D4.1
Summary of Existing CE-Related Standards and Formats for the Automotive Industry

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CE-PASS in a Nutshell

CE-PASS is an industrial research project addressing the issue of **sustainability-aware automotive design for the circular economy**, **in the context of highly networked, interoperable ICT systems and platforms**. Austria has a strong industrial base in the automotive sector and this sector is undergoing radical change: firstly, in terms of technology by moving away from the internal combustion engine and its reliance on fossil fuels, to competing powertrain systems such as hydrogen fuel cells and/or battery-based electric drive trains; secondly, corporate due diligence increasingly dictates a view on industrial design that bears long-term sustainability and value retention in mind. At the same time, cloud-enabled, distributed ICT has brought disruptive potential to all sectors, leading to a new wave of automation and digitally driven manufacturing processes.

The project brings together four complementary actors: AVL as one of Austria's foremost automotive design companies; iPoint as a software company with a unique offering of due diligence and compliance-related software tools and with a keen strategic interest in sustainability support for industry; the Institute of Systems Sciences, Innovation and Sustainability Research of University of Graz with its track record in life cycle assessment, circular economy and sustainable supply chain management; and Salzburg Research's "Intelligent Connectivity" group with a track record in digital technologies, having led a highly successful European project NIMBLE (https://www.nimble-project.org/) that developed an open source, B2B supply chain and logistics platform.

CE-PASS Kurzbeschreibung

CE-PASS hat zum Ziel, die Implementierung eines Produktpasses und den damit verbundenen Datenaustausch zu untersuchen und zu bewerten, um die Nachhaltigkeit und Kreislauffähigkeit von Produkten zu verbessern. Das Projekt erforscht Fahrzeug-Design für Nachhaltigkeit und Kreislaufwirtschaft im Kontext von hochgradig vernetzten und interoperierenden IKT Systemen und Plattformen. Das Projekt wird von vier Organisationen getragen, die zueinander hochkomplementär sind: AVL als österreichisches Vorzeigeunternehmen im Automobil-Sektor; i-Point als Software-Firmamdie auf Nachhaltigkeits- und Compliance-Software spezialisiert ist; das Institut für Systemwissenschaften, Innovation und Nachhaltigkeitsforschung der Universität Graz mit seiner Expertise in Lebenszyklus-Analyse, Kreislaufwirtschaft und nachhaltigem Lieferkettenmanagement; und Salzburg Research, die eine Open-Source B2B Lieferketten-Plattform ins Projekt bringt. Wir gehen davon aus, dass in Zukunft ein wachsender Anteil aller wirtschaftlichen Abläufe digital, über Netzwerke passieren wird: Firmeneigene IT-Systeme werden mit digitalen Plattformen interagieren (z.B. in Lieferketten), und es wird Datenflüsse zwischen Firmensystemen und Kontrollsystemen geben, welche Materialflüsse und die Verwendung gefährlicher Stoffe überwachen. Ebenso wird es zum Datentransfer mit öffentlichen Informationssystemen kommen, die z.B. über die Öko-Bilanz von Produkten informieren. Solche vernetzte Systeme müssen vertrauenswürdig und sicher sein und bergen hohe Investitionsrisiken, wenn sie nicht ausreichend interoperabel sind. Aufgabe des Prototyps ist, Fahrzeugentwicklern schon in der Design-Phase Entscheidungshilfen hinsichtlich ökologischer Ziele und Lebenszyklus-Kosten zu geben. Dazu wird ein Software-Prototype als plattform-basiertes Service angeboten, damit die Ingenieure Produktwerterhaltung und Kreislauf-orientierte KPIs optimieren können. Als Anwendungsfälle dienen eine Traktionsbatterie für Elektrofahrzeuge und Komponenten eines Verbrennungsmotors. Ein wesentlicher Aspekt wird die Entwicklung eines digitalen Produkt-Ausweises sein, der Industrie 4.0 Standards mit den Zielen ökologisch nachhaltiger Industrieproduktion kombiniert.

Executive Summary

The deliverable D4.1 summarizes current regulations, initiatives, data formats and standards related to supply-chain traceability solutions for the Circular Economy (CE), Digital Product Passports (DPPs) and Digital Battery Passports (DBP) to be developed for the automotive industry. Apart from desktop research, this report also identifies the preliminary requirements for the design and implementation of DPP in CE-PASS.

List of Abbreviations

BEV	Battery electric vehicle
BoL	Beginning of Life
CE-PASS	Circular Economy Passport
CEAP	Circular Economy Action Plan
DBP	Digital Battery Passport
DPP	Digital Product Passport
EC	European Commission
EU	European Union
EoL	End of Life
GHG	Greenhous gas
ICE	Internal combustion engine
ICEV	Internal combustion engine vehicle
IT	Information Technology
LIB	Lithium-Ion Battery
MoL	Middle of Life
OEM	Orginal Equipment Manufacturer
SCOPIS	Supply Chain-Oriented Process to Identify Stakeholders
SPPI	Sustainable Product Policy Initiative

1 Introduction

1.1 Problem Definition

This document summarizes the activities of task T4.1 of WP4 “Digital Product Passport” (DPP), including an overview of several regulations, standards, initiatives, and solutions with the relevance to the design and implementation of DPP in the CE-PASS project. The results of this task build the basis for the preliminary requirement specification and the design of DPP, which will be shared with other technical tasks in the project.

The regulations, initiatives, information systems, standards, and formats related to circular economy (CE), DPP and batteries in the automotive industry outline the base for the development of the battery passport (Digital Battery Passport) in the CE-PASS. Figure 1 illustrates an intersection between relevant regulations, standards and initiatives.

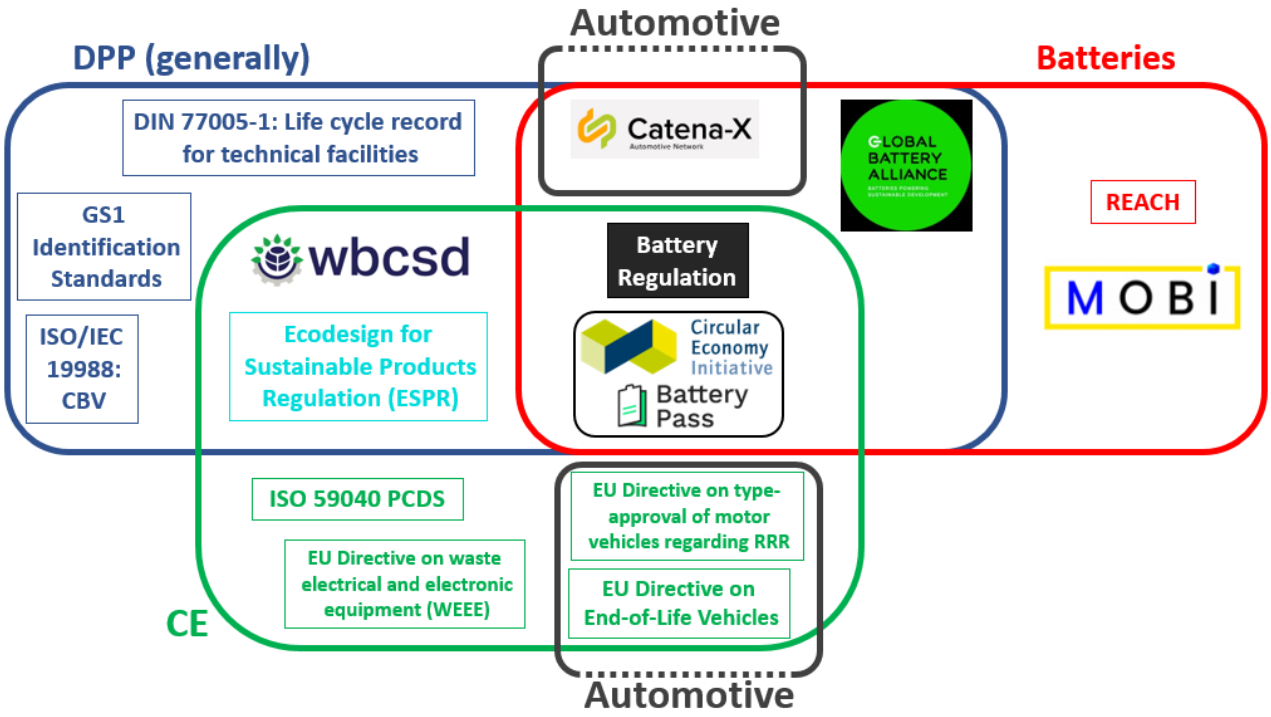

Figure 1: Regulations, Standards, and Initiatives related to the CE, DPP, batteries and the automotive industry

The two proposals for a new Battery Regulation [1] and Eco-design for Sustainable Products Regulation (ESPR) [2] are the main drivers of the current DPP discussion. In addition the following regulations also include relevant requirements that will be considered in the DPP concept: Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) [3]; End-of-Life Vehicles (ELVs) [4]; the Type-

approval of motor vehicles regarding their reusability, recyclability, and recoverability (RRR) [5] and waste electrical and electronic equipment (WEEE) [6].

Regarding the standards and formats, four main standards have been analyzed: ISO 59040 PCDS (Product Circularity Data Sheet) [7], GS1 Identification Standards [9], ISO/IEC 19988: Core Business Vocabulary (CBV) [10], and DIN 77005-1: Life cycle record for technical facilities alongside the D-U-N-S data format [11]. The International Material Data System (IMDS) [12], Global Automotive Declarable Substance List (GADSL) [13], International Dismantling Information System (IDIS) [14], SCIP [15], and the Substitute It Now (SIN) [16] lists are the databases and information systems related to the automotive industry and chemical substances that have been discussed in this deliverable.

Leading intiatives related to batteries and CE have been identified: Gaia-X [17], CIRPASS [18], The Global Battery Alliance (GBA) [19], Catena-X [20], World Business Council for Sustainable Development (WBCSD) [21], Circular Economy Initiative (CEI) [22], MOBI (Mobility Open Blockchain Initiative) [8], and QI-Digital initiative [23]. Most of the regulations, standards, and initiatives are dealing with different aspects, e.g. of technical, social and environmental nature, and focus on a certain topic, like the battery regulation and CEI initiative relate to the DPP, CE, and batteries (Battery Passport focusing on CE) while GBA initiative is only focused on the Battery Passport. Catena-X works on Battery and Product Passports with a focus on the automotive industry. The directive on RRR and ELVs are considering the CE and the automotive industry. Whereas the WBCSD initiative and the ESPR regulation concentrate on general DPP and CE.

The complexity regarding the topic of battery passports becomes clear through the different approaches and number of initiatives. This will be considered throughout the CE-PASS project.

1.2 Organization of the Report

The report is organized in seven sections. Section 1 is an introduction to the deliverable and its scope. The second section summarizes regulations relevant to the CE-PASS. Third comes a discussion related to DBP and CE. Section 4 covers databases and information systems that would provide data to DBP. The fifth section considers relevant initiatives and section 6 discusses several solutions for traceability of supply-chains that could potentially be used in CE-PASS. Section 7 concludes the report and advises on the implementation of DPP (DBP) in CE-PASS.

2 Regulations

Regulations are usually the main drivers to achieve changes in economies and societies. The framework of regulations define how products are designed, produced, traded and disposed for the support of a sustainable CE. This can be displayed through the European Commission's (EC) Green Deal initiative which develops new regulations and updates the existing ones in order to enhance the digitalization of products and their supply chains. The expected regulatory changes in the EU will support CE-PASS concepts and data models related to the DPP, which will be aligned with future regulatory requirements. The main regulatory changes are explained in more detail throughout the section including a description of their relevance for the project.

2.1 New EU Battery Regulation

In December 2020, the European Green Deal initiative (shown in Figure **2** [24]) introduced the new regulation for batteries and waste batteries, in order to minimize their negative environmental impacts. This regulation replaces and repeals Directive 2006/66/EU of the European Parliament and of the Council [1].

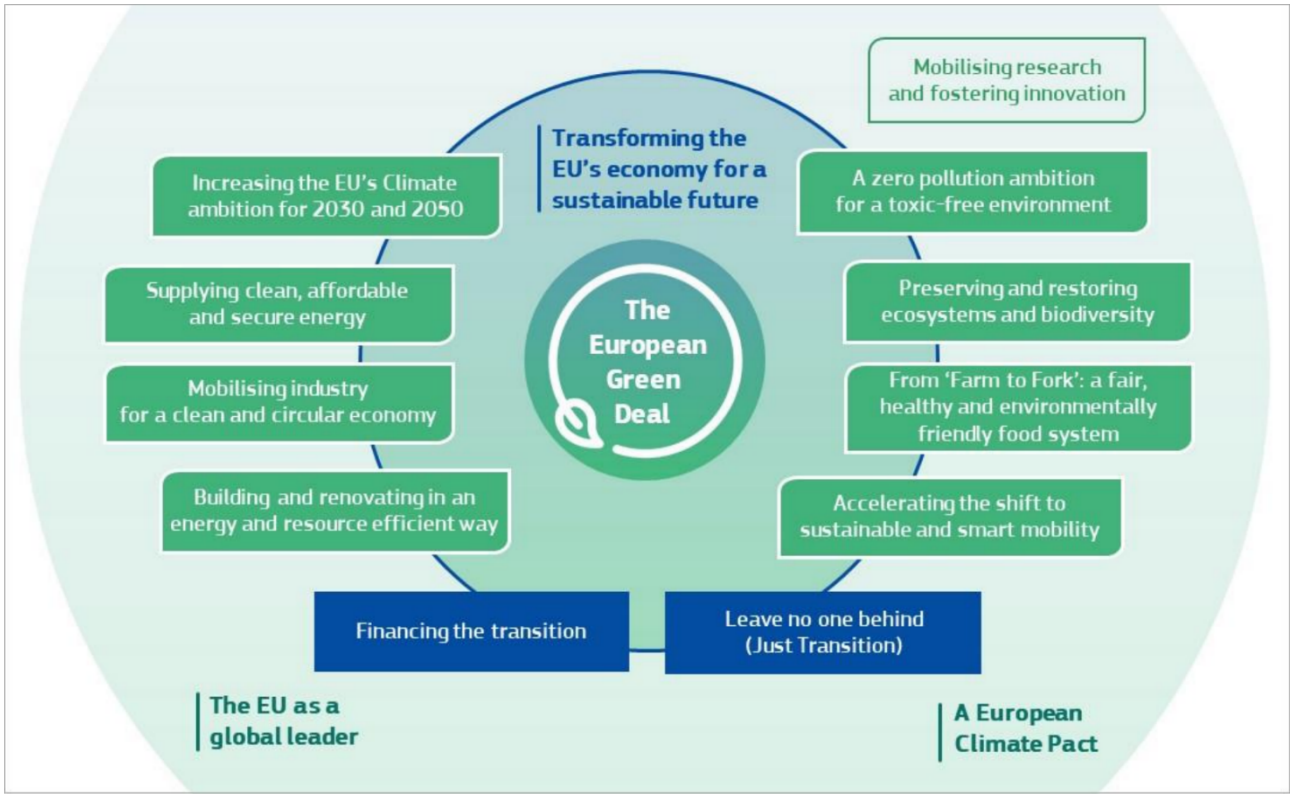

Figure 2: Elements of the European Green Deal [24]

The regulation prohibits the marketing of batteries containing certain hazardous substances, defines measures to establish schemes aiming at high level of collecting and recycling, and fixes targets for collecting and recycling activities. Additionally, provisions on labelling batteries and how they are meant to be removed from other equipment are set as well and aims to improve the environmental performance of all operators involved in the life cycle of batteries and accumulators, e.g., producers, distributors, and end-users [25].

The regulation applies to batteries, accumulators, and other products incorporating either a battery or accumulator, including Electric Vehicles (EVs). Hence, this regulation is of great importance to the automotive industry regarding traction batteries in electric vehicles [1] [25].

An overview of the proposed EU regulation for batteries is shown in Figure 3 [26]:

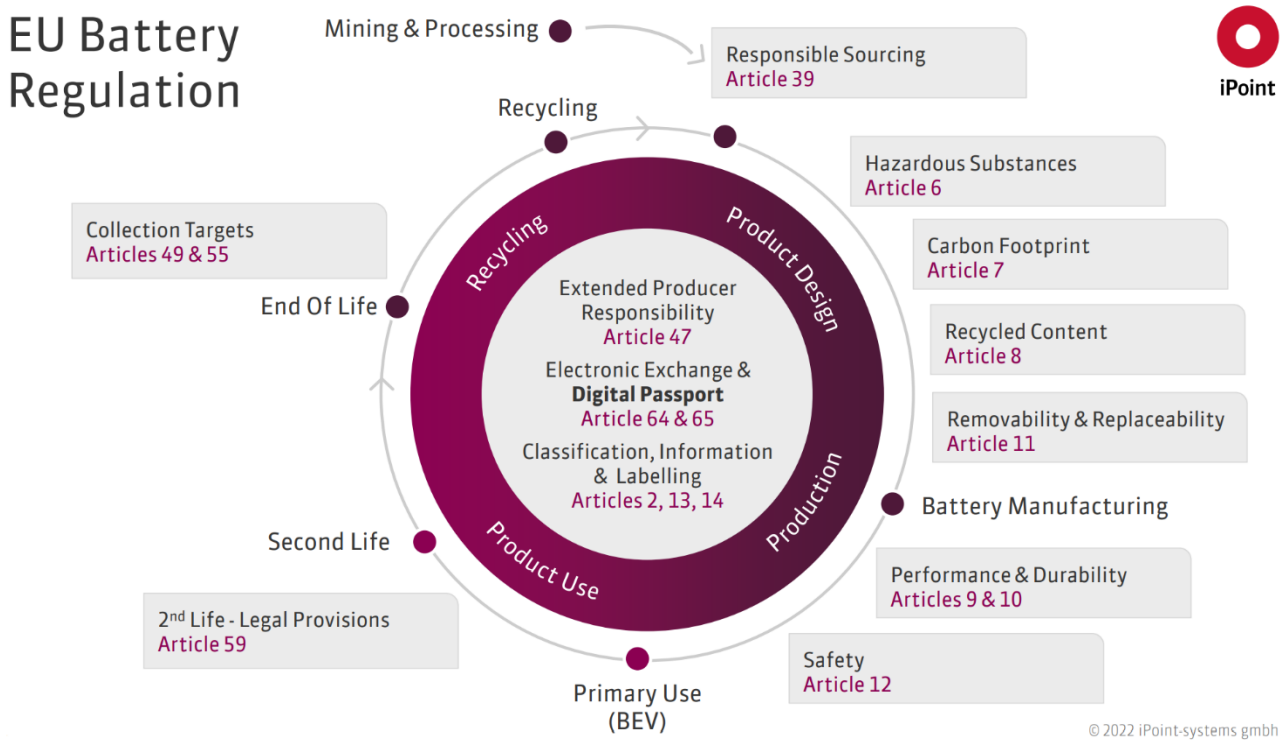

Figure 3: Overview of the EU Battery Regulation [26]

The new battery regulation and its annexes cover sustainability and safety requirements for batteries. This includes the determination of restrictions on the use of hazardous substances in batteries (especially mercury and cadmium) along with conformity assessment procedures. Furthermore, rules on the carbon footprint (CFP) of EV batteries and rechargeable industrial batteries are

established as well as the minimum share of recycled content (e.g., from 2030 12% cobalt, 85% lead, 4% lithium and 4% nickel should be recovered) [1].

One of the requirements of this regulation refers to the labels that should be included on the battery, or the battery packaging. The information should contain lifetime, charging capacity, separate collection, presence of hazardous substances and safety risks. Additionally, a QR code should be printed or engraved on the battery that, depending on the type of battery, giving access to the relevant battery information [1].

Another requirement for rechargeable industrial batteries and electric vehicle batteries refers to supply chain due diligence policies in addition to the battery management system that stores the information and data needed to determine the state of health and expected lifetime of batteries. The obligation concerning the end-of-life management of batteries is an important part of the regulation. It deals with extended producer responsibility, the collection of different types of waste batteries, recycling (including recycling efficiencies and material recovery targets), end-of-life information, repurposing and remanufacturing [1].

Article 65 of the displayed regulation refers to the **battery passport** and foresees its implementation by 2026 for each industrial battery and EV battery with a capacity higher than 2 kWh. The battery passport is an electronic record of the battery that is unique for each individual battery and must include a unique identifier, basic characteristics of the battery types and models, performance and lifetime parameters, as well as any changes due to repairing or repurposing activities [1].

The European Commission proposed setting up an Electronic Exchange System (EES) for battery information by 2026. This system will contain the information and data on rechargeable industrial batteries and EV batteries with internal storage and a capacity above 2 kWh. The EES will be a sortable and searchable online battery database with detailed information about battery types and battery manufacturers [1].

2.2 Ecodesign for Sustainable Products Regulation (ESPR) (Proposal)

The European Commission introduced the Ecodesign for Sustainable Products Regulation (ESPR) as a part of the Circular Economy Action Plan (CEAP) [28]. The ESPR was created to reduce pressure on natural resources and create sustainable growth with focus on the sectors that use most resources

and where the potential for circularity is high, e.g., electronics and ICT, batteries, vehicles, packaging, plastics, textiles, construction and buildings, food, water, and nutrients [27]. The ESPR is part of a package of initiatives fostering sustainable product choices, as shown in Figure 4 [28].

Figure 4: ESPR as the core of package of initiatives presented in CEAP [28]

The ESPR addresses product design which determines up to 80% of a product's lifecycle environmental impact and aims to improve the functioning of the internal market. It sets new requirements to make products more durable, reliable, reusable, upgradable, reparable, easier to maintain, possible to refurbish, recyclable and energy as well as resource efficient [29].

The regulation proposed a framework for setting ecodesign requirements, creating a DPP and prohibiting the destruction of unsold consumer products, as well as the product aspects. It also determines requirements relating to conformity assessment procedures, measurement of energy consumption or performance, the use of online tools to calculate the performance of products as well as requirements for manufacturers [2].

The DPP is a part of applying the ESPR approach to an overly broad range of products which includes the product-specific information that will make it easier to repair or recycle products and facilitate tracking substances of concern along the supply chain [29].

The ESPR also includes a whole chapter[1] covering general requirements, technical design and operation of a DPP and sets out the elements needed to specify the information which should be included as well as the corresponding access rights to the information. The same chapter also presents the necessary provision to implement the DPP and the rules related to unique operator and facility identifiers [2].

The regulation addresses the labels used and when they are to be used by a specific product's group. In addition, general obligations towards transparency for economic operators who discard unsold consumer products can be found. Moreover, the possibility to adopt delegated acts to prohibit economic operators from destroying unsold consumer products is displayed in the regulation. It is also specified that products should be able, where appropriate, to measure the consumed energy while in use, or its performance in relation to other relevant parameters. The data should be made available to the end user and to expand the green public procurement [2].

This regulation will be applied to any physical goods that are placed on the market or put into service, including components and intermediate products. Only a few sectors, such as food, feed, and medicinal products, are exempted [2].

2.3 EU Directive on End-of-Life Vehicles (ELV)

The ELV Directive 2000/53/EC deals with the treatment of vehicles, their components, and materials when they reach the end of their life [4]. The objective is to set targets for reuse, recycling, and recovery to reduce waste and improve environmental performance along the life cycle [4]. The Directive subsequently entails relevant requirements for eco-design to facilitate re-use, remanufacturing, and recycling [30]. It also covers elements of the ESPR-Proposal [2] described in chapter 2.2.

[1] CHAPTER III; Articles 8-13

The ELV Directive regulates the responsibilities of different actors within an automotive value chain (i.e., manufacturers, importers, distributors, waste treatment facilities, and owners) concerning the end-of-life of a car. This includes the collection, treatment operations (and its minimum technical requirements), reuse, recovery, and dismantling of end-of-life vehicles. Vehicles are first stripped before further treatment takes place, so hazardous substances and components are removed and separated. Attention is given to the potential reuse, recovery, or recycling of the waste. Vehicle and equipment manufacturers must consider dismantling, reuse and recovery of the vehicles when designing and producing their products and have to ensure that new vehicles are:

- reusable and/or recyclable to a minimum of 85% by weight per vehicle
- reusable and/or recoverable to a minimum of 95% by weight per vehicle.

Manufacturers, importers, and distributors must provide systems to collect ELVs and, where technically feasible, used parts from repaired passenger cars. Owners of ELVs delivered for waste treatment must receive a certificate of destruction which is necessary to deregister the vehicle.

The Directive 2000/53/EC also prohibits the use of hazardous substances when manufacturing new vehicles (especially lead, mercury, cadmium, and hexavalent chromium) except exemptions in annex II (e.g., copper alloy containing up to 4 % lead by weight, lead and lead's compounds in battery components, mercury in bulbs and instrument panel displays, etc.) when there are no adequate alternatives [4]. As the EC is currently reviewing the ELV Directive, changes may come. The legislative proposal for the review of the ELV Directive is expected 2023 [31].

2.4 EU Directive on the Type-Approval of Motor Vehicles with regard to their Reusability, Recyclability and Recoverability (RRR)

The Directive 2005/64/EC is dealing with the type-approval of motor vehicles regarding their reusability, recyclability, and recoverability and sets administrative and technical rules to ensure that a vehicles parts and materials may ultimately be reused, recycled, and recovered [5] . The Directive is related to the ELV Directive and aims to reduce waste from ELV and makes sure that the reused components do not cause any safety or environmental risks [4].

The main indicators in this Directive are 'recyclability rate of a vehicle (R_{cyc})' and 'recoverability rate of a vehicle (R_{cov})':

- R_{cyc} is the percentage by mass of a new vehicle, potentially able to be reused and recycled, which should be to a minimum of 85 % by mass .
- R_{cov} is the percentage by mass of a new vehicle, potentially able to be reused and recovered, which should be to a minimum of 95 % by mass.

The Annex V of this directive is a list of the components that must not be reused in the construction of new vehicles (e.g., Airbags, Automatic or non-automatic seat belt assemblies, Exhaust silencers, etc.) [5].

This directive shall apply to internal combustion/electric/hybrid vehicles and to new or reused component parts of such vehicles except the special purpose vehicles (such as: Motor caravan, Ambulances, etc.) and vehicles produced in small series (less than 500 units per year).

2.5 REACH Regulation

REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) [3] is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the European chemical industry. It also promotes alternative methods for the hazard assessment of substances to reduce the number of tests on animals, as it establishes procedures for collecting and assessing information on the properties and hazards of substances [3].

REACH applies to all chemical substances, not only those used in industrial processes but also in our day-to-day lives, e.g., in cleaning products, paints as well as in articles such as clothes, furniture, and electrical appliances [3].

REACH makes an impact on a wide range of sectors various value chain actors, including the chemical industry, manufacturers, importers, downstream users and distributors from the EU as well as companies established outside the EU [3].

The regulation includes four processes, namely the registration, evaluation, authorization, and restriction of chemicals, which are briefly described in the following sections.

2.5.1 Registration Process

Registration applies to substances on their own, substances in mixtures and certain cases of substances in articles. Chemical substances that are already regulated by other legislations such as medical or radioactive substances are partially or completely exempted from the REACH requirements. Registration is based on the "one substance, one registration" principle, which means that manufacturers and importers of the same substance have to jointly submit their registration request. The provided analytical and spectral information provided should be consistent and sufficient to confirm the substance identity. The substance registration process includes a certain fee [33].

2.5.2 Evaluation Process

The European Chemicals Agency (ECHA) and the member states evaluate the information submitted by companies to examine the quality of the registration dossiers and the testing proposals and to clarify if a given substance constitutes a risk to human health or the environment [3].

The main actors in the evaluation process are registrants, third parties, ECHA, member states, and European Commission.

The evaluation process under REACH focuses on three different areas [34]:

- Examination of testing proposals submitted by registrants
- Compliance check of the dossiers submitted by registrants
- Substance evaluation

Once the evaluation is done, registrants may be required to submit further information on the substance.

2.5.3 Authorization Process

The aim of the authorisation process is to ensure that the risks related to Substances of Very High Concern (SVHCs) are properly controlled throughout their life cycle and promote the progressive replacement of SVHCs by suitable alternatives (less dangerous substances, new technologies and processes), when technically and economically feasible alternatives are available.

The authorization is a three phases process [35]:

1. Substances of Very High Concern (SVHC)
2. Recommendation for Inclusion in the Authorization List
3. Application for Authorization

Substances with the following hazard properties may be identified as SVHCs [36]:

- Substances meeting the criteria for classification as Carcinogenic, Mutagenic, or toxic for Reproduction (CMR) category 1A or 1B in accordance with the CLP (classification, labelling and packaging of substances and mixtures) Regulation.
- Substances which are Persistent, Bio-accumulative, and Toxic (PBT) or very Persistent and very Bio-accumulative (vPvB) according to REACH Annex XIII.
- Substances on a case-by-case basis, that cause an equivalent level of concern as CMR or PBT/vPvB substances.

The SVHC identification process includes a 45-day consultation. Once a substance is identified as an SVHC, it is included in the Candidate List. The inclusion in the Candidate List brings immediate obligations for suppliers of the substance, such as [36]:

- supplying a safety data sheet
- communicating on safe use
- responding to consumer requests within 45 days and
- notifying ECHA if the article they produce contains an SVHC in quantities above one tonne per producer/importer per year and if the substance is present in those articles above a concentration of 0.1% (w/w).

There are some generic and user-specific exemptions from the authorization requirement which are detailed in the recommendation that ECHA submits to the EC [37].

2.5.4 Restriction of Chemicals Process

"Restriction of Chemicals" is an instrument to protect human health and the environment from unacceptable risks posed by chemicals. Restrictions are normally used to limit or ban the manufacturing, placing on the market (including imports) or use of a substance, but can impose any relevant condition, including technical measures or required specific labels [38].

A restriction may apply to any substance on its own, in a mixture or in an article, including those that do not require registration, for example, substances manufactured or imported below one tonne per year or certain polymers. On-site isolated intermediates and substances used in scientific research and development, and substances only posing risks to human health from their use in cosmetics are exempted from those substances to which REACH restriction applies [38].

The Restriction of Chemicals process involves the following phases [39] :

1. Preparation and submission of a restriction proposal
2. Consultations and opinion development
3. Decision and follow-up.

2.6 EU Directive on Waste Electrical and Electronic Equipment (WEEE)

The Directive 2012/19/EU [6] is dealing with waste electrical and electronic equipment and aims to contribute to sustainable production and consumption. Alongside rare and expensive resources, which can be reused, WEEE contains a complex mixture of materials, some of which are hazardous. These can cause major environmental and health problems if the discarded devices are not managed properly. In addition, modern electronics contain rare and expensive resources, which can be recycled and re-used if the waste is effectively managed [40].

The WEEE Directive aims to contribute to sustainable production and consumption by [41]:

- preventing the creation of WEEE as a priority.
- supporting reuse, recycling, and other ways of recovering waste from electrical and electronic equipment (EEE).
- contributing to the efficient use of resources and the recovery of valuable secondary raw materials through re-use, recycling, and other forms of recovery.

The Directive [6]:

- classifies WEEE into different categories, in Annex I and II, such as small and large equipment temperature exchange equipment, screens, lamps and small IT and telecommunications equipment.

- encourages a cooperation between producers and recyclers and measures to promote the design and production of EEE, notably in view of facilitating re-use, dismantling and recovery of WEEE, its components and materials.
- requires the separate collection and proper treatment of WEEE and sets targets for their collection as well as for their recovery and recycling.
- imposes a minimum selective treatment for materials and components of WEEE (e.g., removing batteries from any separately collected WEEE) according to Annex VII.
- sets out, in Annex V, the minimum recovery targets required for each category of WEEE.
- helps European countries fight illegal waste exports more effectively by making it harder for exporters to disguise illegal shipments of WEEE.

WEEE Directive does not apply to certain types of electrical and electronic equipment, notably material for military or space purposes, filament bulbs, active implantable medical devices or means of transport. The Commission is currently evaluating the WEEE Directive. This evaluation will assess whether the Directive is still fit for purpose, explore possibilities to simplify the Directive, and determine whether a review is needed. To gather evidence from the public and from a wide range of stakeholders, the Commission will hold several consultations over the coming months, assisted by a study to support this evaluation[2].

[2] Waste from Electrical and Electronic Equipment (WEEE) (europa.eu)

3 Standards and Formats

For the interoperability of the DPP with other systems, the use of standards and formats are crucial. This chapter includes an overview of standards related to the Circular Economy that may be relevant for the DPP.

3.1 ISO 59040 PCDS (Product Circularity Data Sheet) Standard

The ISO 59040 standard [7] provides a general methodology for improving the accuracy and completeness of CE related information, based on the usage of a PCDS when acquiring or supplying products. Its purpose is to standardize the presentation of information, enabling users to integrate the information in their own systems (data interoperability). The standardization process includes several phases, as shown in Figure 5 [42].

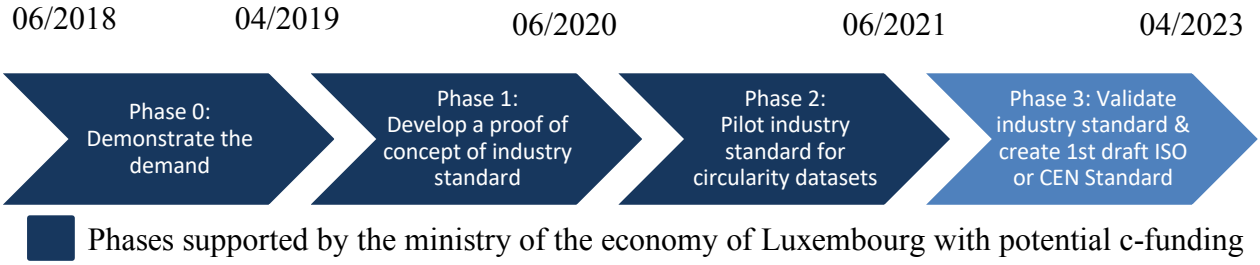

Figure 5: Phases of the international standardization effort [42]

The ISO 59040 standard states how circular a product is and for which circular life cycle it was designed and manufactured. The standard uses a three-fold system which includes:

> "[…]1. A data template containing standardized and trustworthy statements on the product circularity
>
> 2. A third-party verification process to validate the content of the PCDS (audit system)
> 3. A standardized data exchange protocol based on decentralized data storage (IT system) […]" [43]

The standard provides basic data on the circularity of a product, enhances sharing efficiency of circularity data throughout value chains and supports further enhancements of a product regarding circularity. The structure of PCDS is based on the Material Safety Data Sheet (MSDS) system. Additionally, the transparency is kept throughout the value chain of a product. This is done through creating a MSDS for components and materials of a product. This enables to identify those materials

and components in later life cycles of other products in case materials or component got reused, recycled, etc. When a new PCDS is formed for a new product, the old materials and components are documented through the MSDS. In that way, an existing PCDS can be reused by other stakeholders.

The PCDS document is structured in five sections which display key characteristics of product circularity as shown in Table 1 [43]. Additionally, the PCDS document includes definitions of terms following ISO/CEN standards as well as international/EU regulations.

Table 1: The structure of PCDS [43]

Sections	Statements (Examples)
1. General information	"iPoint Air Fryer" All 2023 models All Serial Numbers beginning 223A (Example Product details and identification information.)
2. Composition	The product contains > 75-95% post-consumer recycled content by weight. The article does not contain substances of very high concern (SVHC) from the REACH candidate list in concentration above 0.1% by weight.
3. Designed for better use	The product can be maintained & repaired by untrained personnel at the location of the product use.
4. Designed for disassembly	The product is designed to be installed and demounted using reversible connections
5. Designed for re-use	The product is designed for re-use as-is or with minimal modification.

The PCDS document is handled and developed by a manufacturer at each stage of product manufacturing or its transformation, for use by all stakeholders including recyclers and repair organisations. Each supplier passes on the PCDS to the next actor in the value chain. This ensures that the PCDS is integrated into each step of a value chain. Each participant is responsible for the storage of the data and to make it accessible to stakeholders. Hence, the PCDS document can only be modified by the initial manufacturer. When a modification takes place by a different producer a new PCDS is created containing the description of all changes. A PCDS should be updated to incorporate changes related to new regulations, product compositions or circular properties [43].

Finally, the ISO 59040 standard is adopted by 50 companies from 12 European countries taking part in the initiative that is led by the Ministry of the Economy of Luxembourg. This standard shall apply to any goods or service.

3.2 GS1 Identification Standards

GS1 is a global not-for-profit standardisation body developing and maintaining standards for product location and entity identification. GS1 offers a range of identification standards such as the GTIN (Global Trade Item Number), the GLN (Global Location Number) or the CPID (Component/Parts Identifier), with the GTIN being the best known and worldwide used [9]. The supposed practices of GS1 barcodes and identification keys are described in the GS1 General Specifications, which is the core standards document of the GS1 system [44]. The GS1 Identification standards provide a common language and serve as data carrier to easily exchange data, attributing them a central role with the development of a DPP in terms of traceability and data quality. The example, shown in Figure 65 [45], demonstrates the wide use of various GS1 standards in business.

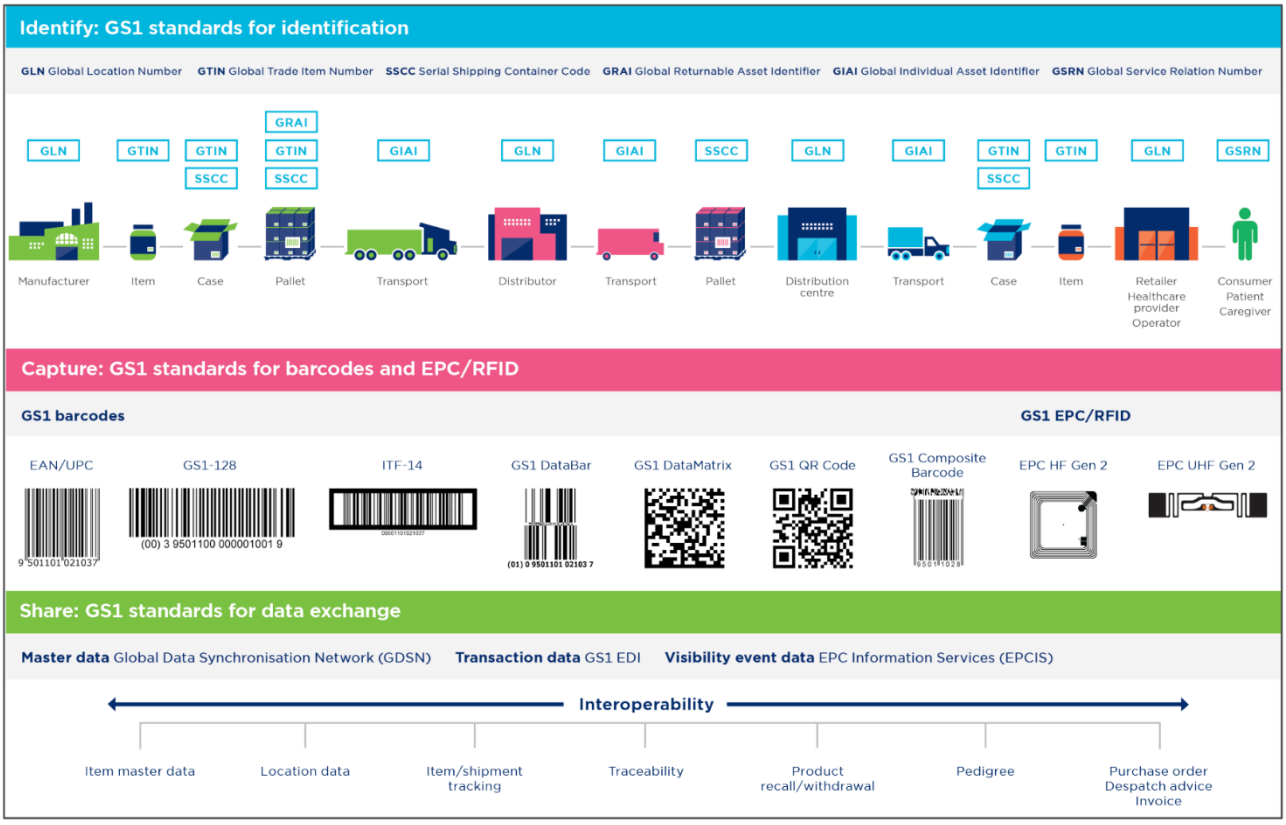

Figure 65: Example of using GS1 standards in a business process that support a retail sale of consumer goods [45]

The standards are applied in a cross-sectoral manner and enable a common ground for companies by identifying, capturing, and sharing important data about products, locations, and assets. Through combining different GS1 standards companies are able to streamline business processes like traceability. Identification standards included within GS1 entail unique identification codes which can be used by an information system to refer to a real entity like a document, location, trade item, logistics unit etc. The GS1 data capture standards entail bar code definitions as well as radio-frequency identification (RFID) data carriers which link the identification keys directly to a physical object as well as to interfaces which connect readers, printers, and other hardware. In general, all software or hardware which link data carriers to business applications. The GS1 standards for information sharing include master data, business transaction data and physical event data. Additionally, the communication standards define the disclosure between applications and trading partners [46]. An overview of how the three types of standards work can be found in the Figure 67 [46] beneath.

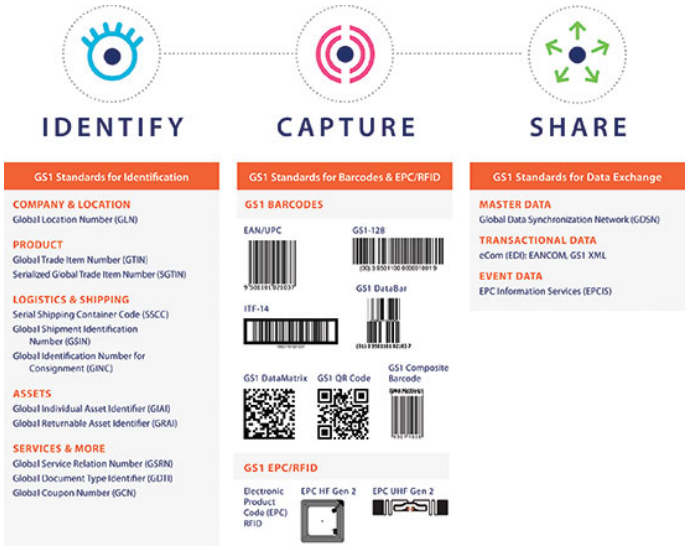

Figure 6: Overview of the three GS1 standard types [46]

3.3 ISO/IEC 19988: Core Business Vocabulary (CBV)

The ISO/IEC 19988, GS1 standard, defines the Core Business Vocabulary [10]. The CBV identifiers and definitions ensure that all parties using this standard will have a common understanding of the semantic meaning of that data (i.e., Enabling standardized product identification). This standard is a companion standard to the Electronic Product Code Information Services (EPCIS) standard [47]. EPCIS also defines the technical interfaces for capturing and sharing event data and defines a framework data model for event data [10].

The CBV standard includes identifier syntax, specific Vocabulary Element values and their definitions, which must be agreed by trading partners, prior to exchanging the events and using the vocabulary [10], [47]:

- Business step identifiers: a vocabulary whose elements denote steps in business processes (e.g., identifier of “shipping” or “receiving”).
- Disposition identifiers: a vocabulary whose elements represent a business state of an object (e.g., identifier of “recalled” or “expired”).
- Business transaction types: a vocabulary whose elements identify a particular type of business transaction (e.g., identifier of “purchase order”). Business Transaction information may be included in EPCIS events to record an event’s participation in particular business transactions.
- Source/Destination types: a vocabulary whose elements denote a specific type of business transfer source or destination (e.g., identifier of “owning party”). A Source or Destination is used to provide additional business context when an EPCIS event is part of a business transfer; that is, a process in which there is a transfer of ownership, responsibility, and/or custody of physical or digital objects.
- Instance/Lot master data (ILMD): a data that describes a specific instance of a physical or digital object, or a specific batch/lot of objects that are produced in batches/lots. ILMD consists of a set of descriptive attributes that provide information about one or more specific objects or lots.

The CBV standard provides identifier syntax options for these User Vocabularies, which is a set of Vocabulary Elements whose definition and meaning are under the control of a single organization, (e.g., Objects, Locations, Business transactions, Source/Destination identifiers, Transformation identifiers, and Event identifiers) [10] [47].

ISO 19988 provides Master Data Attributes and Values for describing Physical Locations including: Site Location, Sub-Site Type, Sub-Site Attributes, Sub-Site Detail [10]. This standard is applicable to a broad set of business scenarios common to many industries that need to share data.

3.4 DIN 77005-1: Life Cycle Record for Technical Facilities

A first version of the DIN 77005-1 "Life cycle record for technical facilities" was made public in September 2018 [48]. A technical facility can be defined as an entirety of technical equipment and devices for accomplishing a specified technical task. The standard specifies how information on plants and their parts is managed in a structural manner [48]. The aim of the standard is to establish a coordinated exchange of information, so that stakeholders can enact with actual and complete information when needed [49]. Different types of life cycle records are available which are organized in a hierarchical way. Users have the possibility to use metadata for the allocation of responsibilities, the search for information and the definition of relationships between information. An application ensures that the life cycle records are consistent, complete and up to date. By using the standard, it is ensured that the file is self-describing and understandable.

The standard considers different perspectives which is a special feature of the standard. Within these different perspectives there are certain data which may be of interest to a certain kind of stakeholder group. The standard proposes five main perspectives which are economical, technical, legal, materially, and procedural. These perspectives are based on important competencies and fields of action concerning the stakeholders within the life cycle of the facility [48]. DIN777005-1 defines important terms and order structures concerning life cycle records and puts them via an information model into relation. The information can be provided through different channels such as documents, data, or references in life cycle records.

In a nutshell, the life cycle record can contain all documented information on an object over the entire life cycle, organized in a chronological order. It provides information on ownership, possession, and responsibility of the object [50]. The practical implementation of a life cycle record brings various design challenges.

3.5 D-U-N-S Format

The Data Universal Numbering System (D-U-N-S) Number [11], by Dun & Bradstreet, is a unique nine-digit identifier for businesses that is used to maintain up-to-date and timely information on more than hundreds of millions global businesses. The D-U-N-S Number also enables identification

of relationships between corporate entities (hierarchies and linkages) and commercial risk assessment practices.

The D-U-N-S Number may include the main company data (e.g., name, address, phone number, headquarters, branches, etc.) along with scores and ratings that assess different financial health indicators. Using D-U-N-S Number, or other business identifiers, of a company, potential partners and lenders can request a business credit report about this company. The D-U-N-S Number can also serve as a primary data key within an organization's Master Data Management architecture, because of its universal recognition (relied on by over 240 organizations across the globe [51]) and unique assignment [11].

4 Databases and Information Systems

Databases and information systems are one of the main sources of information for the DPP. By interconnecting such data systems to the DPP, accurate and easy to access data would be guaranteed. This section is covering some of databases and information systems related to the automotive industry, dismantling, and chemical substances which could be potential input systems.

4.1 International Material Data System (IMDS)

The International Material Data System (IMDS) [12] is an international database, developed and operated by DXC Technology, that contains information on materials used by the automotive industry. In the IMDS, all materials present in finished automobile manufacturing are collected, maintained, analysed, and archived [12]. The collected data from the entire Automotive Supply Chain enables the participating companies to comply to worldwide ELV directives, REACH SVHC, RRR and similar regulations [52] and to track material usage, especially in end-of-life vehicles which considered a significant environmental interest [53]. It is required in IMDS to reduce all parts to Basic Substances, which is an elementary chemical building block. In the IMDS "tree-like" structure, basic substances comprise the "leaves" that occur at the end of every material "branch". Basic substances are created and maintained by the IMDS Chemical Service. Basic substances have universal characteristics such as name, CAS number, and EINECS number [54]. IMDS is necessary for the OEMs to comply with ELV Annex II and other environmental regulations.

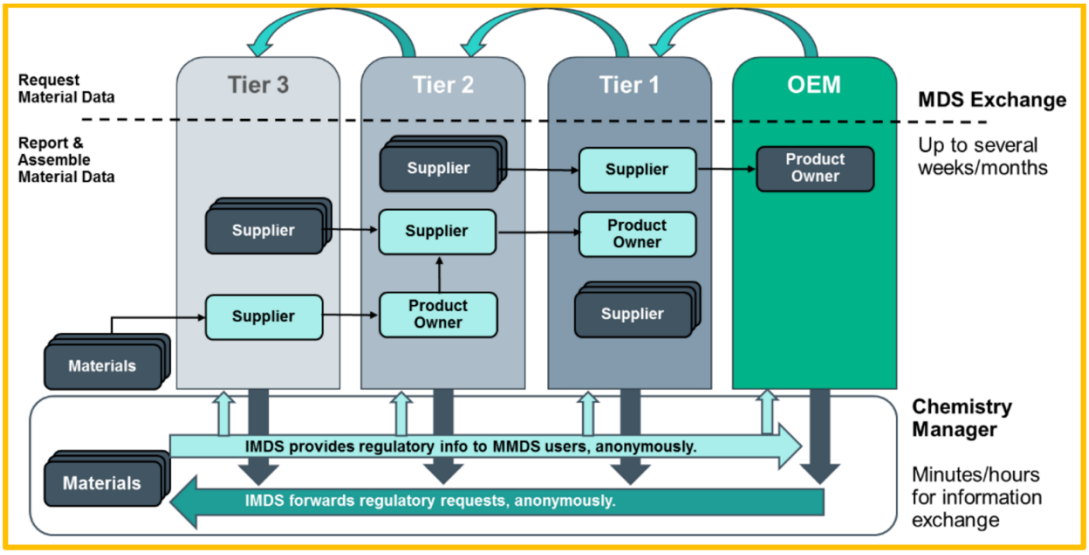

Figure 7: Information exchange of IMDS database along the supply chain through Chemistry Manager [54]

The new IMDS functionality called "Chemistry Manager" allows companies to provide REACH Annex XIV Regulatory information and Biocide Product Regulation (BPR) along the supply chain in a faster way, as shown in Figure **7** [54], and still maintaining the link between the added regulatory information and the related Material Data Systems (MDSs). A Substances of Concern in Products (SCIP) interface also provided by IMDS, to help companies to fulfil their duties concerning the submission of data to the EU's SCIP database [54].

4.2 Global Automotive Declarable Substance List (GADSL)

The Global Automotive Declarable Substance List (GADSL) [13] is the result of the efforts of a global team from the automotive, automotive parts supplier (tier supplier) and chemical/plastics industries who have organized the Global Automotive Stakeholders Group (GASG). The GASG's purpose is to facilitate communication and exchange of information regarding the use of certain substances in automotive products throughout the supply chain. The GADSL only includes substances that are expected to be present in a material or part that remains in a vehicle at point of sale [13].

GADSL covers the declaration of certain information about substances relevant to parts composition and materials supplied by the supply chain to automobile manufacturers. The information is applicable to the use of these parts or materials in the production of a vehicle up to its usage and relevant to the vehicle's re-use or waste disposal. The List includes substances requiring declaration with the target to minimize individual requirements and ensure cost-effective management of declaration practice along the complex supply chain.

The scope is to cover declarable substances in the flow of information relevant to parts and materials supplied throughout the automotive value chain, from production to the End-of-Life (EoL) phase. GADSL is used to enhance further dialogue and cooperation along the supply chain on the benefits and potential risks of certain substances or groups of substances in a specified use within vehicle parts/materials. A reportable substance when present in a material or part in a vehicle will be shown on the GADSL with a classification of "P (Prohibited)", "D (Declarable)", or "D/P (Declarable or Prohibited)" [55].

4.3 International Dismantling Information System (IDIS)

The International Dismantling Information System [14] is the advanced and comprehensive information system for pre-treatment and dismantling information for ELV. IDIS provides a user-friendly navigation to an extensive database with practical information on pre-treatment, safety related issues like airbag deployment and handling of high voltage (HV) batteries, on potentially recyclable parts and other safety related elements mentioned in the EU ELV Directive, discussed in 2.3, (e.g., lead in batteries or mercury and lead in electronic devices). The IDIS is available as an online system, as shown in Figure **8** [14], for desktop and mobile tablet devices with continuous updates or as an offline version produced and updated once per year. Both systems are free of charge for all commercial end of life vehicle treatment operators in all countries covered by IDIS [56]. Relating to finding information of reusing parts, manufacturers offer access to their Repair & Maintenance Information (RMI) websites as prescribed by other regulations, in the EU for example [57].

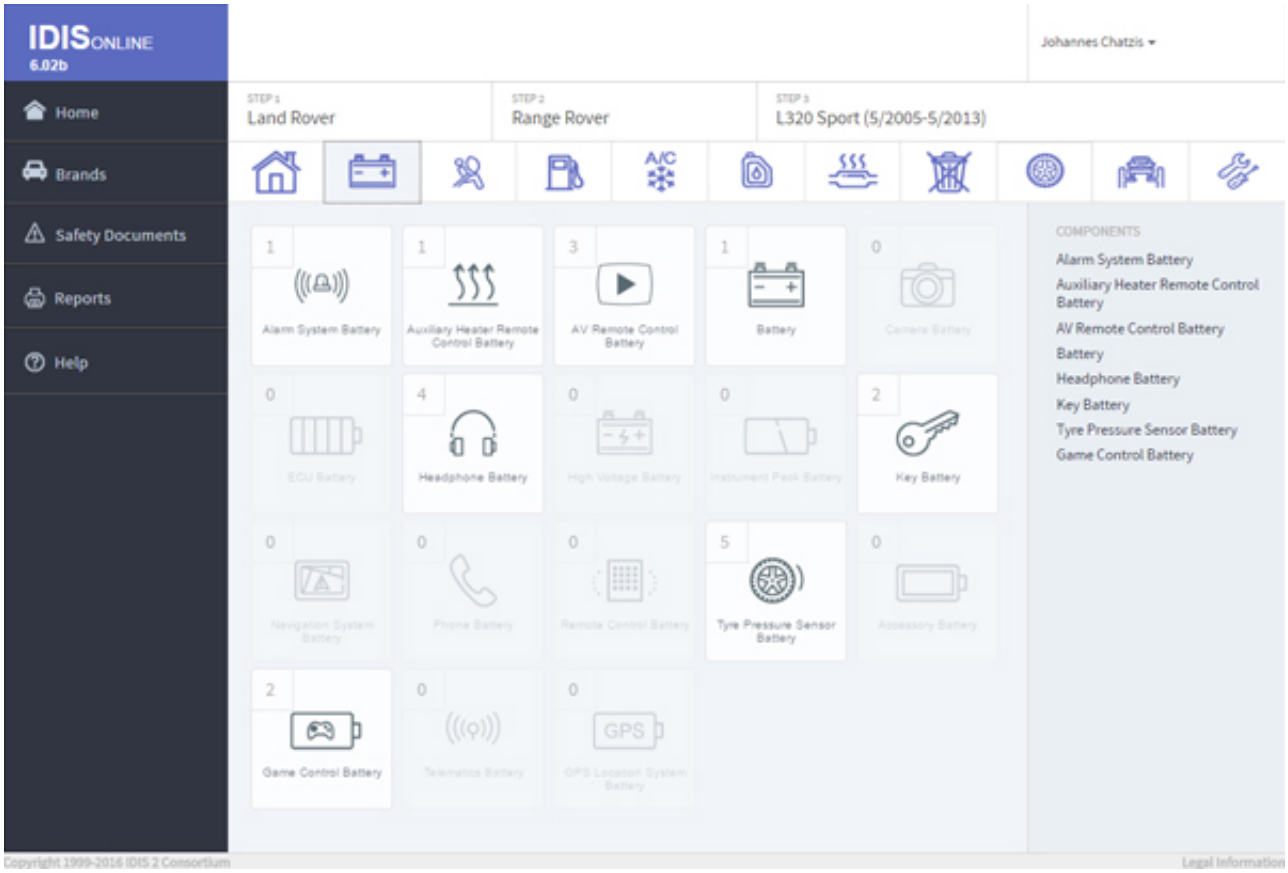

Figure 8: User interface of the IDIS online system [14]

4.4 SCIP

SCIP [15] is the database, developed and operated by ECHA, for information on **S**ubstances of **C**oncern **I**n articles as such or in complex objects (**P**roducts) established under the Waste Framework Directive (WFD). Companies supplying articles containing SVHCs on the Candidate List in a concentration above 0.1% weight by weight (w/w) on the EU market need to submit information on these articles, example shown in Figure **9** [58], to ECHA, as from 5 January 2021. The information in the SCIP database is made publicly available, in particular to waste operators and consumers [59].

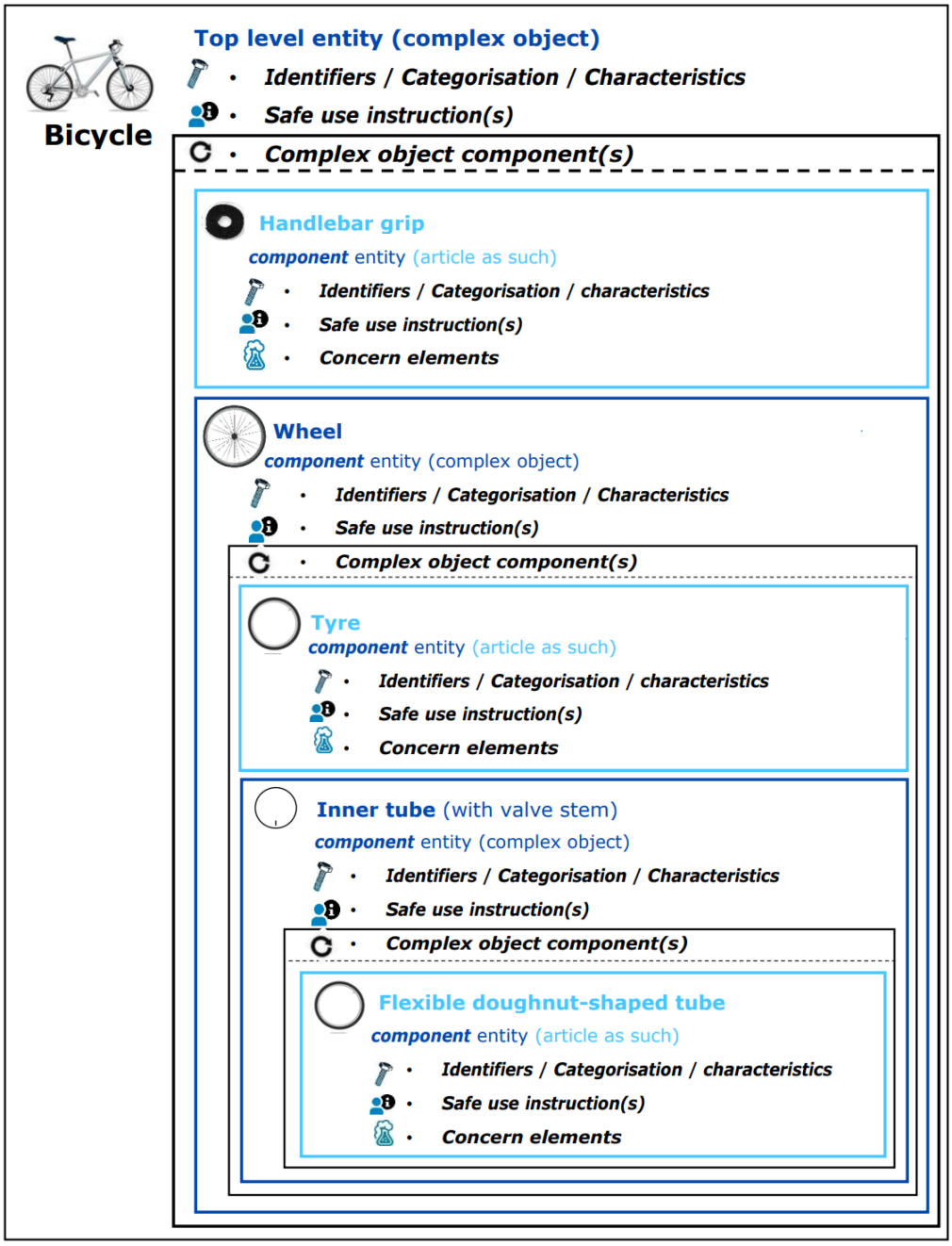

Figure 90: An example of bicycle SCIP notification [58]

The aim of SCIP is to increase the knowledge of hazardous chemicals in articles on their own (or articles as such) and products incorporating those articles (as components) throughout their lifecycle – including at the waste stage [59]. There are three main objectives of the SCIP database [60]:

1. Decrease the generation of waste containing hazardous substances by supporting the substitution of substances of concern in articles placed on the EU market.
2. Make information available to further improve waste treatment operations.
3. Allow authorities to monitor the use of substances of concern in articles and initiate appropriate actions over the whole lifecycle of articles, including at their waste stage.

4.5 Substitute It Now (SIN)

The Substitute It Now [16] is a list of hazardous chemicals that are used in a wide variety of articles, products, and manufacturing processes around the globe. From the name, any chemicals in this list should be removed as soon as possible as they pose a threat to human health and the environment. The SIN list is developed by the non-profit International Chemical Secretariat (ChemSec) in close collaboration with scientists and technical experts, as well as an advisory committee of leading environmental, health, consumer organisations. The list is based on credible, publicly available information from existing databases and scientific studies [61].

The SIN list consists of chemicals that have been identified by ChemSec as being SVHCs, based on the criteria defined within REACH, the EU chemicals legislation. Basically, the SIN list simply looks the way REACH would look without the political roadblocks [61].

Three categories are included in REACH article 57, and the SIN list encompasses substances from these three categories [62]:

1. CMR substances that can cause cancer, alter DNA, or damage reproductive systems.
2. PBT and vPvB substances which do not easily break down and accumulate in the food chain.
3. "Substances of equivalent concern" category for substances that are not covered by the other two categories, but which nonetheless give rise to an equivalent level of concern in terms of potential damage to health and the environment (e.g., endocrine-disrupting chemicals, sensitisers, and chemicals with specific organ toxicity). This category now also includes chemicals that are Persistent, Mobile, and Toxic (PMT) or very Persistent and very Mobile (vPvM).

5 Initiatives

Due to the complexity of product composition and the large network of global supply chains the DPP needs to be designed as a tool that capable to handle extensive amounts of product and supply chain information. To investigate how this can be achieved and what each of the DPP stakeholders require from a DPP, many initiatives have been started in the last couple of years. The most important ones for the CE-PASS project are those from the automotive sector dealing with the Digital Battery Passport (DBP). They are explained in more detail below.

5.1 Gaia-X

Gaia-X [17] is an initiative, by Europe for Europe and beyond, that develops a software framework of control and governance and implements a common set of policies and rules that can be applied to any existing cloud/ edge technology stack to obtain transparency, controllability, portability and interoperability across data and services. The framework is meant to be deployed on top of any existing cloud platform that decides to adhere to the Gaia-X standard [17].

The main goal of Gaia-X is to establish an ecosystem as shown in the Figure **10**1 [63], whereby data is shared and made available in a trustworthy environment alongside with giving the control back to the users by retaining sovereignty over their data. Gaia-X's outcome will be a federated system linking many cloud service providers and users together in a transparent environment that will drive the European data economy of tomorrow [64].

The architecture of Gaia-X is based on the key principles of federation, distributed consensus, decentralization, and regulation by automation, aiming to reduce the complexity, delays and costs associated when verifying the service credentials. The core elements of Gaia-X are [64]:

1. Federation Services: Which define the technical requirements and services necessary to operate the federated Gaia-X ecosystem. They ensure the highest possible security requirements and privacy protection.
2. Standards: Gaia-X is developing an Architecture of Standards, describing, and aligning existing standards and codes of conduct while enforcing data usage policies.

3. Data Spaces: Data Spaces represent a data integration concept without a central storage. Thus, data remains at its source and is only shared when needed. A Data Space is formed by the entirety of its participants, which all follow the same rules.
4. Business Services: Gaia-X will contribute to increasing the availability of digital services. It will create new opportunities for value and business innovation by providing common schemes and rules for collaboration within and across domains.

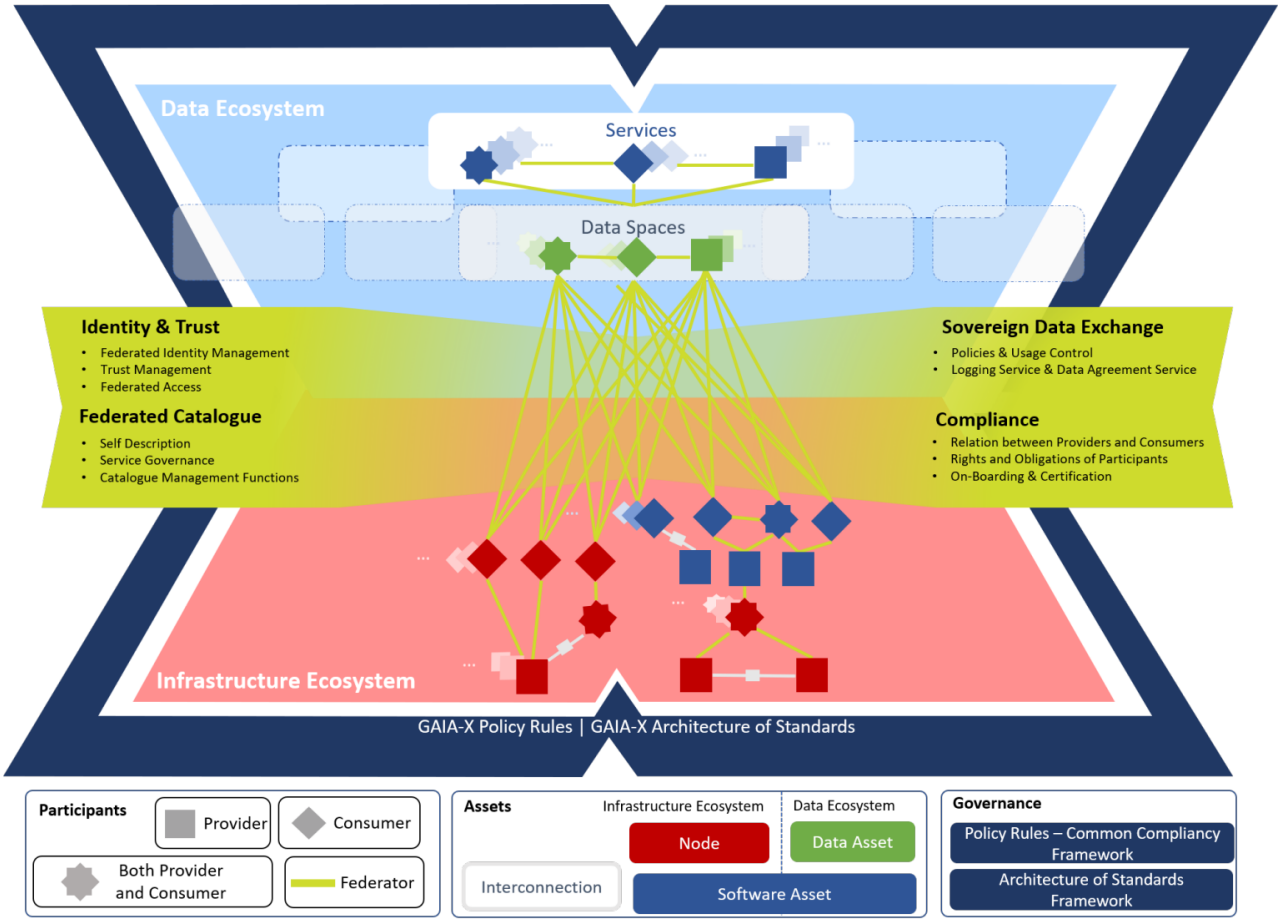

Figure 101: Gaia-X Ecosystem Visualization [63]

Representatives from business, politics, and science from Europe and around the globe are working together, hand in hand, to create a federated and secure data infrastructure. Companies and citizens will collate and share data – in such a way that they keep control over them. They should decide what happens to their data, where it is stored, and always retain data sovereignty [65].

5.2 CIRPASS

CIRPASS is an initiative funded by the European commission under the Digital Europe Program. The project consortium consists of more than 30 partners from industrial, research, digital, international and standards organisations across Europe and beyond. CIRPASS' goal is to prepare the ground for a gradual piloting and deployment of a standards-based DPP. It focuses on the three sectors: electronics, batteries and textiles [18]. The project lasts 18 months in which it will define a cross-sectoral product data model and DPP system to demonstrate that benefits for the circular economy. CIRPASS will develop roadmaps for DPP deployment enabling alignment with the requirements of the Proposal for ESPR. [18] It will also publish a summary of initiatives that are related to DPP activities and pilot projects.

The main objectives of CIRPASS are [18]:

- Presenting a clear cross-sectoral definition and description of the DPP
- Defining a cross-sectoral product data model for the DPP with focus on CE
- Clarifying the requirements related to product identification
- Proposing an open DPP data exchange protocol adapted to the needs of CE stakeholders and propose such a protocol based on up-to-date digital technologies
- Building stakeholder consensus on key data for circularity and related open European and global vocabulary standards to be included in the DPP for the batteries, electronics, and textiles value chains
- Developing use cases and roadmaps for piloting, deployment, and circular business value generation of cross-sectoral DPPs

CIRPASS brings together a core network of leading organizations to support the European vision for a unified DPP approach across multiple value chains.

5.3 Catena-X

Catena-X [20] is a global network of actors within the automotive industry which aims to develop a secure and sovereign data ecosystem, as shown in Figure **11**2 [66], for all players in the value chains of automotive industry. The initiative strives to enable a digital flow of traceable, standardized, and reliable information, making use of the preliminary work of GAIA-X and the International Data Space Association (IDSA) [67].

Catena-X sees itself as a rapidly scalable ecosystem in which all participants in the automotive value chain participate equally with the goal of provide an environment for the creation, operation, and collaborative continuous data exchange along the entire automotive value chain [68].

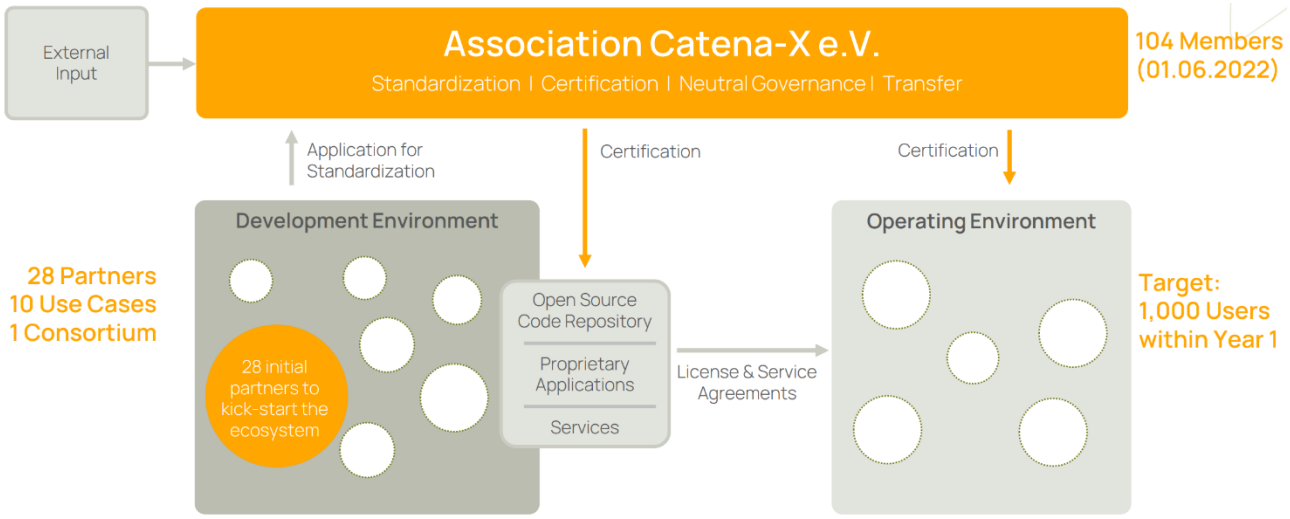

Figure 112: Catena-X's approach of building and running a Global Data Ecosystem for automotive industry [66]

Catena-X is an overall concept consisting of three independent organizational elements [69]:

- **Association:** The association structure Catena-X Automotive Network e.V. bundles the activities around the elaboration, promotion and maintenance of common foundations and standards for the data ecosystem.
- **Development area**: In which, the actual development work is done in the form of the elaboration of various candidate standards.

- **Operating environment**: The operation of the Catena-X network is implemented by different operators in different roles. The goal is a decentralized, federated operator model.

Data offered by the ecosystem of Catena-X is the basis for a successful CE. Catena-X aims to integrate all levels of the automotive value chain by 2023 and make CE more sustainable, durable, and transparent. Catena-X is working with many notable companies to collect information relevant to the CE in a data ecosystem. The goal is to create a digital twin of each product across all industries and throughout the entire value chain [70].

iPoint actively participate in the Catena-x initiative in the Use Cases: Circular Economy and Sustainability.

5.4 Global Battery Alliance (GBA)

The Global Battery Alliance is a private-public initiative established in 2017, with the aim to enable a sustainable and circular battery value chain by 2030 [19]. The manufacturing of a battery can pose high risks to environment and society. These risks can be found throughout the whole value chain, starting from the sourcing of the raw materials to the finished electric vehicle. Therefore, these risks have to be mitigated [71].

To create sustainable sourcing of rechargeable batteries GBA established a research project (Q1/20-Q4/22) to develop a battery passport. The objective of such passport is to achieve full value chain transparency, provide a framework for benchmarking and track progress [72]. Hence, the passport will include a digital twin of its physical battery and will be based on standardized KPIs, with the aim to report on Environmental, Social and Governance (ESG) performance. These KPIs cover the overarching categories of technical, environmental, social, governance and economic aspects with corresponding sub-indicators. The KPIs and sub-indicators form the basis for the development of a master data model to ensure appropriate data aggregation. This leads to data exchanging, collecting, sorting and reporting among the stakeholders supporting a sustainable battery value chain for EVs. Progress concerning global goals can be retrieved and can be communicated to governments for policy creation as well as to inform society and create performance benchmarks. Additionally, a

battery passport can be used as a quality certification for customers and an enabler of a sustainable consumption [71]. Figure 13**12** shows many private and public adopters of GBA.

Figure 1312: Public and private organizations engaged in GBA [73].

5.5 WBCSD

Over 200 CEOs from sustainable companies merged together into a community called World Business Council for Sustainable Development (WBCSD) [21]. The leading people and executives share practical insights about chances and hurdles concerning climate, nature and inequality sustainability challenges. Therefore, guidelines are being developed for CEOs as well as scientific targets with protocols and standards to achieve the system change. The global network of companies represents accumulated around 19 million employees and 8.5 trillion USD in revenue. The network has been formed in 1995 and since then worked across value chains to respond to sustainability challenges. WBCSD builds impactful coalitions and networks that: facilitate the sharing of knowledge, enable and accelerate the adoption of standards and tools, and create advocacy inputs for common policy tasks. The council developed a strategy which is called “Vision 2050: Time to Transform” with the ambitious target to create a planet where 9 billion people can live in within planetary boundaries by 2050.The vision was already made public in 2010 and in 2020 a roadmap called “Action2020” was developed which include the needed business actions and solutions [74].

Circular Economy is one of the main pillars embedded into the vision which include information sharing, new business models, supporting policies, science-based targets, and value chain collaboration. 50 companies are working together to create solutions to enable circularity through developing new standards, tools, advocacy, insights, and experiences [75].

5.6 Circular Economy Initiative (CEI)

In 2019 the CEI started as a project called “CEID (Circular Economy Initiative Deutschland)”, which ended in 2021 [22]. The aim of the project was to create a roadmap for CE in Germany. The project gathered 50 institutions, from science, politics, industry, and civil society, discussing circular business models, packaging and traction batteries. The results of the project can be found in the “Circular Economy Roadmap for Germany” [76]. Furthermore, the project enabled the development of a company network and led to new partnerships and cooperation opportunities which are vital for the integration of Circular Economy in Germany [77].

One of the projects formed within the CEI is the Battery Pass [78]. The objective of the Battery Pass is to create a DBP that includes details on the life cycle of a battery. With the increase of electromobility throughout the next years, more lithium-ion batteries will be needed. These batteries raise environmental concerns as the production is energy intensive. It also requires high amounts of raw metallic resources. The intention of the CEI project is also to contribute to low-carbon mobility and energy storage. Additionally, the use of primary resources is meant to be reduced and the dependency on raw resources through increased material efficiency, lifetime expansion, residual value determination as well as the recycling of batteries should be decreased.

The battery pass should contain data which describes the sustainability of the product, e.g., the CO2 emissions produced throughout the value chain as well as working conditions within the raw material extraction and the state of the product. Technical cross-industry and content-related standards should be formulated, supporting the development of a software prototype with basic concepts and functions of a battery passport.

In overall, the interest in the topic of DPPs is increasing with the CE initiatives. This is due to the lack of data interoperability standards enabling the use of DPPs throughout different companies and supply chain parties, as discussed in the CEI project [78].

The CEI consortium consists of organizations from industry, economy, and science, and follows the GBA initiative.

5.7 Mobility Open Blockchain Initiative (MOBI)

The global non-profit smart mobility consortium MOBI, consists of different stakeholders like vehicle manufacturers, startups, NGOs, transit agencies, insurers, toll road providers as well as smart city leaders and technology companies [79]. The initiative is headquartered in Los Angeles, USA. Its goal is to create interoperability standards for a mobility blockchain. MOBI is working on a standard that addresses the State of Health (SOH) of a battery [8] in addition to developing a decentralized battery identity number (BIN) standard for the battery birth certificate and battery passport [80]. The SOH standard defines the ratio of the total maximum capacity in kWh at a given time and the beginning of the service life or rated capacity. Further it specifies how tamper-proof health can be recorded on the blockchain along with other data related to lifecycle management [8].

The battery SOH standard aims to develop a guideline for how SOH information should be consumed by the stakeholders, shown in Figure 4 [81], for various use cases alongside a complete value chain mapping of stakeholders and various business applications that require SOH [8]. The standard also demonstrates how a stable reliable state of health record can be recorded on the blockchain, along with other data associated to lifecycle management [80].

The Battery SOH is one of the key attributes, that will enable the battery passport track SOH and make it available to stakeholders in the value chain. It will provide key parameters enabling the extension of the battery's life, as the battery needs to be replaced and the whole pack repurposed for its second life when the SOH reaches 80% [8].

The standard will be applied to traction batteries of EVs in the automotive industry.

Figure 14: The battery industry stakeholders in value chain [81]

5.8 QI-Digital

QI-Digital is a German initiative of the main actors of the German quality infrastructure (QI) such as DIN, DKE, DAkkS, PTB and BAM. The initiative is supported by the Federal Ministry of Economics and Climate Protection (BMWK) and aims to create a modern quality infrastructure [23]. In cooperation with a network from economy, research and society solutions will be developed based on an ecosystem. This ecosystem provides test environments including different use cases, identification of research and development needs and knowledge transfer into industrial practice. On the technical level this initiative supports the development of a QI-cloud, smart standards, and digital certificates.

The QI-cloud will be the basis for a distributed IT-platform that will be used to operate digitalized processes of the quality infrastructure, store and share data securely and exchange digital certificates [82]. Smart standards (or “digital norm”) will include all relevant information for a standardization task. It will also provide this information in a suitable manner for the application and can be initialized, created, implemented, optimized, and adapted by people and machines. Partners of the QI-Digital initiative are involved in a complete digital transformation on a national, but also

international level to transfer the current standardization and norms into the digital world. Different levels (level 1-5) of digitalization are defined and will be implemented, starting from paper formats down to machine readable content and fully automized norm relevant actions and decisions [83]. Digital certificates such as calibration certificates will be created and transferred along the product life cycle in the future. Participants of the initiative have already worked on developing digital calibration certificates (DCC) and will use this experience to establish Digital Certificates of Conformance (D-CoC). Such certification data could be accessible for the user via a smartphone and the QI-cloud [84].

6 Supply Chain Traceability Solutions

Tracking a product through its lifecycle is still a challenge. However, more and more solutions are designed and tested to provide an answer to the question of how traceability throughout the supply chains can be successfully implemented. The implementation is often based on blockchain technology, which is supposed to increase trust and transparency between supply chain actors and to provide decentralized data storage. Understanding these solutions will help to build data models and system architectures for a DPP that allow for compatibility and interoperability with other solutions. In the following, several blockchain-based supply chain traceability solutions are presented.

6.1 TradeLens

TradeLens, developed by IBM and GTD Solution Inc., is an open and neutral supply chain platform powered by the blockchain technology. This connected ecosystem enables sharing of true information and collaboration across supply chains partners, thereby increasing industry innovation, reducing trade friction, and ultimately promoting more global trade. TradeLens uses IBM Blockchain technology based on Hyperledger Fabric, an open-source permissioned blockchain that offers immutability, privacy, and traceability of shipping documents [85]. Figure 15**13**5 shows the data sharing in TradeLens [86].

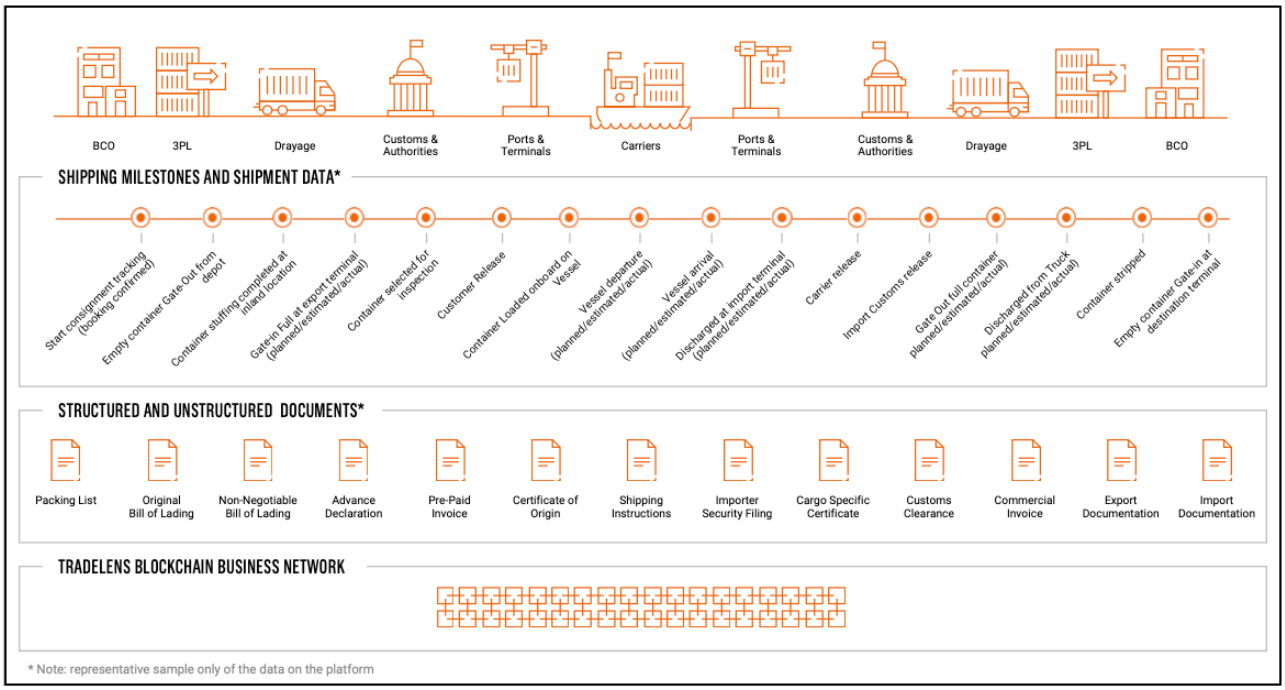

Figure 1513: TradeLens data sharing concept [86]

TradeLens is an example of how traceability can be enabled in different product phases (BoL (Begin of Life), MoL (Middle of Life), EoL).

6.2 Circularise

Circularise is a system that facilitates the knowledge transfer in the CE, which enables information exchange between participants in value chains while allowing them to remain anonymous and fine-tune the amount of information they want to disclose, as well as manage relevant access controls. Circularise utilizes a combination of blockchain, peer-to-peer technology and cryptographic techniques like Zero-Knowledge Proofs (ZKPs) to build a decentralized information storage and communication platform [87]. This solution allows product information to be easily accessible to customers and regulators, without sharing sensitive and confidential information.

6.3 TraceMet

TraceMet is a simplified, fully functional IT system for tracking certified metals along the entire value chain. It uses blockchain technology combined with a novel approach called Chain of Custody (CoC) offering buyers of metals and minerals an option to choose a certain “sustainability level”. The pilot system includes two examples [88]:

1. a value chain for copper, from mine to use in electrical applications such as transformers,
2. for steel, from iron ore mine to steel in trucks.

In CE-PASS, the CoC models used by TraceMet could be applied in the MoL phase of the battery life cycle management. Additionally, the methods developed to determine the carbon footprint of the metal and the percentage of recycled material, could be used in the EoL Phase of batteries (waste batteries).

6.4 CarbonBlock by CircularTree

CircularTree was founded in 2018 with the goal of providing solutions for supply chains, using Blockchain technology. CarbonBlock, one of CircularTree projects, is a Blockchain-powered data platform that is designed to reduce the carbon footprint of companies. The solution develops transparent technology standards that enable a secure exchange of reliable and complex data between different

technological solutions. This results in the elimination of inefficiencies and the minimization of supply chain challenges such as lack of trust, transparency, and traceability [89]. The CarbonBlock solution can be a reference for CE-PASS to provide secure exchange of complex data between different value chain actors and DPPs.

6.5 DIBICHAIN

DIBICHAIN aims to map material and product life cycles using Distributed Ledger Technology (DLT) to enhance circular economy. While DLTs are usually known to provide full transparency between its actors, DIBICHAIN considers the concerns of companies exposing their full identity on the ledger. The aircraft component "Bionic Partition" served as an exemplary use case to develop a software demonstrator. For this prototype the most relevant categories of needed product information to increase resource efficiency in supply chains were identified. To meet the need of supply chain actors to protect their identity or manufacturing details an anonymization process was considered and implemented. Hence, DIBICHAIN publishes only product identifiers and basic product information, but no manufacturer details on the ledger. More detailed information such as the product carbon footprint or recycling information can be requested if needed. The owner of product information has to confirm its release and retains sovereignty over its data.

6.6 IOTA Foundation

The IOTA Foundation is a Layer 1 DLT that can be used to build CE services, including a DPP [90]. IOTA's DLT helps ensure data integrity of the information contained in a DPP, e.g., the origin, production, delivery, use, duration of use, end data, and recycling of the product. It creates unique identifiers for each product, following GS1 new global specifications: the Digital Link standard [91] and the EPCIS 2.0 standard [92]. It also offers a protocol with a different consensus mechanism as a solution to the energy consumption problem of most DLTs, making it a more suitable choice for implementing DPPs.

To build a DPP service, IOTA offers the **Integration Service Framework** that integrates IOTA protocol developments with a high-level API for interactions with decentralized identities and data streams. The framework is composed of:

- IOTA Decentralized Identities (created and maintained using IOTA Self Sovereign Identity (SSI) Bridge)
- IOTA Streams (encrypted channels of data that are anchored on the blockchain)
- EPCIS 2.0 IOTA Protocol Adapter (a JavaScript SDK (client-side- and Node.js-compatible) that sends the data to GS1 EPCIS 2.0-compliant repositories)

In addition, the IOTA Foundation helps the open-source community to use its technology to tackle DPP's challenges related to interoperability, scalability, energy efficiency, security, consensus, identity, and governance. The Foundation is working with industry partners in several areas: electronic waste recycling [93], deposit return schemes for plastic recycling [93], electric vehicles [94], and raw materials [95].

7 Discussion

7.1 The Role of Reference Regulations, Standards, and Initiatives in CE-PASS

In this section, the role of regulations, standards and initiatives presented in Sections 2 - 4, influencing the implementation decisions for a DPP (and a Battery Passport) in CE-PASS, is discussed.

The initial notes about presented regulations include the following:

- The new battery regulation sets out the minimum requirements of the legislation, which will be reflected in the attributes of the passport.
- The ESPR will be the main guideline for creating DPPs. Therefore, attributes mentioned in this guideline will be considered when developing DPP concepts and solutions.

1. In the battery passport, the visualization of CE elements, as well as end of life activities for automotive components, takes a central role within the battery passport. This will follow the Directive on ELV (2000/53/EC). Thus, the International Dismantling Information System (IDIS) is of interest in CE-PASS, because vehicle manufacturers can provide data for disposal companies [32] which is thereby made available and accessible for the relevant companies in the battery EoL phase.

- In CE-PASS, the indicators of directive RRR (2005/64/EC) will be used not only in EoL but also in BoL phases, as manufacturers must design vehicles so that minimum thresholds of parts and materials may be reused, recycled, or recovered once the vehicle comes to the EoL.
- REACH is dealing with information about hazardous substances that will be considered in the battery passport, which will help certain stakeholders in CE-PASS, e.g., dismantlers.

Our notes about the role of reference standards in CE-PASS, include the following:

- Based on ISO 59040 PCDS, the main attributes related to CE are assigned in the DPP. The PCDS standard deals with the CE aspects affecting all phases of a product's life cycle in all its phases (BoL, MoL, EoL).
- According to the MOBI's Battery SOH standard, the battery passport should track SOH and make the information available to stakeholders in the value chain. In the context of promoting a CE, this standard will be a cornerstone to extent the battery's life.
- GS1 Identification Standards provide a common data carrier for the data exchange, also contributing to traceability and data quality of DPPs and Battery Passports.

- The CBV standard will enable the DPP to be compatible with standardized formats of the collected data, providing common identifiers and definitions.

Finally, our notes about the reference initiatives in CE-PASS, include the following:

- The GBA initiative is particularly valuable due to its focus on the use case of a battery and the broad involvement of diverse industries. Therefore, the GBA framework is considered for attributes regarding the CE-Pass.
- The Catena-X initiative, which is an open data ecosystem for the automotive industry and EVs, is highly relevant for CE-PASS.
- The CEI initiative will provide guidance for DBPs as mandated by the EU Battery Regulation and will be a relevant source for CE-Pass in regards to DBP implementation aspects.
- The QI-Digital initiative is relevant to the CE-PASS in terms of its national and international influence. The DPP will need a link to such nationally and internationally relevant certificates and its quality infrastructure in some way to provide the DPP stakeholders relevant information on the quality of the product. Therefore, connecting DPPs to such infrastructures should be considered.

A summary of the scope of each regulation, standard, and initiative discussed in this deliverable is demonstrated in Appendix A.

7.2 Preliminary Requirements for the Development of DPP in CE-PASS

In order to identify the data requirements of stakeholders involved in the traction battery use case, as a part of the ongoing work in WP2, a comprehensive survey will be conducted. The survey aims at the identification of the most important data requirements for a DPP for traction batteries. It will also investigate requirements related to availability of the data and accessibility to the relevant value chain actors. The relevant stakeholders will be asked to rate the identified data attributes and to assess their availability within the value chain. The survey[3] will suggest an initial set of attributes, to be rated by the relevant stakeholders. These data attributes were identified through the desktop research, by a literature review and through expert consultations.

[3] https://survey.uni-graz.at/index.php/611959?lang=de

The process of preliminary requirements gathering includes the following steps:

In order to create a comprehensive list of attributes that are relevant for Electric Vehicle Battery (EVB) value chain's stakeholders, iPoint and the University of Graz intensively collaborated and consulted a wide range of sources.

- Firstly, the collection of potential attributes was based on the pre-work of Berger et. al [96] who have presented a concept for Digital Product Passports for EVBs and who started with a preliminary assessment of information requirements for such battery passports. They revealed that a battery passport requires information regarding the battery itself (e.g., the underlying chemistry), its circularity and sustainability potential, its state of health and maintenance history and the related value chain actors. Consequently, the attributes that have been defined by Berger et al. [96] were included into the list of potential attributes which was created by the University of Graz and iPoint.
- Secondly, multiple regulations, standards and initiatives were screened to detect further attributes that could be integrated into the attribute list. The screening included the following:
    - Circular Economy Action Plan, 2020
    - End of Vehicle Life Directive, 2000
    - REACH Regulation, 2007
    - Product Circularity Data Sheet, 2021
    - Proposal for a new Ecodesign for Sustainable Products Regulation, 2022
    - Regulation of the European Parliament and the Council concerning batteries and waste batteries, 2020
- Thirdly, the attribute list was further supplemented by insights that iPoint gained within own projects (Rediblock, Dibichain[4]) and initiatives (Catena-x, GBA, WBCSD, etc.) with their respective partners. The consultation of these three types of sources resulted in an extensive list of attributes which comprised around 200 attributes.

During the preliminary requirements gathering process, the University of Graz partner listed initially 162 attributes and then shortened the list down to 76 attributes. This was followed by expert validations and consultations during which the University presented the sub-set of attributes to

[4] More information on iPoints projects can be found here: https://www.ipoint-systems.com/company/projects/

selected attributes from iPoint and AVL. This led to a final selection of 40 attributes which was also considered an appropriate number of attributes to be included in the survey. The list of attributes and a detailed description of the selection and summarization process will be part of the WP2 intermediate report, by the University of Graz.

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Appendix A: Scope of each regulation, standard, and initiative discussed in this deliverable

Abbr.	Regulation, Standard, or Initiative	Scope
————	New EU Battery Regulation (Proposal repealing Directive 2006/66/EC)	Battery, CE, DPP, Chemical Substances
ESPR	Ecodesign for Sustainable Products Regulation (Proposal repealing Directive 2009/125/EC)	Product, Performance, DPP
ELV	Directive on End-of-Life Vehicles (2000/53/EC)	CE, Automotive
RRR	Directive on the type-approval of motor vehicles with regard to their Reusability, Recyclability and Recoverability (2005/64/EC)	CE, Automotive
REACH	Regulation concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (1907/2006/EC)	Chemical Substances
PCDS	Product Circularity Data Sheet Standard (ISO 59040)	CE, Product
SOH	Battery State of Health (SOH) Standard (by MOBI)	Battery, Performance
————	GS1 Identification Standards	Product, Data Carrier, Identification
CBV	Core Business Vocabulary GS1 standard (ISO/IEC 19988)	Data Format
————	Life cycle record for technical facilities standard (DIN 77005)	Data Management
CIRPASS	Collaborative Initiative for a Standards-based Digital Product Passport	CE, DBP, DPP Standardization
GBA	Global Battery Alliance	Battery, Performance
————	Catena-X initiative	Automotive, DBP
WBCSD	World Business Council for Sustainable Development	CE
CEI	Circular Economy Initiative	CE, DBP
QI-Digital	QI-Digital initiative	Data Management, Quality Infrastructure

Appendix B: Table of Abbreviations

BAM	**Bundesanstalt für Materialforschung und -prüfung (EN: Federal Institute for Materials Research and Testing)**
BIN	Battery Identity Number
BMWK	Bundesministerium für Wirtschaft und Klimaschutz (EN: Federal Ministry for Economic Affairs and Climate Action)
BoL	Beginning of Life
CBV	Core Business Vocabulary *[Standard]*
CE	Circular Economy
CEAP	Circular Economy Action Plan
CEI	Circular Economy Initiative
CEO	Chief Executive Officer
CFP	Carbon Footprint
CIED	Circular Economy Initiative Deutschland
CIRPASS	Collaborative Initiative for a Standards-based Digital Product Passport
CLP	Classification, Labelling and Packaging *[Regulation]*
CMR	Carcinogenic, Mutagenic, or toxic for Reproduction *[substance]*
CoC	Chain of Custody
CPID	Component/Parts Identifier
DAkkS	Deutsche Akkreditierungsstelle (EN: The National Accreditation Body of the Federal Republic of Germany)
DBP	Digital Battery Passports
DCC	Digital Calibration Certificates
D-CoC	Digital Certificates of Conformance
DIBICHAIN	Digitales Abbild von Kreislaufsystemen mittels Blockchain–Technologie
DIN	Deutsches Institut für Normung (EN: German Institute for Standardization)
DKE	Deutsche Kommission Elektrotechnik Elektronik Informationstechnik (EN: German Commission for Electrotechnical, Electronic & Information Technologies)
DLT	Distributed Ledger Technology
DPP	Digital Product Passports
D-U-N-S	Data Universal Numbering System
EC	European Commission
ECHA	European Chemicals Agency
EEE	Electrical and Electronic Equipment
ELV	End-of-Life Vehicles *[Directive]*
EoL	End of Life

EPCIS	Electronic Product Code Information Services *[Standard]*
ESG	Environmental, Social, and Governance
ESPR	Eco-design for Sustainable Products Regulation
EU	European Union
EV	Electric Vehicle
EVB	Electric Vehicle Battery
GADSL	Global Automotive Declarable Substance List
GASG	Global Automotive Stakeholders Group
GBA	Global Battery Alliance
GLN	Global Location Number
GTIN	Global Trade Item Number
ICT	Information and Communications Technology
IDIS	International Dismantling Information System
IDSA	International Data Space Association
ILMD	Instance/Lot master data
IMDS	International Material Data System
ISO	International Organization for Standardization
IT	Information Technology
KPI	Key Performance Indicators
MDS	Material Data System
MOBI	Mobility Open Blockchain Initiative
MoL	Middle of Life
MSDS	Material Safety Data Sheet
NGO	Non-Governmental Organization
PBT	Persistent, Bio-accumulative, and Toxic
PCDS	Product Circularity Data Sheet
PMT	Persistent, Mobile, and Toxic
PTB	Physikalisch Technische Bundesanstalt (EN: National Metrology Institute, Germany)
QI	Quality Infrastructure
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals *[Regulation]*
RMI	Repair & Maintenance Information
RRR	Reusability, Recyclability, and Recoverability
SCIP	**S**ubstances of **C**oncern **I**n articles as such or in complex objects (**P**roducts)
SDK	Software Development Kit
SIN	Substitute It Now *[list]*

SOH	State of Health
SSI	Self-Sovereign Identity
SVHCs	Substances of Very High Concern
vPvB	very Persistent and very Bio-accumulative
vPvM	very Persistent and very Mobile
w/w	weight per weight (concentration)
WBCSD	World Business Council for Sustainable Development
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive
WP	Work Package
ZKP	Zero-Knowledge Proofs