ETSI TS 103 881 V1.1.1 (2024-01)

TECHNICAL SPECIFICATION

Environmental Engineering (EE); Global digital sustainable product passport opportunities to achieve a circular economy

Reference

DTS/EE-EEPS55

Keywords

environmental impact, LCA, sustainability

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Contents

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (https://ipr.etsi.org/).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM**® and the GSM logo are trademarks registered and owned by the GSM Association.

Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Environmental Engineering (EE).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Executive summary

The present document provides an overview of global and common opportunities to represent sustainability, mainly environmental-related, details about digital technology products, either collective ICT product models, batches or individual ICT product items. These product details are intended to be represented in digital format instead of paper-based. The details can represent design-related information, products at the time of manufacturing, including relevant information for product transparency and a potential for a circular lifecycle, such as details related to the origin of materials composition, design, manufacturing, energy consumption, maintenance, repair, preparation for reuse, final recycling, and may include links to related documentation. Product details can include or relate to details that change over the lifespan of a product as a result of reconfiguration events, including repair, upgrade, usage, sale, and final recycling. The details should exclude any personal or business-sensitive information.

NOTE: Human health can be considered part of environmental concerns. From now, just mentioned as environmental.

The present document provides an overview of sustainability opportunities, environmental related, about product-related digital information common to all ICT products, with global scope for harmonization, i.e. relevant to any region, that can support the development of the circular economy of ICT products. The product-related digital information can be represented under digital technology, such as product identifiers, data formats, linked data, and system architectures. It relates to and can complement regional and global standards.

Introduction

The 2005 World Summit on Social Development [i.1] identified **sustainable development** goals with three pillars: economic development, social development, and environmental protection. The economic pillar has to do with trade. The social pillar has to do with people: workers, users and other people and collectives affected. The environmental pillar has to do with the challenges of consuming materials to produce products and energy to power them, their use, the production of e-waste, and any indicators related to positive and negative effects on people and nature.

In the context of sustainability, the Agenda 2030 [i.2] defines a shared blueprint for peace and prosperity for people and the planet, now and into the future. It defines the Sustainable Development Goals (SDG) for social, economic, and ecologically sustainable development [i.3].

There are well-defined targets for the climate crisis. The IPCC defines the different trajectories, specifically compliance to the 1,5 °C objectives described by the IPCC Special Report on 1,5 °C [i.4]. To meet this goal, the world should cut emissions down to net zero by 2050.

ITU defined the Connect 2030 Agenda with Goal 3 on Sustainability, where ITU recognizes the need to manage emerging risks, challenges and opportunities from the rapid growth of ICT. There are several initiatives to speed up reductions in environmental impact like SDG 2030 (UNEP), Race to Zero (COP26), NetZero, and science-based targets. Data is needed for implementing all that.

The Aarhus convention [i.5] and the related Escazu agreement [i.6] recognize environmental rights related to *access to environmental information and* the need for mechanisms to render these rights effective.

ICT products (e-equipment such as routers, switches, consumer products like smartphones, etc.) have environmental, social, and economic **impacts** at each stage in their life cycle, starting from the supply chain, including the reverse supply chain, ending as e-waste at end-of-life. It has to do with energy, natural resource consumption, and emissions of various kinds, to name a few.

Currently, more than 6 billion new ICT products are sold annually worldwide. There are estimates of 1,5 billion smartphones [i.7] in 2021, 126 million desktop computers, 659 million laptops, and 513 million Wi-Fi® routers produced every year (2021). These numbers are expected to grow over the next five to ten years with new "smart" technologies see Recommendation ITU-T L.1024 [i.8].

As a result of the growing production and sales, e-waste is one of the fastest growing waste stream, most of it discarded in the municipal waste stream, leading to a loss of secondary resources [i.9] valued at US$ 57 billion in 2019 (more than the gross domestic product of many countries) Additionally, e-waste is often shipped illegally to developing countries [i.10].

The contribution of ICT in terms of electricity use is a significant factor: by 2030, ICTs could use a larger share of global electricity and globally released GHG emissions as reported in [i.11]. Clean sources of energy and locality can nevertheless help reduce GHG emissions see [i.12].

However, for some ICT products, upstream activities of raw material acquisition, transport and production contribute most to the environmental impact [i.13].

In contrast, ICTs can enable vast efficiencies in social and economic life through digital solutions that can improve energy efficiency, inventory management, and reduction of travel and transportation impacts (e.g. telework and videoconferencing, substituting physical products with digital information). This capacity is referred to as second-order or enablement effects.

Recommendation ITU-T L.1470 [i.14] defines GHG emissions trajectories for the ICT sector as compatible with the UNFCCC Paris Agreement. Therefore, *the digital world is part of the problem and may be part of the solution*.

The Circular Economy (CE), and the term circularity, is about *"designing out waste and pollution, keeping products and materials in use, and regenerating natural systems"* [i.15]. In the context of ICT products, circularity aims to achieve the best use of ICT products with maximal lifespan, which helps decarbonize the environment. A circular approach in the electronics industry is widely accepted as the required transformation to move away from a linear "take-make-waste" model of production and consumption [i.16].

With environmental sustainability and circularity focus on the DPP for ICT products, the present document presents:

- The description of the scope of the Digital Product Passport (DPP) in clause 5.
- The description of DPP opportunities.
- The definition of the required ICT product types to consider in DPPs.
- The definition of required principles and properties of digital product information in DPPs, all in clause 6.
- The feasibility of implementing these opportunities in a global DPP system is discussed in clause 7.

The present document provides a basis for other DPP standards about detailed information models for ICT products, specific ICT product categories, as well as regional and global DPP standards.

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5. It is published respectively by ITU and ETSI as Recommendation ITU-T L1070 [i.17] and ETSI TS 103 881 (the present document), which are technically-equivalent.

1 Scope

The present defines a "digital product passport" for ICT products to be represented in digital format, including an overview of the opportunities and benefits to include information relevant to sustainability, mainly environmental related, focusing on circularity and transparency.

The present document does not intend to define which items should be filled out for all or different product families in their "digital product passport", nor define the targets, limits, or specific requirements a product has to meet.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] United Nations General Assembly 2005 World Summit Outcome, Resolution A/60/1, adopted by the General Assembly on 16 September 2005.

[i.2] United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development; New York, NY, USA, 2015.

[i.3] United Nations, Department of Economic and Social Affairs. The 17 Goals.

[i.4] Intergovernmental Panel on Climate Change. Special report Global warming of 1.5 C. Technical Report 2018.

[i.5] Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, June 25, 1998, UN Doc. ECE/CEP/43, 38 I.L.M. 517 (Aarhus Convention).

[i.6] Escazú agreement (2021).

[i.7] Statista, Smartphones industry: Statistics & facts.

[i.8] Recommendation ITU-T L.1024: "The potential impact of selling services instead of equipment on waste creation and the environment - Effects on global information and communication technology".

[i.9] Forti, V., Baldé, C., Kuehr, R., Bel, G. (2020): "The Global E-waste Monitor 2020". UNU/UNITAR and ITU.

[i.10] Department of Economic and Social Affairs of the United Nations Secretariat: "Trends in Sustainable Development - Chemicals, Mining, Transport, Waste Management, 2010-2011" isbn:978-92-1-104600-7.

[i.11] Andrae, A.S.G. (2020): "New perspectives on internet electricity use in 2030". Eng. Appl. Sci. Lett. 3(2), pp. 19-31.

[i.12] N. Y. Amponsah, M. Troldborg, B. Kington, I. Aalders, R. L. Hough: "Greenhouse gas emissions from renewable energy sources: A review of lifecycle considerations". In Renewable and Sustainable Energy Reviews 39 (2014), pp. 461-475.

[i.13] A. S. G. Andrae: "Life-Cycle Assessment of Consumer Electronics: A review of methodological approaches". In IEEE Consumer Electronics Magazine 5.1 (2016), pp. 51-60.

[i.14] Recommendation L.1470: "Greenhouse gas emissions trajectories for the ICT sector compatible with the UNFCCC Paris Agreement".

[i.15] Ellen McArthur Foundation: "What is a circular economy?".

[i.16] Ellen MacArthur Foundation (2018): "Circular Consumer Electronics: An Initial Exploration". https://ellenmacarthurfoundation.org/circular-consumer-electronics-an-initial-exploration.

[i.17] Recommendation ITU-T L.1070: "Overview of global digital sustainable product passport opportunities to achieve a circular economy".

[i.18] Dykstra, Clarence A. (February 1938): "The Quest for Responsibility". American Political Science Review. 33 (1): 1-25. doi:10.2307/1949761.

[i.19] Schedler, Andreas (1999): "Conceptualizing Accountability". In Andreas Schedler; Larry Diamond; Marc F. Plattner (eds.). The Self-Restraining State: Power and Accountability in New Democracies. London: Lynne Rienner Publishers. pp. 13-28. ISBN 978-1-55587-773-6.

[i.20] ISO/DIS 59040: "Circular economy - Product circularity data sheet (under development)".

[i.21] ETSI EN 303 808: "Environmental Engineering (EE); Applicability of EN 45552 to EN 45559 methods for assessment of material efficiency aspects of ICT network infrastructure goods in the context of circular economy".

[i.22] OECD: "Going Digital: Shaping Policies, Improving Lives" (2019).

[i.23] European Commission: "Proposal for Ecodesign for Sustainable Products Regulation" (2022).

[i.24] European Commission COM/2020/798: "Proposal for a Regulation of the European Parliament and of the Council concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020".

[i.25] Recommendation ITU L.1031: "Guideline on implementing the e-waste reduction target of the Connect 2020 Agenda".

[i.26] Recommendation ITU-T L.1021: "Extended producer responsibility - Guidelines for sustainable e-waste management".

[i.27] ETSI ES 203 199: "Environmental Engineering (EE); Methodology for environmental Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks and services".

[i.28] Recommendation ITU-T L.1410: "Methodology for environmental life cycle assessments of information and communication technology goods, networks and services".

[i.29] Recommendation ITU-T Y.2213: "NGN service requirements and capabilities for network aspects of applications and services using tag-based identification".

[i.30] Boritz, J.: "IS Practitioners' Views on Core Concepts of Information Integrity". International Journal of Accounting Information Systems Volume 6, Issue 4, December 2005, Pages 260-279.

[i.31] Recommendation ITU-T L.1022: "Circular economy: Definitions and concepts for material efficiency for information and communication technology".

[i.32] European Commission: "Standardisation request to the European Committee for Standardisation, the European Committee for Electrotechnical Standardisation, the European Telecommunications Standards Institute as regards digital product passports in support of the COM(2022) 142 final proposal for a Regulation of the European Parliament and of the Council and Regulation (EU) 2023".

[i.33] UN. Secretary-General; World Commission on Environment and Development (1987) Report of the World Commission on Environment and Development: Our common future.

[i.34] ISO 9000: "Quality management systems - Fundamentals and vocabulary".

[i.35] K. van Dorp: "Tracking and tracing: a structure for development and contemporary practices", Logistics Information Management, vol. 15, no. 1, pp. 24-33, 2002.

[i.36] International Telecommunication Union, the WEEE Forum, the GSMA and Sofies Group, 2021: "Digital solutions for a circular electronics value chain", A thought paper for International E-Waste Day.

[i.37] European Commission: "EU countries commit to leading the green digital transformation, 19 March 2021.

[i.38] Recommendation ITU-T L.1034: "Adequate assessment and sensitization on counterfeit information and communication technology products and their environmental impact".

[i.39] Recommendation ITU-T L.1102: "Use of printed labels for communicating information on rare metals in information and communication technology goods".

[i.40] Fifteenth Meeting of the Conference of the Parties to the Basel Convention. Matters related to the implementation of the Convention: work programme of the Open-ended Working Group for the period 2022-2023. Document symbol: UN/CHW.15/19.

[i.41] SERI COP. (2021). Advisory No. 23: Remote Auditing for Surveillance Audits.

[i.42] Leif, D. (2020, July 30): "Pandemic upends certification audit sector". E-Scrap News.

[i.43] Wilkinson, M.D., et al. 2016: "The Fair Guiding Principles for Scientific Data Management and Stewardship". Scientific Data. 3, 160018.

[i.44] Elise Golan, Barry Krissoff, Fred Kuchler, Linda Calvin, Kenneth Nelson, and Gregory Price: "Traceability in the U.S. Food Supply: Economic Theory and Industry Studies", 2004.

[i.45] KEEP: "Keeping Electrical and Electronic Products", 2021.

[i.46] Molly Macauley, Karen Palmer, Jhih-Shyang Shih: "Dealing with electronic waste: modeling the costs and environmental benefits of computer monitor disposal", Journal of Environmental Management, Volume 68, Issue 1 (2003).

[i.47] Kristofer Elo, Erik Sundin: "Automatic Dismantling Challenges in the Structural Design of LCD TVs", Procedia CIRP, Volume 15 (2014).

[i.48] S.C Lee, Sanches Lam, Ho Kin Fai: "Characterization of VOCs, ozone, and PM10 emissions from office equipment in an environmental chamber", Building and Environment, Volume 36, Issue 7 (2001).

[i.49] Recommendation ITU-T L.Sup28: "Circular economy in information and communication technology; definition of approaches, concepts and metrics".

[i.50] United Nations, Annex 4 (2007): "Guidance on the preparation of safety data sheets (SDS)".

[i.51] Luxembourg government (2021):"PCDS Product circularity data sheet".

[i.52] Platform for Accelerating the Circular Economy. (2019): "A new circular vision for electronics - Time for a global reboot".

[i.53] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

[i.54] Recommendation ITU-T L.1015: "Criteria for evaluation of the environmental impact of mobile phones".

[i.55] Recommendation ITU-T L.1010: "Green battery solutions for mobile phones and other hand-held information and communication technology devices".

[i.56] Recommendation ITU-T L.361: "ID tag requirements for infrastructure and network elements management".

NOTE: Former Recommendation ITU-T L.64 renumbered as Recommendation ITU-T L.361 on 2016-02-15 without further modification and without being republished.

[i.57] Recommendation ITU-T L.1061: "Circular public procurement of information and communication technologies".

[i.58] Recommendation ITU-T L.1030: "E-waste management framework for countries".

[i.59] Recommendation ITU-T L.1050: "Methodology to identify key equipment for environmental impact and e-waste generation assessment of network architectures".

[i.60] Recommendation ITU-T .1032: "Guidelines and certification schemes for e-waste recyclers".

[i.61] Recommendation ITU-T L.1100: "Procedure for recycling rare metals in information and communication technology goods".

[i.62] Recommendation ITU-T L.1400: "Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies".

[i.63] Kowalkowski, C., Gebauer, H., Kamp, B., Parry, G. (2017): "Servitization and deservitization: Overview, concepts, and definitions", Indust. Market. Manag. 60, pp. 4-10.

[i.64] Luxembourg government (2020): "Circularity Showcase: The Product Circularity Data Sheet (PCDS) Questions and Answers.

[i.65] ITU Product Conformity Database.

[i.66] Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (Text with EEA relevance).

[i.67] ITU (2023): Statistics. Geneva: International Telecommunication Union. Available (viewed 2023-12-15).

[i.68] GSMA Mobile Economy, 2023.

[i.69] Association for Progressive Communications: "A guide to the circular economy of digital devices".

[i.70] Mauro Cordella, Felice Alfieri, Christian Clemm, Anton Berwald: "Durability of smartphones: A technical analysis of reliability and repairability aspects", Journal of Cleaner Production, Volume 286, 2021.

[i.71] Statista: "Smartphones industry: statistics & facts".

[i.72] United Nations: "Safety data sheets", 2007.

[i.73] A.S.G. Andrae, M. Samuli. (2020): "Cost effective method for determining the Relative Hazardousness of substances and compounds", International Journal Of Advanced Research in Engineering& Management (IJAREM) ISSN: 2456-2033, PP. 16-28.

[i.74] United Nations, Globally Harmonized system of classification and labelling of chemicals (GHS), 7th revised edition, 2017.

[i.75] United Nations, Globally Harmonized System of Classification and Labelling of Chemicals (GHS), Rev. 9, 2021.

[i.76] Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC.

[i.77] ISO/DIS 59040: "Circular economy - Product circularity data sheet" (under development).

[i.78] ISO IEC/DIS 82474-1: "Material declaration - Part 1: General requirements" (under development).

[i.79] Recommendation ITU-T L.1023: "Assessment method for circular scoring".

[i.80] Recommendation ITU-T L.1604: " Development framework for bioeconomy in cities and communities".

[i.81] Recommendation ITU-T L.1020: "Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

accountability: equivalent to answerability, liability, and the expectation of account-giving, with the obligation to inform about (past or future) actions and decisions, to justify them

NOTE: Adapted from [i.18] and [i.19].

authenticity: ability of proving an assertion, such as the identity of a computer system user

centralization: data, function, process, system where a single entity, or a small group, has exclusive control or responsibility for it

circular economy: An economy closing the loop between different life cycles through design and corporate actions/practices that enable recycling and reuse in order to use raw materials, goods and waste in a more efficient way as defined in Recommendation ITU-T L.1604 [i.80].

NOTE 1: The circular economy concept distinguishes between technical and biological cycles, the circular economy is a continuous, positive development cycle. It preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows, while reducing waste streams.

NOTE 2: Definition adapted from Recommendation ITU-T L.1022 [i.31] and Recommendation ITU-T L.1020 [i.81].

NOTE 3: The definition is based on [i.15] and amended.

circularity: designing out waste and pollution, keeping products and materials in use, and regenerating natural systems

NOTE: As defined in [i.15].

collective product: product batch or product model with common characteristics for multiple product items

component: hardware constituent of a product that cannot be taken apart without destruction or impairment of its intended use

NOTE 1: See ETSI EN 303 808 [i.21].

NOTE 2: A populated printed circuit board may be considered a component and/or apart from the perspective of the present document.

decentralization: data, function, process, system that is not centralized, controlled by a single or few entities

digitalisation: use of digital technologies and data as well as interconnection that results in new or changes to existing activities

NOTE: As defined in [i.22].

digital product passport: structured collection of product-specific data conveyed through a unique identifier

NOTE: Definition based on European Commission documents [i.23].

Digital Product Passport (DPP) provision: process and responsibility of collecting, creating, maintaining, validating, supplementing, storing and delivering data from source(s) to targets, which includes the provision of a service and managing the data related to it

Digital Product Passport (DPP) supplier: any product operator responsible for provisioning (supplying) the associated data that is included or linked in a DPP

NOTE: Product operator can be a manufacturer, refurbishment service provider, or importer who introduces the product into the market, whereas an external third-party DPP service provider is not considered as a DPP supplier as they are not primarily responsible for the product details contained in the DPP.

economic operator: manufacturer, authorized representative, importer, distributor, fulfilment service provider, or any legal person with legal responsibility concerning manufacture

NOTE: Adapted and modified from [i.24].

e-waste: electrical or electronic equipment that is waste, including all components, sub-assemblies and consumables that are part of the equipment at the time the equipment becomes waste

NOTE: The terms e-waste and Waste Electrical and Electronic Equipment (WEEE) are used interchangeably [i.25].

extended producer responsibility: policy principle to promote total life cycle environmental improvements of product systems by extending the responsibility of the manufacturers of the product to various parts of the entire life cycle of the product, and especially to the take-back, recycling and final disposal of the product

NOTE: As defined in [i.26].

Global Digital Sustainable Product Passport (GDSPP): subset of a digital product passport, global in regional scope, focused on environmental sustainability aspects

ICT goods: tangible goods deriving from or making use of technologies devoted to or concerned with: the acquisition, storage, manipulation (including transformation), management, movement, control, display, switching, interchange, transmission or reception of a diversity of data; the development and use of the hardware, software, and procedures associated with this delivery; and the representation, transfer, interpretation, and processing of data among persons, places, and machines, noting that the meaning assigned to the data is preserved during these operations [i.27] or [i.28]

NOTE: ETSI ES 203 199 [i.27] use the word "equipment" instead.

ID tag: physical object which stores one or more identifiers and optionally application data such as name, title, price, address, etc.

NOTE: As defined in [i.29].

identity: ability of indicating a person or thing's identity, authentication is the process of verifying that identity

individual product: product item

information accessibility: ability to access and benefit from information to the widest range of actors and situations

information composability: ability to combine and assemble self-contained and stateless information components, as with structured linked data

information confidentiality: set of rules or a promise to limits access or places restrictions on certain types of information

information privacy: relationship between the collection and dissemination of data

information transparency: clarity about relevant details, needed for a decision or an assessment

information verifiability: ability to review, inspect, audit, test to establish, document, confirm the veracity of an assertion

integrity: maintenance of, and the assurance of, data accuracy and consistency

NOTE: As defined in [i.30].

intermediate product: product that requires further manufacturing or transformation such as mixing, coating or assembling to make it suitable for end-users

NOTE: As defined in [i.23].

linear economy: cradle-to-grave; the 'take-make-waste' model; that is, extracting, manufacturing, using, and wasting

NOTE: As defined in [i.31].

modular product: product that, in a container product, includes module(s) (component products) that can easily be replaced or added

product: any physical good that is placed on the market or put into service

NOTE 1: As defined in [i.23].

NOTE 2: ICT goods are ICT products.

product batch: subset of a specific model composed of all products produced in a specific manufacturing plant at a specific moment in time

NOTE: As defined in [i.32].

product item: single unit of a model

NOTE: As defined in [i.32].

product model: version of a product of which all units share the same technical characteristics and the same model identifier

NOTE: As defined in [i.32].

product operator: any actor that can transform and supply modified products and therefore can supply the information a Digital Product Passport (DPP) conveys about them, as a result of manufacture or other operations

NOTE: These other operations could be: packaging, configuration, maintenance, repair, upgrade, refurbishment, remanufacturing, or recycling.

refurbishment: industrial process which produces a product from used products without any changes influencing safety, original performance, purpose or type of the product

NOTE: New and/or used parts can be used during refurbishment. The definition is based on ETSI EN 303 808 [i.21] and amended.

remanufacturing: industrial process which produces a product from used products or used parts where at least one change is made which influences the safety, original performance, purpose or type of the product

NOTE: The product created by the remanufacturing process may be considered a new product when placing on the market. The definition is based on ETSI EN 303 808 [i.21] and amended.

repair: process of returning a faulty product to a condition where it can fulfil its intended use

NOTE: As defined in [i.31].

risk: combination of the probability of occurrence of harm and the severity of that harm limited to human health or safety of persons, to property or to the environment

NOTE: As defined in [i.24].

servitization: The process of creating value by adding services to products. In more detail the offering in terms of "goods or services" through "goods and services" to the marketing of bundles of "goods + services + support + knowledge + self-service" [i.8]

NOTE: See [i.65] for a definition as "The transformational processes whereby a company shifts from a product-centric to a service-centric business model and logic.

supply chain due diligence: obligations of the economic or product operator which places a product on the market concerning its management system, risk management, third-party verifications by notified bodies and disclosure of information to identify and address actual and potential risks linked to the sourcing, processing and trading of the raw materials required for product manufacturing

NOTE: Based and adapted from [i.24].

sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their needs

NOTE: As defined in [i.33].

tag-based identification: process of specifically identifying a physical or logical object from other physical or logical objects by using identifiers stored on an ID tag

NOTE: As defined in [i.29].

traceability ISO 9000**:** ability to trace the history, application or location of that which is under consideration

NOTE: As defined in [i.34].

tracing: ability to follow the supply chain upward and determine the source of a product

NOTE: As defined in [i.35].

tracking: ability of keeping track of the flows of products transporting from upstream to downstream in a supply chain

NOTE: As defined in [i.35].

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ADR	International carriage of Dangerous goods by Road
CRT	Cathode Ray Tube
DGS	Delivery and Global Solutions
DPP	Digital Product Passport
ECHA	European Chemicals Agency

NOTE: ECHA: Candidate list: https://echa.europa.eu/candidate-list-table, Authorization list: https://echa.europa.eu/authorization-list.

EEC	European Economic Community
e-equipment	electrical and electronic equipment
EoLT	End-of-Life Treatment
EPR	Extended Producer Responsibility

EPREL European Product Registry for Energy Labelling

NOTE: EPREL.

ETSI	European Telecommunications Standards Institute
e-waste	electrical and electronic waste
FAIR	Findable, Accessible, Interoperable, and Reusable
GDSPP	Global Digital Sustainable Product Passport
GHS	Globally Harmonized System
HMIS	Hazardous Materials Identification System
HS	Harmonized System
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICT	Information and Communication Technology
ID	Identifier
IEC	International Electrotechnical Commission
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ITU	International Telecommunication Union
KB	Kilobyte
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
PaaS	Product as a Service
PCD	Product Conformity Database
PCDS	Product Circularity Data Sheet
PIC	Prior Informed Consent
RAM	Random Access Memory
RID	Regulations concerning the International carriage of Dangerous goods by rail
SCIP	Substances of Concern In articles as such or in complex objects (Products)
SDG	Sustainable Development Goals
SDS	Safety Data Sheet
SERI	Sustainable Electronics Recycling International
SVHC	Substances of Very High Concern
TPS	Transactions Per Second
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URL	Uniform Resource Locator
URN	Uniform Resource Name
WEEE	Waste Electrical and Electronic Equipment

4 Conventions

Generally, ETSI ES 203 199 [i.27] and Recommendation ITU-T L.1410 [i.28] use the term "ICT goods" instead of "ICT products", however considering the present document is about the Digital Product Passport, both terms are used interchangeably. Hence the term "product" should be considered synonymous to the term "goods" in the present document.

5 Description and scope of the digital product passport

For ICT products, access to digital information about a product, a DPP, enables or facilitates the activities of product operators, such as manufacturers, buyers, owners, repairers, refurbishes, recyclers, market surveillance authorities, environmental and sustainability auditors, customs, etc.

DPP may provide access to digital data, such as linked data, with access to lists, datasheets, manuals, and guides, that contain reliable environmental sustainability data. For instance, it can facilitate circulation (maintenance, repair, reuse, recycling tasks) by providing support information for tasks that contribute to extended use.

Access to digital data about products can help diverse organizations exchange and aggregate data records about models and individual products to produce factual/empirical statistics about the durability of products, among other qualities and make recycling and e-waste management more accountable and verifiable. The demand for **public digital data** can result in manufacturers, governments, and users implementing voluntary or mandatory reporting and monitoring mechanisms to assess these qualities and become an **incentive** to design and use more circular ICT products and processes.

Relevant **digital information can be anything useful to a product operator, user, general public or researchers about materials, design, usage, maintenance, repair, spare parts, and ways to dismantle, recover components and recycle them**. That can be extended to specifications, programming, firmware, and software to allow maintenance and usage, even when manufacturers stop maintenance, to allow third parties to do so.

Raw materials, which include scarce critical raw materials, secondary materials, and the adverse social and environmental **risks** from the presence of hazardous substances, deserve special attention and require environmental responsibility from product manufacturers to monitor and inform about the social and environmental implications of their supply chain in design and manufacturing, facilitate due diligence by public procurement, as well as regarding the reverse supply chain when products may be reused or are no longer used and should ~~to~~ be recycled and materials recovered.

Having all this information related to **sustainability** and specifically about **circularity** in digital and standardized format can bring qualities, facilitate and improve many processes, and help citizens, organizations, and governments to assess their environmental **footprints** and other statistics about the digital/ICT sector. This is a central topic of the idea behind the so-called "product information sheets" or "*digital product passport*" as part of a sustainable digital transformation of society see [i.36] and [i.37]. The **global harmonization** of sustainability requirements can facilitate regional regulation to all stakeholders to promote circular and sustainable ICT products.

This structured collection of product-related information, represented as digital data, can facilitate and bring transparency about design, manufacturing, use, reuse and recycling processes, such as facilitating impact assessment on the environment. A product passport can help **integrate existing and new data**, facilitate **interoperability** across different actors involved, and bring in **quality** properties such as transparency, traceability, verifiability, and accountability of digital products, infrastructures, and services that lead to sustainable digitalisation.

There are related initiatives and standards regarding which product information is relevant from an environmental perspective from several standard development organizations. These are described in annex A.

Different sources and viewpoints influence the design and implementation of DPP systems:

- Global environmental sustainability and circular economy opportunities raised in this recommendation.
- Regional requirements resulting from policy and regulatory choices by governmental actors in different regions.
- The self-regulation choices among the involved actors in the supply and demand of DPPs.
- Results from the experience and the evolution of DPP implementations.

A phased introduction of DPP, driven by regional legislation or regulation by public authorities or multi-stakeholder self-regulation agreements, would enable an early introduction of core product digital information and evolution towards comprehensive information details to promote the most environmentally sustainable products.

6 Circular digital products

6.0 General

The **scope** of products in the present document is digital technology products (ICT products/goods and their components, e-equipment, and e-waste), focusing on circular and sustainable products.

This clause describes stages, challenges, digitalisation considerations in different stages and for different actors of the circular economy, desirable properties of DPP data, and the definition of what constitutes a product in terms of a DPP in terms of sustainability information.

6.1 Objectives for a circular economy

Three are recognized as the main objectives for the circular economy for electronics as reported in [i.52]:

1) New products use more recycled and recyclable content.

2) Products and their components are used for longer.

3) After the end of the use stage products are collected and recycled to a high standard.

These objectives translate into **eco-design, circular business and ownership models,** and more **circular e-waste management**.

The following list gives some examples of aspects that can support taking circular economy into use:

- product durability and reliability;
- product reusability;
- product upgradability, reparability, maintenance and refurbishment;
- the presence of substances of concern in products;
- product energy and resource efficiency;
- recycled content in products;
- product remanufacturing and recycling;
- product' carbon and environmental footprints;
- product' expected generation of waste materials.

6.2 Lifecycle stages

Circular digital products undergo several lifecycle stages see Recommendation ITU-T L.1410 [i.28] or the technically aligned ETSI ES 203 199 [i.27] and face challenges that the digitalisation of the life cycle information supported by a DPP can help with.

The life cycle stages of ICT products are grouped as goods raw material acquisition, production, use, and end-of-life. They can benefit from circularity in diverse ways:

- **Raw material acquisition:** Raw material acquisition starts with extracting natural resources (e.g. iron ore, crude oil, etc.). It ends with transporting raw materials from raw materials processing to part or component production facilities see Recommendation ITU-T L.1410 [i.28] or the technically aligned ETSI ES 203 199 [i.27].

- **Production:** Production or manufacturing starts with parts production, followed by assembly and ends with the transportation of ICT goods and support goods to use see Recommendation ITU-T L.1410 [i.28] or the technically aligned ETSI ES 203 199 [i.27].
  Design and manufacturing decisions determine the use of primary materials extracted from nature and secondary materials captured from e-waste.

- **Use:** The use stage includes ICT products procurement, sale, use, reuse, repair, modification and other support activities see Recommendation ITU-T L.1410 [i.28] or the technically aligned ETSI ES 203 199 [i.27]. In the use stage, products can be used and transferred for reuse until they are no longer valid for that purpose. During use, products consume energy, parts can be added or replaced, and suffer from wear and tear and change during an expected long lifespan. The product warranty period, access to product repair, availability of security and software updates, access to repair instructions, repair tools and services, spare parts, consumables, the ability to detect counterfeit products and parts, and the ability to reuse or single-use nature make a difference in durability and quality of service.

- **End-of-life treatment:** It starts with the collection, and transport of de-installed ICT products or support products to storage, disassembly, parts reuse, dismantling, and shredding facilities and ends with the recycling of raw materials, recovery of secondary materials, and final disposal of treatment of waste ICT and support products see Recommendation ITU-T L.1410 [i.28] or the technically aligned ETSI ES 203 199 [i.27].

6.3 Challenges in the electronics life cycles

Despite the push towards a circular economy, with an impetus to systemic improvement and awareness-raising, on-ground implementation challenges hold back a more efficient and circular electronics life cycles. These are, according to [i.36]:

- **Insufficient and unreliable data on e-waste flows**, such as for the definition of fair and effective regulation and policies, realistic collection targets and tailored e-waste management programmes. The Global E-waste Statistics Partnership helps countries compile data and statistics on e-waste flows using an internationally harmonized measurement framework.

- **Information asymmetry and limited trust**, such as between suppliers of components, producers and recyclers on product compositions, or repairers and recyclers on product components, due to concerns from producers on the confidentiality of their product information, often without mechanisms to verify the data by external parties, risk of fraud.

- **Informal and not reported e-waste**, such as when the informal sector primarily manages the e-waste; regulatory obligations of the ICT products sector, especially under the EPR policy schemes, require producers to have visibility over and report where their raw materials came from and where products end up. The Basel Convention [i.53] requires that hazardous and other wastes in its scope move transboundary by the Prior Informed Consent (PIC) procedure, whereby every shipment should travel with a movement document and the consent of all States concerned by transboundary movement.

- **Insufficient consumer participation and the proper end-of-life channels**, such as returning it to the producer or dropping it off at a municipal e-waste bin. Low worldwide collection and standard recycling rates indicate that a barrier exists.

- **Inefficient e-waste management processes**, such as costly and complicated as more ICT products are introduced in the market.

- **Insufficient cooperation between all stakeholders along the life cycles,** such as installers may change the original hardware configuration of the equipment during the installation; users may change or upgrade a product with new/altered components, repairers may modify a defective product and hence change the product's composition in use.

6.4 Digitalising the information about ICT product' life cycles

Applying digital technologies, specifically a DPP, can support the transition to a circular electronics industry, helping address the challenges just introduced, helping optimize existing solutions with digitalisation and enabling new transformative ways. That implies satisfying the needs of all stakeholders. Each actor that creates and modifies products has its own responsibility in contributing the corresponding product information.

A DPP enables transparency and facilitates traceability implementation in the supply chain across all actors. For instance, digital certification of legitimate parts and components, materials, actors and product tracking, can be used to create a digital chain of custody across the lifespan, ranging from primary or secondary materials to e-waste and prevent the introduction of counterfeit elements with environmental risks see Recommendation ITU-T L.1034 [i.38].

These properties are described in more detail in clause 6.5. In terms of the lifecycle stages defined previously, the benefits can be the following.

Raw material acquisition:

The raw material acquisition stage can provide transparency and traceability by reporting about the supply chain in terms of actors involved in material extraction or **secondary** (recycled) material recovery, processing, and tracking, particularly the presence of **critical raw materials** or **hazardous substances**, and manufacturing waste. For instance, Recommendation ITU-T L.1102 [i.39] allows the communication of information about rare metals.

Production:

The production (manufacturing**)** stage can support transparency and traceability by reporting information coming from supply chain actors (e.g. designer, tier 2, tier 1, manufacturer) involved in parts production and assembly. In the design phase, **circular design** can contribute useful digital data about designed energy efficiency, durability, repairability, reusability, and recyclability. Readily accessible digital information in a DPP for that product can facilitate and even automate processes along the supply chain and product lifecycle, proving compliance with legislation, facilitating market surveillance by public authorities and customs, and supporting sustainability claims. This information will help identify and buy sustainable products.

Use:

A DPP can facilitate **public procurement** by providing standardized informative details, document links, verificative details, ecolabels, environmental scorings, and energy efficiency labels, to guide due diligence, selection and purchase, and give valuable data to keep track of products in an inventory to manage preventive maintenance and repair.

Precise, detailed and updated product information can facilitate decisions towards increased durability through the use, upgrade, repair and reuse of parts, components or the product, provide information to enable public policies that may restrict single-use or prevent the destruction of unsold products, detect premature obsolescence, and incentivise servitization.

Regarding the reuse of refurbished and remanufactured products, a DPP can help reduce uncertainty when procuring pre-owned ICT products.

It can facilitate repair, upgrade or refurbishment (repair manuals, spare parts for users or professionals), which helps prevent unnecessary replacement. It can facilitate the collection of empirical repairability metrics, as well as the collection of actual energy consumption measurements in the use stage.

Products with a DPP for collective products, a product **model** or product **batch**, can become unique individual product items in the use stage. Circularity and a long lifespan imply processes that modify products which make them unique. They may require **product operators** to produce an **individual DPP** that reflects these unique characteristics and changes in a unique product item over the initial model-specific DPP.

ICT products change during the use stage due to usage, reconfiguration of modular products, repair and reconfiguration, wear and tear and, therefore, that leads to the possibility of dynamic data addition or item-level updates for their corresponding individual DPPs. That can increase the divergence and mismatch between the DPP at the production stage and after modifications during the use stage, particularly when these changes affect the product's environmental performance and composition.

All these processes contribute to product life extension, combined with more circular business models, such as leasing rather than product ownership, Product-as-a-Service (PaaS) and asset sharing, increasing the longevity of ICT products as they pass through several users before its end-of-life is reached.

End-of-life treatment:

In the EoLT, the collection of products can be improved by providing information to assist in the correct return or disposal of products. Improved recycling can be achieved by having accurate information about materials and other product characteristics that can facilitate or automate triage and prevent environmental risks, including informing the selection of components to reuse or product remanufacturing, improving sorting and pre-treatment of waste to extract secondary materials better, treating and preventing damage to people and nature from the presence of hazardous substances.

Digitalisation supports informal sector worker' transition to the formal system by building capacity and introducing more transparency and accountability with business opportunities that enable social innovation. Specifically, precise and reliable data can help optimize and automate e-waste sorting, dismantling and recycling.

Digital data can facilitate creating marketplaces for e-waste, materials, and pre-owned products throughout the product life: with platforms for traceable and transparent transactions for e-waste and secondary resources, enabling informal sector integration and mainstreaming. This transparency can inform and facilitate the implementation of public policies to **prevent the destruction** of unsold or still usable (and reusable) consumer products, or transborder movements of e-waste, which are environmental problems.

Convenient, incentivised, and optimized e-waste collection and takeback help transfer incentives to consumers to dispose of waste responsibly in return for digital rewards. EPR schemes can involve manufacturers in a more efficient, informed and accountable way.

Market surveillance:

Authorities in charge of market surveillance or customs authorities should get precise digital information about source attribution for all DPP-covered products in a market: unique product identifiers (what), unique operator identifiers (who), unique facility identifiers (where), and additional information, such as information about and verification of regulatory compliance, when relevant and according to regional laws and regulations. Authorities need to interact with the DPP system that represents the market, to verify correctness of product information.

On collecting and maintaining product information:

Digital standardized and linked information allows and provides the required details to assess the sustainability impacts of ICT products and their supply chain. Specifically, it can bring several benefits.

- Facilitate **knowledge generation** throughout the product life: feed databases and datasets for data integration and analysis and comply with national or regional regulations about the right to reuse and repair.
- **Reduced paperwork and administrative burden:** digitalisation can help streamline the administrative aspect of the electronics life cycle apart from the direct benefits such as reducing paperwork, record-keeping effort, and human error, digitized ways to report product conformity, digitization efforts in the e-waste management sector will improve the accessibility of practical information in the field of e-waste.
- The digitalisation of information necessary to comply with the **Prior Informed Consent** Procedure for transboundary movements of e-waste under the Basel Convention. In its 2022-2023 Workplan, the Basel Convention Parties established a working group to explore electronic approaches to notification and movement documents [i.40].
- Creating a **digital chain of e-waste custody:** integrate multiple layers of logistics, administration and approval processes to go into an efficient and effective e-waste management system; digitalise and automate operations to provide a credible chain of custody, manage inventories, issue recycling certificates, financial calculations, settlements, and report creation for compliance purposes.
- Making **monitoring and enforcement** more efficient: virtual monitoring and auditing processes. Audits, previously carried out in person, are now conducted virtually. SERI provides advisories for the necessary checks and balances to conduct remote audits [i.41]. These digital audits are also helping auditors overcome the stress of continuous physical audits [i.42].
- **Building capacity and creating awareness:** provide information to inculcate a positive attitude towards circularity.
- Promote the **reduction of carbon and environmental footprints**, by providing impact related information and linking incentives to sustainability performance levels.

These improvements rely on agreements to identify relevant data and access to it.

This information should protect personal data privacy and business data confidentiality, as well as ensure credibility and usefulness. These desirable data quality properties are described next.

6.5 Desirable properties of product information

In the context of access to environmental information, following what the Aarhus convention [i.5], the Escazu agreement [i.6] or EU directive 2003/4/EC [i.76] recognize, the quality properties described below render environmental and sustainability-related information useful and reliable at the product level and in aggregate terms for statistical purposes.

Among the desirable principles, product information shall implement measures to apply the following:

- **Digitalisation:** beyond creating a digital representation, it refers to the enabled changes, usually optimizing and improving activities.
- **Data findability, accessibility, interoperability, and reusability** are commonly referred to as **FAIR Principles [**i.43**]**.
- **Usefulness:** fit for a purpose, avoiding unneeded information.
- **Accuracy:** correct, precise, according to fact; bringing clarity, avoiding vague and confusing information.
- **Inclusivity:** limited or progressive complexity and cost to prevent excluding small economic actors.
- **Transparency:** clarity is a need to trust and scale up circular processes.
- **Accountability:** a key to answerability, liability, and the expectation of account-giving, and linked to past and future actions.
- **Standardization:** it can help maximize compatibility, interoperability, quality, repeatability, or quality. Harmonisation can facilitate the normalization of formerly custom processes, also across national or regional boundaries.
- **Information privacy:** is the relationship between the collection and dissemination of data, and privacy protection of the subjects involved.
- **Information protection:** respect and protection of intellectual property and business confidentiality.

Among the data quality properties, about providing guarantees, and ensuring "bad things do not happen" product information shall implement measures to apply the following:

- **Accessibility:** despite the ability to facilitate access and benefit from information on a need basis to a **broad** range of actors and situations may be helpful, some information may require or benefit from **restricted access** (e.g. industrial and trade secrets, personal **privacy**, business **confidentiality**) according to the needs and profile of the actors involved, or appear in summarized information (e.g. yes/no answers to questions as in PCDS).
- **Consumers** (i.e. anyone in the general public) need free access to relevant information in the DPP of a product for informed purchases and use. This also raises the need to present information consumers can understand, which bring the need to use appropriate presentations (e.g. user friendly, in their local language).
- **Persistency:** accessibility in terms of the longevity of accessibility to information, related to the expected longevity of products (durability).
- **Authenticity:** the ability to prove an assertion and the **identity** and **authentication** of actors involved helps ensure digital information has an accurate and representative value.
- **Identifiability:** authenticity as it applies to prove the matching to the corresponding product.
- **Composability:** linked data is vital for products composed of components and materials in products that transform and get reconfigured along their lifespan.
- **Integrity:** maintaining data accuracy and consistency over the entire life cycle of a product is vital for a circular economy. Data carriers can reduce manual data entry errors, and internal software in ICT products can report internal data directly to the DPP (i.e. digital twin) to ensure information integrity.
- **Verifiability:** allows a way to confirm the veracity of assertions about sustainability and circularity. It can be implemented through third-party verification schemes, digital signatures (it identifies information sources, and non-repudiation, and can determine integrity or alteration) and (links to) documents.
- **Traceability** (of products): tracking and tracing are essential for a responsible circular economy, following individual product items and flows across supply chains. Digital linked data and identifiers for products and actors can facilitate that throughout the life cycle.

Digitalised information enables accessibility, contributing to the clarity (**transparency**) of the electronics/ICT sector and its users and monitors. That clarity relies on **accuracy** and maintenance to assure **information integrity**. Information should have the property of being accurate and valid. Confidence in the **validity** of information leads to the quality of being **verifiable**, supported by documented facts. Verifiability enables **accountability**, the ability to answer, an enabling attribute to support the access to **environmental information** in line with what international agreements recognize about environmental information quality. In fact, verifiability and accountability enable preventing **greenwashing**, the avoidance of vague, unfounded, unsubstantiated claims, and dependent on clarity and accuracy.

DPPs are **enablers** to the ability to **track and trace** product flows (e.g. products, components, materials, e-waste) after the product has been placed on the market. **Tracing** allows for verifying an aftermarket item's history, status, location, or components using documented recorded identification, finding out about origin, composition, and actors involved and deducting from that repair or end-of-life handling possibilities. **Tracking** allows to find out what happened to a product after it was placed on the market and in the future, which is helpful for impact assessment and reporting. Since aftermarket repair and enhancement of products rely on components and materials, which can change over the lifespan of products and components, these relationships lead to the requirement of data **composability**, as linked data that can change by linking as the related material element changes over its circular life.

Complete **traceability** information is unfeasible as it encodes digital data and every detail of every input. Details are relevant according to the system's objectives. There are differences to consider in traceability system' breadth, depth, and precision see [i.44]. [i.45] adds **access** and **latency** (speed), both applicable to DPP and traceability applications:

- **Breadth** (level of detail) describes the amount of information the digital system records. It can range from high (many) to low (few, including product ID).
- **Depth** of the system is how far back or forward in time the system tracks. Can range from high (e.g. from raw materials acquisition) to lower (e.g. from production).
- **Precision** (granularity) reflects the degree of assurance that the system can pinpoint a particular product or those with common characteristics. It can range from high (individual product items, components or parts) to low (batches or models).
- **Access** refers to the number of different parties with full or partial access to product and process data. It can range from high (economic and product operators such as suppliers, customers, users, regulators, legislators, etc.) to low (owners only).
- **Latency** (change) refers to how long it takes between parties to share and update product information. It can range from instantly, the moment it happens, to slow (eventually) to out of date (already changed again).

In summary, **standardized** ways should be provided to share linked data about all related **participants** and **items** (traceable) related to **specifications** (design), **materials**, **parts**, **products**, **flows** (as business processes), **decisions with outcomes** (e.g. production, sale/purchase, transfer, disposition). This data should be in **digital form**, **accessible and transparent** (transparency) to the relevant actors, **trustable** (integrity, verifiability) and **detailed** (composable, traceable) to facilitate **informed and efficient decision-making, action, scaling up to the global market and the assessment of impacts**.

Regarding **accuracy**, while some environmental information in ICT products would remain static (unchanged), other information will change during a product's lifespan as the product changes to keep it precise and up-to-date (latency). The two categories of attributes have some issues to consider:

- **Static attributes** are product information required at the moment of placement on the market, remaining stable over the product lifetime. Static attributes can be applied at the model level and are the manufacturer's responsibility. They serve mainly for purchasing decisions, not circular economy activities.
  Examples of static attributes include the model identifier, the reparability score, dismantling information, estimated energy consumption and environmental footprint information, including when new spare parts are integrated.
- **Dynamic attributes** are modifiable product details that remanufacturers, refurbishers and repairers can change as they perform circular economy activities.
  Examples of these attributes are changes in critical raw material information or updates to the percentage of recycled content resulting from integrating spare parts with differing specifications from the original part.

For the dynamic attributes to remain correct during the entire life cycle of a product, DPPs should cope with a few **issues**:

- Circular economy actors shall ensure accurate DPP updates when there are changes in a product.
- It is very burdensome for circular economy actors and consumers to host DPP records and assume product liability for information requirements.
- Market surveillance authorities will need to expand their capabilities to enforce and verify compliance with timely updates of the dynamic attributes by independent repairers.
- There may be large energy usage implication from a jump in data storage needs in cases when model- or batch-based DPPs are replaced by individual DPPs.
- Economic operators, the market, need a "learning period" to fully understand and build on the DPP potential.

Regarding **accessibility** and **longevity (persistence)**, information can be encoded as data placed either on:

- In a **data carrier on the product:** very accessible but limited data storage space depending on the different label method types (e.g. one and two-dimensional codes), with priority for product and actor identification, and for risks (e.g. presence of substances of concern) and value (e.g. presence of rare metals Recommendation ITU-T L.1102 [i.39], digital/URL link to retrieve further information). Longevity, as long it is readable, equal to the product, but updates typically require data carrier replacement.
- **Inside the product or packaging:** in a non-volatile medium inside (internal storage) or outside the product (external storage such as a pen drive). Longevity, as long it is readable, updates require local data file updates, as long as the medium allows.
- **Online:** through a web link (e.g. GS1 digital link) obtained from a data carrier. Longevity, as long it is provided updates by the data provider.

The choices depend on the technical limitations of the different storage options, the dimensions and capabilities of physical products in their ability to incorporate a data carrier, legislation in different regions, as well as self-regulation and preferences of manufacturers. However, online information needs to be accessible (a URL that resolves into the required data) for a period that matches the expected durability of the product (considering a circular lifespan with reuse).

6.6 Definition of the product

6.6.0 General

What is the product in the context of electronics and ICT products has to do with the required level of detail in terms of **breadth**, **precision** or **granularity** of identification. A DPP shall refer to the following not exhaustive list of product type:

- Individual ICT goods: such as a serialized or customized individual product item.
- Collective ICT products: a product batch or product model with common characteristics for multiple product items.
- Modular ICT product: an ICT product that combines a container product (e.g. rack, chassis) with included modules (ICT products) that can easily be replaced or added.
- Replaceable parts (products) such as batteries, display modules, or consumables like print cartridges.
- Accessory products such as cables and keyboards.

Choices on breadth, precision or granularity depend on product characteristics and agreements across actors about the level of detail to report in a DPP.

The product scope of DPP has considerable implications for the DPP architecture and implementation. Alternatives are discussed and compared in clause 7.

6.6.1 Classes of products (verticals)

Some characteristics are specific to ICT product classes (verticals) with specific environmental requirements for function or form (components). Some examples of product categories:

- Electric and autonomous vehicles have large batteries and many critical ICT elements (products), with specific environmental and personal safety requirements.
- Smartphones with mobility requirements and smaller batteries and electromagnetic emissions.
- Computers with diverse characteristics and product ranges.
- Displays, with the potential presence of lead in CRT monitors see [i.46] or mercury in LCDs see [i.47], among others.
- Office equipment: including fax machines, laser printers, ink-jet printers, scanners, and photocopying machines), with serious potential environmental risks to human health from the concentration of volatile organic compounds, ozone, and respirable particles (PM_{10}) [i.48].
- Network products with diverse characteristics and product ranges.

These verticals are not covered in the specific details in the present document.

6.6.2 Customization and change

While new or remanufactured consumer or industrial ICT products are produced in large quantities with identical features, therefore represented by a DPP in common, customized (modified) products as a result of reconfiguration, repair, refurbishment, incorporating new, modified or second-hand pieces tend to acquire unique characteristics and may require individual DPPs to accurately reflect the unique environmental characteristics of these product items.

The details about the sustainability of products in a DPP can be fixed at different times:

- A model passport may be fixed at design time (at product launch).
- A product batch passport may be fixed at manufacturing time.
- Changes during the lifespan affect one or a few product item units, not all. Environmentally sensitive changes may require individualized DPPs that extend or replace the DPP for the product model or batch (as a supplement, complement or specific variant of the previous or collective DPP). A decentralized approach would allow a new passport or supplement to be created, linked to the previous one every time the information changes due to the modifications done by the product operator that has the specific information to report, and attached to a data carrier in the product or registered in a decentralized search or lookup service for serialized/unique products.

NOTE: Linked to the previous DPP for traceability. The degree of change is related to latency as defined in clause 6.5.

6.6.3 Relevant details to sustainability

Considering a circular lifespan of products that results in the need for reporting information related to or resulting from processes, ranging from raw material acquisition, manufacturing, usage, servitization, transfer, maintenance, repair, refurbishing, remanufacturing, disassembly, recycling, and recovery (more information are available in Supplement ITU-T L.Sup28 [i.49]. That results in relevant information, affected and extended by these processes, with details in annex A about sustainability-related standards and databases. However, design decisions result in many relevant informative details as introduced by clause 6.1 of the present document, in line with the details described by Recommendation ITU-T L.1023 [i.79].

7 Guidance for implementation

7.0 General

The present global and broad (generic) document contains an overview from an environmental perspective (sustainability) about the digitalisation of product-related information integrated and harmonized under a digital product passport representation.

DPPs are expected to incorporate data in response to demand from ICT service providers, product operators, consumers and sector regulatory authorities. DPPs can be linked and provide information about compliance with regulations and norms: such as requirements, responsibility, support, verifiability, audit, traceability, and transparency, that can be checked digitally. That should benefit all stakeholders and reduce the burden of taking informed decisions to optimize and assess the sustainability of ICT products.

Specific product categories, regions, governments, industries, and citizens (stakeholder groups) may raise additional requirements from sustainability and other perspectives, so DPPs are expected to evolve in terms of refinement and harmonization, similarly to other global public information systems have evolved. Discussion, consensus, standardization and legislative processes on these can enable agreements to develop concrete and specific DPP specifications, including required and voluntary (recommended or optional) values, static and dynamic. This can be achieved according to existing standards, public regulations, and industrial self-regulation, to deliver all the digital data that can help achieve more sustainable ICT products as a result of the efficiencies and savings from the digitalisation of product information.

However, there are two aspects of DPP from a circularity perspective:

- **Collective: product model or batch**. Manufacturers and importers, as economic operators introducing industrial, professional or consumer products into the market, are the informed and responsible actors to produce DPPs for new or remanufactured ICT products in volume entering the market, which can be found from a data carrier in the product itself. All product items in a given batch or model usually share the same reported characteristics and, therefore, can share the same DPP. The economic operator introducing a product into the market can publish and even update that DPP information (versioning) in their website to allow anyone to read the data carrier in the product, find out and access that DPP document, with informative details and links to the latest related informative and verificative details, and with content that can be customized to the needs and profile/credentials of the visitor.
  These DPPs can be updated to reflect improved or localized information (specific details or in local languages of a region), the effect of software updates and adapt to comply with changing or different regulations for products already in the market.

- **Individual: product item**. Product operators in the circular economy can modify individual product items and, therefore, their environmental information. Product items get modified through repair, reconfiguration, refurbishment and recycling. Given their knowledge about the details of product item modifications, they can issue a new DPP for that modified product item that refines, updates or complements the original collective (e.g. model based) DPP. A new product item DPP, should relate to the previous or initial (model or batch, collective) DPP. The new DPP may be found by either attaching a new data carrier to the product item or by a model+serial unique number lookup in a public searchable DPP repository.
  These individual DPPs, precise to the product item's environmental characteristics and performance, with verifiable information linked to public databases and digital ledgers, precisely identifying the economic and product operators and third parties involved, increase trust in the DPP information on users of modified (repaired, reconfigured or refurbished) second-hand products and helps the final recycler to manage e-waste according to the latest product item characteristics at end-of-life, which may differ significantly from those at manufacturing time. Reliable and accurate DPPs are key to facilitating the development of a circular economy of long-lasting ICT products and increasing the circularity supported by safe (precise, reliable, etc.) environmental sustainability information while reducing processing costs, and increasing scale and quality/accuracy in product processing.

Therefore, DPP information can be corrected, and extended by responsible actors that can provide information meeting the desirable quality properties in clause 6.5. However, product information changes for an unmodified material product (versioning) differs from product modification or customization, usually done for individual items, which can require an individual DPP issued by the product operator that modified the product, with its corresponding data carrier attached to the product.

DPPs should be available, on a product item, the web or the internet, for a long enough period (retention period), at least covering the time a product can be in the market and reach recyclers. This means content should be hosted not only on the economic operator's website.

In addition to providing informative product details, specifically about environmental sustainability, DPP can also refer to details about the quality of information, allowing to validate claims made by diverse product operators in the circular economy market.

7.1 DPP architecture considerations

The product-level scope of DPP has considerable implications for the DPP architecture and implementation. Alternatives are compared in Table 1.

Table 1: Impact of the product-level scope of DPP architecture

	Product-level scope of DPP			
Comparison item	brand	Product model (collective)	Product batch (collective)	individual product item
Who creates/maintains DPP and the data, see note 1	manufacturer	manufacturer	manufacturer	manufacturer/ 3rd party
3rd party horizontal infrastructure to maintain DPPs, see note 2	-	-	-	infrastructure capability rollout needed, see note 3
DPP identity is based on:	brand ID	model ID	batch ID	serial number
Track passport versions forwards/backwards, see note 4	-	ok	ok	implementation open, see note 5
DPP data & data transaction volume, see note 6	lowest	low	low/medium	high

NOTE 1: 'Maintaining' refers to either DPP editing capability or the capability to create an updated version or a DPP supplement. It can also refer to maintaining a DPP data delivery service.

NOTE 2: If the manufacturer creates DPP, it can be read-only for other actors, who can start using it at will. This is very different compared to a large-scale horizontal/product-item DPP with maintaining/updating/editing capability of relevant actors.

NOTE 3: This involves several implementation & data security-related questions to be defined, see discussion in notes 5 and 6.

NOTE 4: This row assumes that model- or batch-based product passports are maintained by the manufacturer, as it might be somewhat difficult to justify other approaches. When manufacturers maintain the data, the solution architecture is still distributed since each manufacturer maintains their own data. In that case, it is also easy to arrange the linking of different passport versions, both backwards and forwards.

NOTE 5: If each individual product item has its own passport so that 3rd party upgrade/repair services need to produce a new revised passport, they have to either have editing rights to the manufacturer's data (which can be problematic in many ways), or they will need to establish their own data. In the latter case product's passport history can be obtained by searching for all passport versions in a web service having the links to the information about product identifier and economic operator placing the product in the market. If the manufacturer desires to analyse the events in the life of a product, then forward-tracking of passport versions may be very difficult in this type of scenario.

NOTE 6: This has an implied impact on data storage, data processing, energy consumption. In the worst case, this could even compromise getting any net benefits from DPP (see annex B).

Annex A (informative): Related work, standards and data sources about environmental sustainability

A.1 Related work

A DPP relates to existing available data formats, linked data, wire and storage data formats, and system architectures, as well as relates to and complements upcoming regional initiatives (e.g. European digital product passport) and global (ISO PCDS [i.77], IEC 82474-1 [i.78]) specifications and standards. Integration and standardization with a global scope aiming at **reducing the burden** of already providing partial information through multiple specific and regional standards.

The present document considers **ICT products** classified according to the Recommendation ITU-T L.1023 [i.79] on an assessment method for circularity performance scoring by facilitating data collection that can show the effect of a design decision in practice. It can help collect details as data records along the lifespan of ICT products to assess and report impacts of circular business models as in Recommendation ITU-T L.1024 [i.8], about **servitization**: selling services instead of equipment. It can facilitate the calculation of lifecycle environmental impacts of different ICT products according to Recommendations ITU-T L.1400 [i.62] series and mobile phones according to Recommendation ITU-T L.1015 [i.54]. These and more are listed in more detail below.

A.2 Standards and data sources related to sustainability

International standards provide guidance and the framework to implement circularity across the electronics life cycle. The aim is to collect opportunities from existing standards about valuable details represented in a DPP.

Table A.1 presents Recommendation ITU-Ts according to the main stages of a circular lifecycle, introduced in clause 6.2.

Table A.1: ITU-T Recommendations according to life cycle stages

Products raw material acquisition and production	Use	End-of-life treatment	Other sustainability - related Recommendations
ITU-T L.1010 [i.55] Green batteries for hand-held devices	ITU-T L.1024 [i.8] Servitization	ITU-T L.1021 [i.26] Sustainable e-waste management	ITU-T L.361 [i.56] ID tag requirements
ITU-T L.1023 [i.79] Assessment of circular scoring	ITU-T L.1061 [i.57] Circular public procurement	ITU-T L.1030 [i.58] e-waste management for countries	ITU-T L.1015 [i.54] Criteria evaluation env impact of mobiles
ITU.T L.1050 [i.59]: Methodology to identify key equipment for environmental impact and e-waste generation assessment of network architectures		ITU-T L.1032 [i.60] Certification of e-waste recyclers	ITU-T L.1022 [i.31] Material efficiency and circular economy definition
ITU-T L.1102 [i.39]: Printed labels for communicating information on rare metals in ICT products		ITU-T L.1100 [i.61] Recycling rare metals	ITU-T L.1400 [i.62] Env impact assessment
		ITU-T L.1031 [i.25] E-waste reduction targets	
ITU-T L.1410 [i.28] Methodology for environmental life cycle assessments Technically aligned with ETSI ES 203 199 [i.27]	ITU-T L.1410 [i.28] Methodology for environmental life cycle assessments Technically aligned with ETSI ES 203 199 [i.27]	ITU-T L.1410 [i.28] Methodology for environmental life cycle assessments Technically aligned with ETSI ES 203 199 [i.27]	

Recommendation ITU-T L.1410 [i.28] and the equivalent ETSI ES 203 199 [i.27] provides a "methodology for environmental life cycle assessments of information and communication technology products, networks and services", for the environmental assessment of the life cycle impact of ICT goods, networks and services. Data should be collected for all mandatory processes. The collected data, whether measured, calculated or estimated, are utilized to quantify the inputs and outputs.

Recommendation ITU-T L.1023 [i.79] outlines the circularity aspects and indicators for circular product design of relevance for circular ICT.

Recommendation ITU-T L.1023 [i.79] methodology translates into guidance for the identification of the margin of improvement level for each indicator. The detailed table brings specific Digitalised details required for scoring (yes/no questions in the style of PCDS) and supporting information.

The Product Circularity Data Sheet (PCDS) [i.64], [i.51] and [i.20] is an initiative that provides a public specification for suppliers of materials and semi-finished products to provide verifiable information about the circularity properties of their materials. It is inspired by the (material) **safety data sheet [**i.50**]**, which chemicals suppliers use to provide safety information about their substances and mixtures. The PCDS offers a standardized format with trustful data without scoring or ranking these aspects. There is a third-party verification process to validate the content (audit) and a data exchange protocol to be defined separately. It has three objectives: provide basic data on materials circularity, improve the sharing efficiency of circularity data, and encourage the circularity performance of products. A new PCDS can be created at each stage of the material transformation process. The material supplier passes their PCDS one step up the supply chain to allow for its integration into the next tier's material transformation process. Each material manufacturer is responsible for storing the information related to the PCDS statements and making such information accessible to other stakeholders upon request. PCDS is designed to be integrated through the supply chain. Given its aim, PCDS constitutes a product generic circularity information source for a DPP.

There are information and data sources (databases, lists, registries, codes) agreed in the scope of regional and global conventions that provide details about agreements on substances, materials, labelling and identification of national, regional or global scope, that can be referenced in a DPP:

- Globally Harmonized System for the classification and labelling: categories symbols and risk phrases for hazardous substances.

NOTE 1: GHS can be used for determining the Relative Hazardousness of substances and compounds [i.73].

- UN Numbers for hazardous substances.
- Hazardous substances and materials safety data sheets.
- Harmonized Systems codes. for trade categories of products and e-waste, related to the World customs organization.

NOTE 2: WCO Trade tools: https://www.wcotradetools.org/.

NOTE 3: The World Customs Organization: http://www.wcoomd.org/.

- Basel Convention codes.
- Transport codes (ADR, ICAO, etc.).
- Schemes for classification and labelling of raw and secondary materials.
- Product Conformity Database by ITU [i.65].
- Traceability registries.

Table A.2: Information and data sources on regional and global environmental agreements

Acronym	Full name	Region	Description
GHS See note 1.	Globally Harmonized System of Classification and Labelling of Chemicals International	Global	The GHS includes the following elements: a) harmonized criteria for classifying substances and mixtures according to their health, environmental and physical hazards; and b) harmonized hazard communication elements, including requirements for labelling and safety data sheets.
HS Codes	Harmonized Commodity Description and Coding Systems	Global	The Harmonized System is an international nomenclature for the classification of products. It allows participating countries to classify traded products on a common basis for customs purposes. At the international level, the Harmonized System (HS) for classifying products is a six-digit code system.
UN Numbers	UN numbers are assigned by the United Nations Committee of Experts on the Transport of Dangerous Products	Global	UN numbers or UN IDs are four-digit numbers that identify dangerous products, hazardous substances and articles (such as explosives, flammable liquids, toxic substances, etc.) in the framework of international transport.
Transport codes and requirements (ADR, RID and ICAO/IATA DGS)	ADR: Agreement concerning the International Carriage of Dangerous Products by Road. RID: Regulations Concerning the International Carriage of Dangerous Products by Rail. ICAO/IATA Dangerous Products Regulations	UNECE region and global	Regulations including transport codes, hazard classification symbols, packaging instructions and safety data sheets for the different means of transport (road, train and air).
SDS [i.72]	Safety data sheet	Global	

Acronym	Full name	Region	Description
ITU PCD [i.65]	Product Conformity Database	Global	Result of the ITU Conformity and Interoperability (C&I) programme to enhance the conformity and interoperability of ICT products implementing ITU Recommendations or part thereof.
SCIP See note 3.	Database for information on Substances of Concern In articles as such or in complex objects (Products)	European Union	
ECHA-Candidate list. See note 4.	Candidate List of substances of very high concern for Authorization	European Union	
ECHA-Authorization list See note 5.	Authorization list	European Union	
EPREL See note 6.	European Product Registry for Energy Labelling	European Union	
HMIS	Hazardous Materials Identification System	USA	
	Workplace Hazardous Materials Information System	Canada	
Directive 67/548/EEC and the related amendment [i.66]	European hazard symbols from Dangerous Substances	European Union	
NOTE 1: See [i.74] and [i.75]. NOTE 2: https://unece.org/about-ghs. NOTE 3: https://echa.europa.eu/scip. NOTE 4: https://echa.europa.eu/candidate-list-table. NOTE 5: https://echa.europa.eu/authorisation-list. NOTE 6: https://eprel.ec.europa.eu/screen/home.			

Annex B (informative): A simple estimate of the volume of data and transactions

ITU estimates [i.67] that at the end of 2019, a bit more than 51 % of the global population, or 4 billion people, were using the Internet. In Europe, this percentage goes up to 83 %, which means 620 million people.

Regarding ICT products, GSMA 2020 [i.68] has global estimates of 5,2 billion active individual products in 2020, with a forecasted 5,7 billion in 2025. That translates for Europe to 472 million in 2020, with a forecast of 480 million in 2025. Forecast of shipments of ICT products [i.11] estimates more than 100 million desktops, 350 million laptops, and 780 million customer routers in the coming years, representing 1,23 billion individual products. Regarding the yearly sale of smartphones, [i.71] estimates 1,5 billion sold globally. [i.70] reports a durability range of 3-5 years for these smartphones, with typically one battery change (i.e. battery issues after use periods of 2-3 years).

Regarding relevant details about a digital product that might be reflected in a digital product passport, a proposal from the Luxembourg government [i.51] considers hundreds of statements (data items). Some of these items may require references to external data, like documentation, certificates, and databases such as those about hazardous substances, etc. A rough working assumption about the volume of data per item could be around 1 KB.

Regarding relevant events along with lifespan, these relate to processes, design decisions, and the supply chain, which in manufacturing typically includes tier 2, tier 1, and production/assembly steps, then distribution, sale and use by a customer, and final recycling, considering a circular lifespan [i.69]. The manufacturing phase can produce secondary materials (industrial mining). The use phase can be further detailed, including update, repair, upgrade, end-of-use, refurbishment, product reuse, reuse of their parts, recycling, and secondary material extraction (urban mining). All that translates into about 17 different processes that may affect a product and its related digital data.

Products are in different phases of their lifespan, with a rate of change probably significant during the manufacturing phase and the recycling phase and then slowly changing over years (e.g. 1-2 changes of battery during an extended lifespan, one repair, 1-2 cycles of reuse, until final recycling. A rough estimate of the change volume is around one event per each process during lifespan.

The volume of direct data that may represent a digital product passport could be estimated considering all the products available in different stages of their lifespan in a year, in the range of 1,5 billion smartphones + 1,23 billion computer and networking products sold every year, multiplied by four years of average durability, multiplied by 1 KB. That results in roughly 11 TB of data if every single product in the world adopts a DPP.

Looking at the number of transactions associated with any relevant event or changes to the record. That can be estimated to be equivalent to 2,73 billion products sold yearly multiplied by 17 events over their total lifespan (assuming the imprecise simplification that these events are spread uniformly). That results in roughly 46 billion transactions per year or 1 471 transactions per second (tps) if every product item (individual) in the world adopts a DPP to record changes in every step of its extended lifespan.

However, if the number of transactions per item (e.g. serial number) gets reduced to the minimum of manufacturing and recycling each item, the rate reduces to 167 tps. If the transactions only occur per batch or model, that reduces the rate to a negligible tps rate.

History

Document history		
V1.1.1	January 2024	Publication