described at https://gs1.se/digitala-%20produktpass/propare-digital-product-passport-solution-guide/

The ProPare project was carried out in 2023 in collaboration between non-profit actors Axfoundation, Ecolabelling Sweden AB, GS1 Sweden and the Swedish Trade Federation, as well as trading companies Ahlsell, Dagab, Mio and technology developer Blue Cromos. The focus of this project was on the DPP system and not on the DPP content. The objective of the project was to verify that a working infrastructure for DPP, compliant with the draft ESPR, could be established built on existing web technologies. For this reason, the prototype offers only a very simplistic view of what a DPP could look like. Here, GS1 standards were used for product identification and for building web resolvable links. For each of the three products, the project involved pulling data from two data sources:

-From the brand owner for general product data

-And from an ecolabel organization for verification of product certification status.

The products used in the demo are identified at model level with GTINs, which is the GS1 standard for product identification at model level. The GTINs are embedded in a web address which are encoded in GS1 Digital Enabled QR codes. This web address leads to a resolver capable of redirecting queries to one or more data sources using typed links. Here we defined two link types: a product information "*pip*" link type and a certification info "*certificationInfo*" link type.

The video shows what happens depending on the application that is used to scan the data carrier.

A dedicated app is used: A dedicated app is installed on a smartphone. When scanning the QR code with the app, it uses the link in the QR code to make a request to the resolver asking for all known links associated with the GTIN. The resolver responds back with the links it has, indicating the link type for each link. In the demo, this response returns three links:

-A link to the human readable default product page

-A link to machine-readable certification information

-A link to a machine-readable product information page

The app is designed to use the two links to machine-readable data to fetch the information from the two sources. It then presents it locally in the app. (Here, the data is encoded in the JSON LD format according to the GS1 web vocabulary.)

The default camera app is used: Scanning the same QR code with the phone's native camera app makes a regular web call to the resolver and is then redirected to the default human readable product page on the brand owner's web site.

Key concepts illustrated:

- A resolver can be used to combine data from different sources. This technique could be used to present both mandatory data and non-mandatory information.
- Different link types can be defined and used for different purposes, in particular to provide additional or differentiated data depending on the request. The request may concern different types of data or data appropriate for different roles in the circular economy (repairers,

recyclers, etc.) If role link types are used in the DPP system architecture, then their use must be defined and agreed upon (and likely standardised).

- Link types are not necessary for default access to public data for consumers.
- Similarly, dedicated apps should not be needed to allow default access to mandatory DPP data by consumers.
- Implementing a resolver based on typed links was easy for pilot participants.
- In this demo, a dedicated app is needed to access the certification data. An alternative approach has already been demonstrated by the Trace4Value demo which has developed a cloud-based DPP reading application that is able to pull data from multiple sources. Scanning the QR code in the figure below pulls data from several sources using typed links, similarly to the video example. This proves that the resolver approach to pull data from multiple repositories can be used even by a "dumb" camera QR code reading app.

Figure 23. QR code example from the Trace4Value[33] project

4.3 DPP cross-sectoral ontology alignment video

The DPP system architecture proposed by CIRPASS is based on linked data and uses ontologies to provide a semantic interoperability layer. The DPP cross-sectoral ontology alignment video was created for the following reasons:

- Provide a working example on how cross-sectoral interoperability can be achieved for DPPs whose information requirements are defined by different delegated acts or regulations;
- Demonstrate the extensibility, combinability and flexibility properties of a DPP system based on linked data;
- Show how the DPP system can leverage existing open-source tools and ontologies;
- Provide an example of the use of ontology alignments in the context of the DPP system and provide resources to developers interested in ontology alignment tools.

This video is available on the CIRPASS youtube channel:
https://www.youtube.com/watch?v=2UfHxKV48r0

[33] https://trace4value.se/

Figure 24. Extract from the DPP cross-sectoral ontology alignment video demo

About the demo:
This demo was developed as part of the Datapipe project[34] in close collaboration with CIRPASS. The DATAPIPE project is an EU project funded by the European Union's Technical Support Instrument Programme. The DATAPIPE project explores how authorities could potentially access and use data from data sources that reside in different business digital infrastructures for several purposes. Thus, for the DATAPIPE project (differently from CIRPASS), the purpose of this video is to demonstrate the power of aligned ontologies to explore how authorities could potentially exploit Digital Product Passport data in the future.

The example that is provided is an imaginary scenario which goes beyond what is currently possible or required for customs. In this imaginary scenario provided for demonstration purposes, we explore how DPP information may be potentially used by customs in customs risk analysis related to the export of second-hand cars in order to prevent the export of End-of-life Electric vehicles. For this video, a number of assumptions are made, the most important one being that a car producer issues a car DPP voluntarily and registers the manufactured car along with its DPP with registration authorities, and finally that the VIN number is mentioned on the customs export declaration. In the demo, we assume that customs wishes to prevent the export of End-of-Life vehicles and accesses electric vehicles' battery state-of-health data as part of its risk analysis. This is done by querying data from the car registration authority and from the car producer. Because the car DPP is linked to the battery DPP, the Car manufacturer can obtain necessary battery data from the battery producer.

Here, the video focuses on the use case and hides all the implementation details. A second video for developers[35] presents the technical implementation details.
https://collegerama.tudelft.nl/Mediasite/Channel/datapipe-project/watch/f3a9265c04e0449db155393c68dd80fc1d

These resources show how ontology alignment is performed using an upper ontology (FEDeRATED) and sector-specific ontologies: a car ontology (AUTO), a battery ontology (CatenaX Battery Pass 3.0.1 Aspect Meta Model) and an electronics ontology (ReplanIT).

[34] https://www.tudelft.nl/tbm/onderzoek/projecten/datapipe-project
[35] Code and resources: https://github.com/Datapipe-demonstrator/semantic-interoperability

Key concepts illustrated:

- A DPP system based on linked data has extensibility, combinability and flexibility properties that make it future proof.
- Because semantic models are used, they can be easily distributed and transformed.
- Extensibility means that new data sources can be added to the system easily. For example, a Tyre DPP, an Electronic systems DPP, an Engine DPP.
- Flexibility means that existing queries can be easily extended to exploit new data sources as they appear.
- Combinability means that complex product manufacturers can combine data from different suppliers into their DPP.
- An upper ontology can be used to align sector-specific ontologies, effectively enabling cross-sectoral interoperability.
- The DPP system can be easily extended to many sectors by adapting the aligned ontologies and the corresponding API configurations, instead of generating and configuring completely new APIs.
- Quick progress can be made by deploying already existing ontologies and open software tools.

4.4 DPP-as-a-Service for textiles demo

It is expected that many economic operators will choose to use the services of DPP-as-a-Service providers to issue DPPs for their products instead of issuing them themselves. There may be several reasons for this: the economic operator does not have sufficient technical know-how, such a choice is more cost efficient, or the DPP-as-a-Service provider is already a service provider to the economic operator and offers the DPP issuing service in addition to other services. The DPP-as-a-Service for textiles video was created for the following reasons:

- Illustrate how future DPP-as-a-Service providers will interact with their clients to make issuing Digital Product Passports easy;
- Show how the DPP can be accessed both by consumers and by circular economy operators, with restricted reading and writing access for the latter;
- Explore the use of the DPP in a textile sorting application.

This video is available on the CIRPASS youtube channel:
https://www.youtube.com/watch?v=p3moyKBltI8&feature=youtu.be

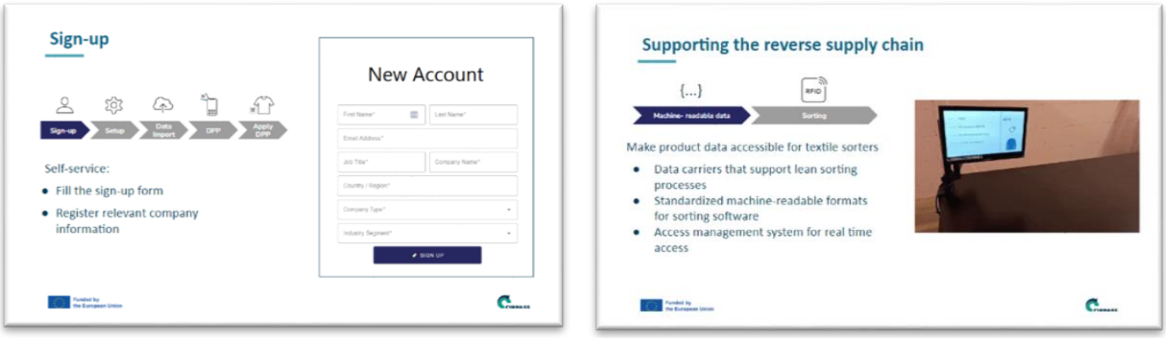


Figure 25. Extract from the DPP-as-a-Service for textile video demo

About the demo:

The video takes the point of view of a textile company that has decided to use the solution offered by a DPP-as-a-Service operator rather than issuing its DPPs themselves. The video explains the different steps followed by the company to sign-up to the solution provider's platform and to import all the necessary product data and the information required by the product-group specific DPP regulation. This can be done through manual file imports or by integrating with other systems via standard APIs. Next, the data presentation layout is defined for different stakeholders, including consumers and sorters. The next step consists in generating and downloading QR codes which can then be added into the label layout.

Access to data by consumers: The video shows that, after scanning the QR code using a smartphone, consumers are directed to the Digital Product Passport. The displayed information can include all the necessary details about the product, including its composition, care instructions, traceability, environmental impact and compliance certifications. The circularity section is particularly important and provides insights into how the product should be handled at the end-of-life. Clear and concise instructions can be provided, highlighting different recycling facilities and drop off points.

Access to data by sorters: Finally, the videos shows how DPP is used to facilitate sorting for circular use cases. After the garment is disposed of by the consumer and received at the sorting facility, textile sorters can use the DPP data to process discarded textiles and allocate them accordingly to reuse and recycling use cases. Here, it is crucial that the chosen data carrier is machine readable and supports seamless automated reading, likely through the use of a second data carrier based on RFID technologies. To facilitate efficient sorting processes, sorters require real-time access to data that will be read through augmented or automated sorting stations. Furthermore, the software applications that the sorters use require a machine-readable data format.

Some of the product data points that could help sorters are currently not publicly available, such as fiber composition or dyestuffs. Thanks to user access management, this information can be provided thanks to role-based, need-to -know access. Other information, such as original sales price, could be used in the future to augment or fully automate the sorting decision process, using algorithms to identify the best reuse and recycling channels. In this way, the sorting process efficiency, reliability and consistency can be significantly improved.

Further downstream, sorting based on digital product passports can also enable the tracking of sorting event data. This creates valuable information about the product's journey that benefits multiple stakeholders in the circular economy. Updating the DPP with sorting information can benefit multiple stakeholders including:
-brands, who can use this information to improve their reporting while preparing for Producer Responsibility Organization obligations,
-authorities, who can utilize the data, for example with the introduction of Extended Producer Responsibility schemes,
-consumers, who can learn about the product journey, further enhancing their engagement and trust in the circular economy.

Key concepts illustrated:

- Many possibilities for issuing DPPs: economic operators can either issue them themselves or use the services of a DPP-as-a-Service operator.
- In the latter case, this will be an easy and streamlined process.
- The DPP should allow for both human readable presentations of data for consumers and machine-readable presentations for machines and software applications.
- The DPP should offer restricted access to specific data points, both for reading and writing.
- In the future, sorting decision processes could be augmented or fully automated using DPP data and algorithms to identify the best reuse and recycling channels.
- DPP post-sorting data aggregation can support both brands and authorities.

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