# Residual Value Assessment for Circular Products and Materials (RVACPM)

A Framework for Turning Product Life-Cycle Information into Value
Semantic Interoperability of Value Information in Circular Value Chains
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## Introduction: Information Flow in the Circular Economy and Value Retention

This document introduces a framework for assessing the residual value of products, components, and materials in a circular economy. It explains how value-related information can be shared through digital infrastructures and outlines a direction for future international standardisation.

Digital infrastructures for sharing product life-cycle information are now being developed in Europe and Japan. Examples include the Digital Product Passport (DPP), introduced in Europe under the Ecodesign for Sustainable Products Regulation (ESPR), and Japan's Chemical and Resource Circulation Information Platform (CMP). These initiatives mainly address product identifiers, material composition, contained chemical substances, and regulatory compliance information. However, information that explains the residual value of products, components, and materials as they circulate across multiple life cycles remains insufficiently structured and shared.

In this document, platforms such as DPP and CMP are referred to as digital infrastructures: practical systems through which information is exchanged. By contrast, the information infrastructure refers to the semantic and rule-based layer that gives structure and meaning to residual value information shared through those systems. The flow of such residual value information is referred to here as the Value Information Flow. This perspective is important because a circular economy depends not only on the movement of products and materials, but also on the movement of information that allows their value to be understood and used again.

Based on an examination of Japan's plastics circulation market, this document identifies two structural information gaps: a gap in use-case information and a gap in life-cycle information. These are not merely missing data points; they are discontinuities in how information is connected and carried forward across actors and life-cycle stages. Together, they prevent markets from adequately recognising residual value. This condition is described here as a Value Vacuum.

To address this challenge, this document introduces Residual Value Assessment for Circular Products and Materials (RVACPM). RVACPM is proposed as a horizontal, cross-industry framework for assessing residual value and for enabling residual value information to be interpreted and shared consistently across actors, sectors, and life cycles.

## 1. Residual Value and Value Information Flow in the Circular Economy

In a circular economy, products and materials are not discarded after a single life cycle but circulate across multiple life cycles through processes such as reuse, repair, remanufacturing, and recycling. Within such a circulation structure, it becomes essential to determine whether a circulating product, component, or material can satisfy the requirements of its next intended application.

Such determinations cannot be made using the original manufacturing specifications alone. They depend on information accumulated over the lifetime of a product, component, or material, including use history, repair and maintenance records, inspection results, and regeneration or recycling processes. This accumulated information helps determine the value that a circulating product, component, or material continues to have as it moves into its next use. In this document, that value is called Residual Value, defined as the value that a circulating product, component, or material provides when it meets the requirements of its next downstream use case.

Traditionally, the movement of products and materials has been described using the concept of the *supply chain*, which emphasises the physical flow of goods from raw material extraction through manufacturing, distribution, and sales[1][2]. The information exchanged along this chain—here referred to as the *information flow*—typically includes identifiers, material declarations, chemical content, regulatory compliance data, and transactional histories.

Many factors influence how products and materials are valued as they move through conventional supply chains. These include the reliability of information, environmental performance, compliance with relevant standards, and certification status. Porter's concept of the value chain frames economic activity as a linked sequence of value-creating processes [3]. When this perspective is extended to circular and reverse flows, such as reuse, repair, remanufacturing, and recycling, additional information is needed. In particular, actors need to understand how usable products, components, and materials are for subsequent applications and what level of residual value they retain.

The information used to support residual value assessment is referred to in this document as the Value Information Flow. It includes performance characteristics as well as life-cycle information accumulated across use, repair, refurbishment, inspection, and recovery. Together with conventional supply-chain information, the Value Information Flow enables residual value to be assessed, compared, and exchanged, thereby supporting economic activity in circular markets.

Certain digital infrastructure initiatives, including DPP [4] and CMP [5], have begun to implement life-cycle data sharing. However, they remain primarily focused on traditional, largely linear supply-chain information. As a result, an information gap emerges when a product, component, or material reaches the end of its initial life and is expected to circulate into a new use. At that point, market actors often lack the value-critical information needed to judge residual value and support circularisation. This lack of information impedes value assessment on the demand side and hinders production planning and quality stabilisation on the supply side. The formation and growth of circular markets are therefore constrained.

## 2. Structural Information Gaps and the “Value Vacuum” in Circular Markets

An examination of Japan's plastics circulation market revealed two structural information gaps between supply-side and demand-side actors. These gaps are structural because they concern how information is linked, transferred, and preserved across actors and life-cycle stages, rather than simply whether isolated data items exist.

The first is the use-case information gap. Demand-side actors need materials that meet application-specific performance and compliance requirements, such as mechanical strength, thermal resistance, processability, and chemical safety. When these use-case requirements are not adequately communicated to the supply side, suppliers cannot plan and supply circular resources that reliably meet downstream needs.

The second is the life-cycle information gap. Manufacturing-origin information, such as product specifications, component structures, material composition, and chemical substance data, is often disconnected from state and history information generated during use, repair, refurbishment, recovery, and the period in which resources remain in market stock. This state and history information also includes information on the location of circular resources, the timing of their availability, and the condition in which they can be used. When products are dismantled and recycled into materials, these forms of information are frequently lost or no longer carried forward in a usable form.

These two information gaps create information asymmetry within circular markets. As described in classic market theory, market failure may occur when sellers and buyers possess asymmetric or insufficient information regarding quality [6]. In circular markets, when demand-side actors cannot reliably assess the residual value of circulating products or materials, they tend to default to virgin materials or new products.

Consequently, the value of circulating products, components, and materials is not accurately recognised, compared, or priced by the market. This document conceptualises that condition as the Value Vacuum. The Value Vacuum is a systemic barrier to the creation, expansion, and maturation of circular markets because it prevents residual value from being visible and usable in market transactions.

## 3. Proposal of the Residual Value Assessment Standard: RVACPM

To address the Value Vacuum, a standardised framework is required that enables residual value to be assessed in relation to explicit use-case requirements and shared in a consistent and interoperable manner across digital infrastructures. This document therefore proposes Residual Value Assessment for Circular Products and Materials (RVACPM) as a horizontal, cross-industry standard.

As outlined above, use information refers to information describing the intended application of products, components, or materials. It includes the corresponding performance, quality, and regulatory requirements defined at the level of industries, enterprises, or specific markets. Under RVACPM, residual value is not assessed in the abstract. Rather, it is evaluated in relation to explicitly defined use conditions.

RVACPM is designed to assess the residual value of circulating products, components, and materials and to enable relevant actors to share both assessment results and their evidentiary basis throughout circular value chains. Its primary objective is to systematise the information underpinning residual value and to express it through a standardised information structure that supports semantic interoperability, meaning that residual value information can be interpreted consistently and with the same meaning across life cycles, actors, and sectors.

Based on the above, and with reference to the principles for systematising concepts, terms, and definitions set out in ISO 704:2022 [7], Figure 1 organises the structure of residual value information, its constituent information elements, and its relationship to assessment outcomes that are common across life cycles.

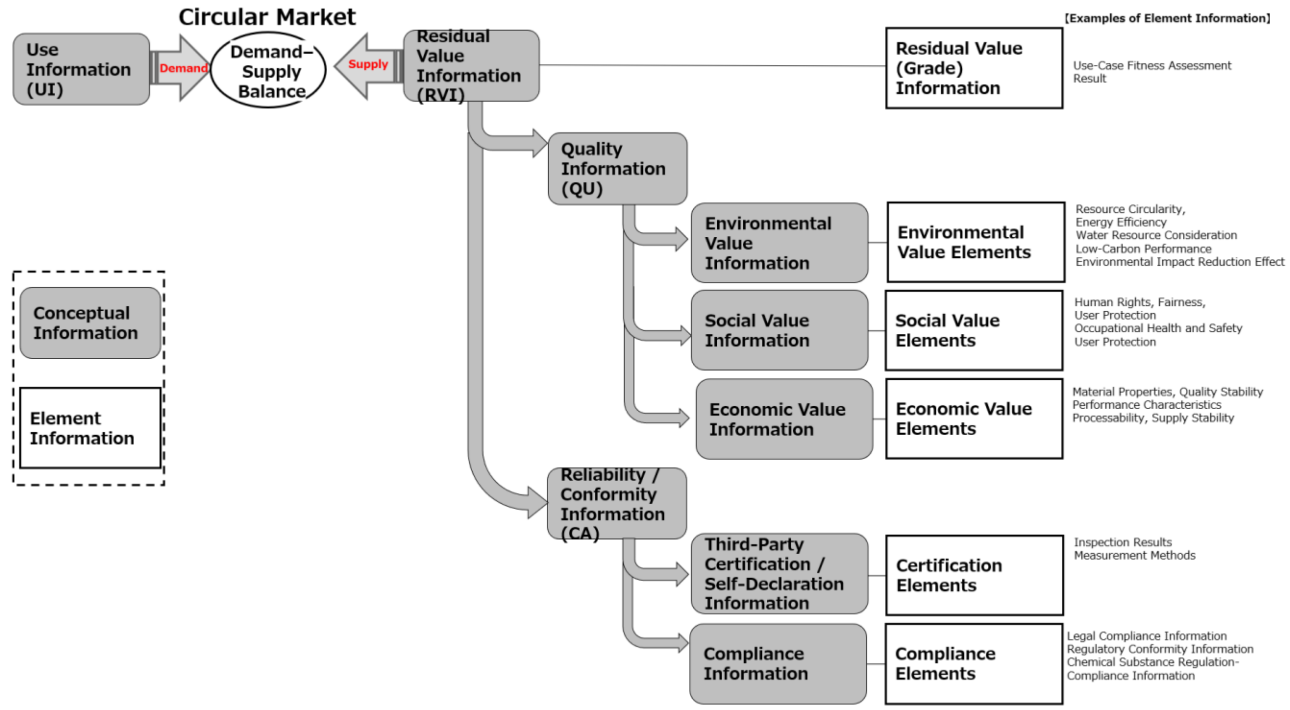


Figure 1 — Conceptual structure of residual value information aligned with use-case-based assessment, in accordance with ISO 704.

As illustrated in Figure 1, residual value information within RVACPM is centred on two core categories of information: quality information (Quality, QU) and reliability / conformity information (Reliability, CA). Life-cycle-related information is positioned as fundamental evidence supporting both categories, with detailed attributes accumulated across use, repair, remanufacturing, and recycling processes.
Quality information represents multidimensional value structured along economic, environmental, and social dimensions.

- *Economic value information* expresses the functional suitability of circulating products and materials for subsequent applications, including material properties, performance characteristics, quality stability, processability, and supply stability.
- *Environmental value information* reflects contributions to resource circularity and environmental impact reduction, such as energy efficiency, water resource consideration, low-carbon performance, and overall environmental burden reduction.
- *Social value information* addresses social sustainability aspects relevant to circular use, including human rights, occupational health and safety, fairness, and user protection.

In addition to quality information, residual value assessment requires reliability / conformity information, which provides the basis for judging the credibility of declared quality. Reliability / conformity information comprises legal compliance information and third-party certification or self-declaration supported by inspection results, test outcomes, and documented measurement or assessment methods. Together, these elements correspond to conformity assessment practices and ensure that quality declarations are consistent, verifiable, and comparable.

Within RVACPM, the outcomes of residual value assessment are expressed in the form of Residual Value Grade Information. A Residual Value Grade represents a validated indicator summarising the result of use-case fitness assessment in a user-comprehensible manner. By design, Residual Value Grades support demand-side decision-making while avoiding overstatement of value and allowing phased implementation even in contexts where fully digitised infrastructures are not yet in place.

Because residual value information is shared among multiple actors in circular value chains, it is essential that the same information is interpreted with the same meaning across systems and organisations. RVACPM therefore explicitly adopts the principle of semantic interoperability, as defined in the European Interoperability Framework (EIF) [8]. Furthermore, as residual value assessment applies across diverse product and material domains, RVACPM is positioned as a horizontal standard, operating above and in conjunction with product-specific standards, in accordance with IEC Guide 108 [9].

On the basis of this framework, and in order to advance the international standardisation of RVACPM, the following issues need to be examined in future standardisation activities:

1. A standardisation framework that supports the international circulation of circular products and circular materials formed under different circular economy schemes and waste-management regulations, and that contributes to the reduction of trade barriers.
2. Guidelines for grading that appropriately express the results of use-case fitness assessments in accordance with the actual conditions of circular markets.
3. A data model of residual value information that enables semantic linkage with use information, ensures semantic interoperability, and supports compatibility with Digital Product Passports (DPP).
4. The organisation of information related to social availability, including how information on the location, timing of availability, and usable condition of circular resources can be described and shared—within the limits of protecting confidential business information—in order to enhance connectivity between supply and demand in circular markets.

These items collectively define the scope of future RVACPM standardisation work and clarify its role as an information-centric enabler of circular markets.

This standardisation is significant because it can reduce the Value Vacuum by making the residual value of circulating products and materials visible to markets. In practical terms, it enables information derived from new product processes, which often remains within the product process side, to be linked with information on circulating products in market stock and carried continuously across life cycles into material processes. The arterial-venous information linkage (linkage between forward and reverse flows) supported by RVACPM can therefore provide a foundation for stable supplies of recycled materials whose quality can be verified for both product assembly industries and material industries.

## Conclusion

The standardisation of residual value assessment proposed in this document provides a foundational information infrastructure for circular markets, enabling residual value to be transparently represented, compared, and utilised across circular value chains. By structuring residual value information in relation to explicit use-case requirements, RVACPM contributes to the stabilisation of quality in the utilisation of circular products and materials and facilitates transactions based on credible and interoperable information rather than implicit assumptions or fragmented data.

By enabling demand-side actors to communicate use requirements and suppliers to express residual value in a verifiable and semantically consistent manner, RVACPM supports a transition from reactive, demand-driven markets to proactively coordinated, information-integrated circular markets. This transition is essential for overcoming the Value Vacuum described above and for enabling circular resources to be recognised as reliable economic assets rather than as inferior substitutes for virgin materials.

Furthermore, the systematic organisation and sharing of residual value information established by RVACPM provides a critical response to evolving international regulatory environments. Regulatory frameworks such as the Corporate Sustainability Reporting Directive (CSRD) [10] and the Carbon Border Adjustment Mechanism (CBAM) [11] increasingly require organisations to demonstrate environmental, social, and economic performance across both supply chains and value chains based on reliable and traceable information. RVACPM offers a structured means of responding to these requirements by integrating multidi-mensional value information with conformity and compliance evidence.

In this respect, RVACPM is positioned as a horizontal, use-case-driven information standard that complements existing product-specific and sector-specific standards rather than replacing them. By establishing a common language for residual value and enabling semantic interoperability across digital infrastructures such as DPP, RVACPM supports both the practical implementation of the circular economy and the formation of international consensus on how residual value should be assessed, communicated, and governed.

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