



BSI Standards Publication

Method to achieve circular designs of products

National foreword

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English Version

Method to achieve circular designs of products

Méthode pour réaliser des conceptions circulaires de produits

Verfahren zur Realisierung zirkulärer Produktgestaltung

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European foreword

This document [EN 45560:2024] has been prepared by CEN/CLC/JTC 10 “Material efficiency aspects for products in scope of Ecodesign legislation”.

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2025–11–30
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2027–11–30

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

CEN/CLC/JTC 10 has the objective to produce generic and horizontal CEN-CENELEC publications covering aspects such as assessment methods, design rules, dematerialization, digitalization and transfer of information on a variety of material efficiency topics, in particular (but not limited to):

- a) Extending product lifetime;
- b) Ability to reuse components or recycle materials¹ from products at end-of-life;
- c) Use of reused components and/or recycled materials in products.

This document is intended to be used by organizations applying directly to products but can also be used by product technical committees when producing horizontal, generic, product-group, or product-specific standards. It can, therefore, be cited together with product-group or product-specific standards, e.g. developed by product technical committees.

Any feedback and questions on this document should be directed to the users’ national committee. A complete listing of these bodies can be found on the CENELEC website.

¹ Including coverage of the European Commission defined list of critical raw materials (CRM).

Introduction

0.1 Background

Climate change, biodiversity loss, resource depletion and the ever-increasing production of waste and pollution represent major challenges to society today. Circular economy, with its focus on material efficiency and the promise for longer lifetime of products, minimization of waste and closing the flows for materials is believed to be an important means to overcome these challenges. When transitioning into a circular economy, design plays a crucial role. It has been reported that 80 % of a product's environmental impacts are determined at the product design phase [1] and design choices can determine whether the efforts to improve circularity will be successful or not. Circular product design is a key element of developing and implementing circular business models and transitioning towards a circular economy.

In Europe, the Green Deal [2] launched in 2019 proposes a concerted strategy for a climate-neutral, resource-efficient and competitive economy. Scaling up the circular economy from front-runners to the mainstream economic players will make decisive contributions to achieving climate neutrality by 2050 and to decoupling economic growth from the use of natural resources by using these resources more effectively, while ensuring long-term competitiveness of and within the EU. This document, focusing on circular product design, supports achieving the ambition stated in the European Circular Economy Action Plan (CEAP) [3].

Sustainable management and efficient use of natural resources is addressed by the UN's sustainable development goals (SDGs). This document supports these goals, particularly SDG 12, to ensure sustainable consumption and production patterns (see Annex A for more details).

The main purpose of this document is to develop a systematic way (method) of defining design rules and activities for the design and development of products such that these are made circular by design within a circular economy.

This document is intended for organizations designing and developing products that fall under the scope of the ecodesign legislation [4]. It focusses on optimizing material utilization and efficiency with strategies that enable narrowing (use less materials), slowing (extend product life, keep quality of products and materials as high as possible for as long as possible) and closing flows (parts recovery, remanufacture, repurpose and recycling).

0.2 Relation with other horizontal or generic standards

Although there are regulatory requirements for resource efficiency across most geographies, to date, the focus has been mostly on the energy efficiency of products. Recently standards focusing on the material efficiency became available, with the publication of the CEN/CLC/JTC 10 EN 4555X-4556X series of standards. These standards focus on the assessment of different aspects of material efficiency, such as durability of products (EN 45552 [5]), ability to remanufacture (EN 45553 [6]), ability to be repaired, reused and upgraded (EN 45554 [7]), recyclability (EN 45555 [8]), proportion of reused components (EN 45556 [9]), recycled content (EN 45557 [10]), and communication on the use of critical raw materials (CRMs) (EN 45558 [11]) and material efficiency (EN 45559 [70]). These standards address how to assess ability (how easy or difficult it is) to e.g. repair, remanufacture or recycle a product. However, these standards do not provide guidance on what aspects to consider when designing a product. This document intends to fill in such a gap.

The standard EN IEC 62430 (see Clause 2 in this document) assists organizations to incorporate environmentally conscious design (ECD) into their product design and development process. IEC/TS 63428 [12] links circularity to environmentally conscious design.

ISO 14009 [13] provides guidelines to organizations on how to incorporate circular product design strategies in the design and development within their environment management system. ISO 14006 [14] provides guidelines to assist organizations in establishing a systematic and structured approach to the incorporation and implementation of ecodesign within an environment management system, such as described in ISO 14001 [15]. Assessments of environmental impacts including aspects of material circularity and material cost accounting are considered in documents such as EN 50693 [16], EN 15804 [17], and ISO 14040 [18], ISO 14044 [19], and ISO 14051 [20].

IEC 62309 [21] contains guidance and requirements for dependability assessment of products containing reused parts and it also specifies requirements about declaration and designation of reused parts "qualified-as-

good-as-new". The IEC 60300 series [22] include general guidance on dependability, availability, reliability and maintainability, and IEC 62402 [23] addresses obsolescence management.

International standards currently under development by ISO/TC 323 on circular economy are ISO 59004 on terminology, principles and guidance for implementation [24], ISO 59010 providing guidance on the transition of business models and value networks [25], ISO 59020 on measuring and assessing circularity [26], and ISO/FDIS 59040 proposing a product circularity data sheet [27].

The ITU-T recommendation L.1023 [28] has standardized a framework for circularity performance scoring, defining key circularity terms and how these fit together in a scoring system.

In the design rules for circular economy, all domains such as environmental, social, economic, and technical are considered. As part of this holistic approach, value management is addressed in EN 12973 [29] and EN 16271 [30].

To avoid duplication as much as possible, this document references the above listed standards (sometimes normatively).

1 Scope

This document proposes a method to achieve circular designs of products. It details principles, requirements and guidance associated with the proposed method. This document:

- specifies requirements and guidance for integrating circularity into the design and development process of products by an organization and,
- supports organizations to develop product design rules to fulfil their chosen circular business targets (e.g. the circular business models chosen by the organization or the legislation requirements).

Having life cycle thinking as a core principle, this document provides guidance on how to reduce environmental impacts, and how to deal with challenges such as trade-offs during circular product design, without compromising other product functions including safety.

This document focusses on material efficiency. It is not a management system standard.

This document can be applied when no product-specific or product group standard exist. Where such documents are developed, this document can be used as reference to ensure consistency and harmonization across the different product areas and supply chains or networks.

NOTE For the purpose of this document, the following products are excluded: food, feed, medicinal products for human use, veterinary medicinal products, living plants, animals and microorganisms, products of human origin, products of plants and animals relating directly to their future reproduction.

2 Normative references

The following documents are referred to in the text in such a way that some or all their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN IEC 62430:2019, *Environmentally conscious design (ECD) — Principles, requirements and guidance*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 Terms and definitions relating to circular product design

3.1.1

circular economy

economic system that uses a systemic approach to circulate products and materials at highest value for as long as possible by aiming to eliminate waste and pollution, while contributing to sustainable development and giving the opportunity for natural systems to regenerate themselves

Note 1 to entry: The inflow of primary material is kept as low as possible.

[SOURCE: IEC 60050-193:2024² (IEV 193-01-01)]

3.1.2

circular goal

goal aligned with the principles of a circular economy

² Stage at the publication of this document is CD.

Note 1 to entry: The principles of a circular economy [31] include: (i) eliminate waste and pollution; (ii) circulate products and materials at their highest value; and (iii) regenerate nature.

3.1.3

circular product attribute

characteristic or property of a product addressing circularity

3.1.4

circular product design

circular design of products

process of creating products that are aligned with the principles of a circular economy

Note 1 to entry: The principles of a circular economy [31] include: (i) eliminate waste and pollution; (ii) circulate products and materials at their highest value; and (iii) and regenerate nature.

Note 2 to entry: The concept can be also applied to existing products through redesign.

3.1.5

circularity

alignment with the principles of a circular economy

Note 1 to entry: Can refer to an organization, system, product, part or material.

Note 2 to entry: The principles of a circular economy [31] include: (i) eliminate waste and pollution; (ii) circulate products and materials at their highest value; and (iii) regenerate nature.

[SOURCE: IEC 60050-193:2024² (IEV 193-01-03)]

3.1.6

function

effect of a product or one of its constituents

[SOURCE: EN 16271:2012, 3.8]

3.1.7

functionality

ability to deliver intended functions

3.1.8

material efficiency

degree of performance in relation to the materials used

Note 1 to entry: Materials used can refer to materials utilized consumed or both.

Note 2 to entry: Materials used can refer to both production and utilization stage.

Note 3 to entry: Performance includes satisfaction of the needs in relation to product function, product durability and recovery at end of life.

[SOURCE: IEC 60050-193:2024² (IEV 193-01-09), modified — Figure and note 4 were removed]

3.1.9

performance

effectiveness with which an intended function is carried out

[SOURCE: IEC 61226:2020, 3.16, modified — Examples were removed]

3.1.10

value

gains from satisfying needs and expectations, in relation to the resources used

EXAMPLE: Revenues, savings, productivity, sustainability, satisfaction, empowerment, engagement, experience, trust.

Note 1 to entry: Value is relative to, and determined by the perception of, the organization and interested parties.

Note 2 to entry: Value can be financial or non-financial.

Note 3 to entry: Value can be created, realized, acquired, redistributed, shared, lost, or destroyed.

Note 4 to entry: The value of an entity is generally determined in terms of the amount of other entities for which it can be exchanged.

Note 5 to entry: The word “value” sometimes refers to a (numerical) unit of data, e.g. the output from measurement and “values” sometimes refers to principles or standards of behaviour, e.g. included in the concept of culture. When “value” is used in these senses, it should always be used with some form of qualifier, e.g. “numerical value” or the meaning should be obvious from the context.

Note 6 to entry: When a process is inefficient, the amount of resources used can exceed the amount of resources required.

Note 7 to entry: The formula below illustrates that value is proportional to satisfaction of needs in relation to resources used:

$$\text{value} \propto \frac{\text{satisfaction of the needs}}{\text{resources used}}$$

[SOURCE: ISO 56000:2020, 3.7.6, modified — Notes 6 and 7 to entry have been added]

3.2 Terms and definitions relating to environment

3.2.1

environment

surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelationships

[SOURCE: ISO 14050:2020, 3.2.2]

3.2.2

environmental aspect

element of an organization's activities or products that interacts or can interact with the environment

[SOURCE: ISO 14050:2020, 3.2.20]

3.2.3

environmental impact

change to the environment, whether adverse or beneficial, including possible consequences, wholly or partially resulting from an organization's environmental aspects

[SOURCE: ISO 14050:2020, 3.2.22]

3.2.4

environmentally conscious design

ECD

systematic approach which considers environmental aspects in the design and development with the aim to reduce adverse environmental impacts throughout the life cycle of a product

Note 1 to entry: Other terminology used worldwide with the same meaning includes ecodesign, design for environment (DFE), green design and environmentally sustainable design.

Note 2 to entry: This note applies to the French language only.

[SOURCE: EN IEC 62430:2019, 3.1.1]

3.2.5

life cycle thinking

LCT

life cycle perspective

LCP

consideration of all relevant environmental aspects of a product during its entire life cycle

Note 1 to entry: LCT does not imply undertaking a life cycle assessment.

Note 2 to entry: This note applies to the French language only.

[SOURCE: EN IEC 62430:2019, 3.2.3]

3.3 Terms and definitions relating to product and resource

3.3.1

component

constituent of a product which cannot be fragmented without losing its particular function

[SOURCE: IEC 60050-151:2001/AMD5:2021 (IEV-151-11-21), modified — The term “part of a device” was replaced by “of a product, and “physically divided into smaller parts” was replaced by “fragmented”]

3.3.2

material

matter of which an object is composed

[SOURCE: IEC 82474-1:2024,³ 3.1.7]

3.3.3

part

constituent of a product

EXAMPLE: Hardware or other physical matter, software, firmware, liquid, gas, etc.

Note 1 to entry: A part can be an assembly, sub-assembly or a component.

3.3.4

product

goods, service, or combination thereof

[SOURCE: ISO 14050:2020, 3.5.12, modified — In the definition the term “any” has been removed, and the term “or combination thereof” has been added]

3.3.5

resource

asset that is utilized or consumed to satisfy a need

Note 1 to entry: Resource can be physical, financial, intellectual, and social. Resource can also include skills and time.

³ Stage at the publication of this document is FDIS.

[SOURCE: IEC 60050-193:2024² (IEV 193-03-01)]

3.3.6

modular

composed of modules for easy construction or arrangement and adaptation or disassembly

[SOURCE: ISO 20887:2020, 3.22]

3.4 Terms and definitions relating to recycling

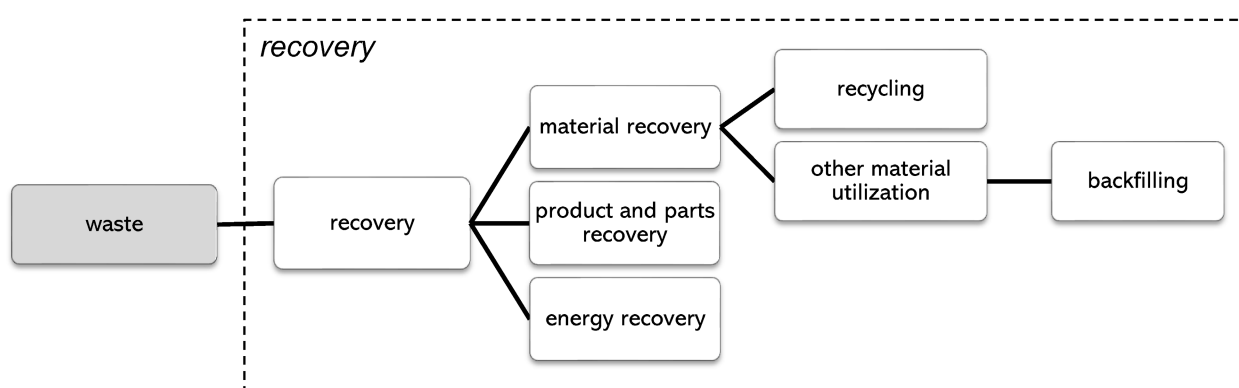
3.4.1

recovery

operation that gives value to waste

Note 1 to entry: Recovery can result in products, parts, materials and/or energy.

Note 2 to entry: A concept diagram of recovery is provided here below:



[SOURCE: IEC 60050-193:2024² (IEV 193-04-06)]

3.4.2

recycled content

proportion, by mass, of recycled material in a product or part

Note 1 to entry: The proportion is often expressed as a percentage of mass.

[SOURCE: ISO 14021:2016, 7.8.1.1 a), modified — “or packaging” has been replaced by “or part” and Note 1 to entry was included]

3.4.3

recycled material

secondary material

material that has been reprocessed from end-of-life products, parts and material

3.4.4

recycling

production of useful material through controlled processing of waste, excluding energy recovery

[SOURCE: IEC 60050-193:2024² (IEV 193-04-11)]

3.4.5**waste**

material or object which the holder decides or is required to dispose of

Note 1 to entry: Triggers for the decision or need to discard include, for example: function no longer available, change in the needs by the user, interoperability with new system elements not supported, loss or unavailability of data or history information about the object (e.g. instruction for use not available; service information; information needed for refurbishment).

[SOURCE: IEC 60050-193:2024² (IEV 193-04-01)]

3.5 Terms and definitions relating to durability**3.5.1****durability**

ability to function as required, under specified conditions of use, maintenance and repair, until the end-of-life is reached

Note 1 to entry: For the purpose of this document, the designer has to specify the criteria for durability.

Note 2 to entry: The criteria are based on predictable aspects (e.g. technical aspects) so that the durability can be estimated.

Note 3 to entry: Durability can be expressed in units appropriate to the part or product concerned, e.g. calendar time, operating cycles, distance run, etc. The units should always be clearly stated.

[SOURCE: EN 45552:2020 definition 3.1.1.1, modified — In the term “<of a part or a product>” was deleted, in the definition “defined” has been replaced by “specified” and “a limiting state” has been replaced by “the end-of-life”, notes 1 and 2 to entry were removed and three new notes were added]

3.5.2**useful life**

time interval from first use until the requirements of the last user are no longer met due to social, economic, or technical reasons

Note 1 to entry: Concept not intended for measurement.

Note 2 to entry: Useful life can only be quantified retroactively.

Note 3 to entry: Social (e.g. trends in fashion), economic, or technical reasons can result in parts obsolescence.

[SOURCE: IEC 60050-193:2024² (IEV 193-05-04)]

3.5.3**service life****expected service life**

time that a manufactured item can be expected to be economically maintainable, or supported by its manufacturer

[SOURCE: IEC TS 63265:2022, modified — In the definition, the term “any manufactured” was replaced by “a manufactured” and the term “serviceable” was replaced by “maintainable”]

3.5.4**end-of-life****EoL****end-of-last-use**

point in the life-cycle of a product where the decision is made to either dispose it or to give it a new life under new identity

[SOURCE: IEC 60050-193:2024² (IEV 193-05-06)]

3.5.5

end-of-use

point the life-cycle of the product when the user or owner does not want maintain, or does not want to use the product anymore

[SOURCE: IEC 60050-193:2024² (IEV 193-05-07)]

3.5.6

limiting event

occurrence which results in a primary or secondary function no longer being delivered

Note 1 to entry: Examples of limiting events are failure, wear-out failure or deviation of any analogue signal.

[SOURCE: EN 45552:2020, 3.1.1.3]

3.5.7

reliability

probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event

Note 1 to entry: The intended function(s) and given conditions are described in the information for use provided with the product.

Note 2 to entry: Duration can be expressed in units appropriate to the part or product concerned, e.g. calendar time, operating cycles, distance run, etc. The units should always be clearly stated.

[SOURCE: EN 45552:2020, 3.1.1.2]

3.6 Terms and definitions relating to lifetime extension

3.6.1

disassembly

process whereby a product is taken apart in such a way that it could subsequently be reassembled and made operational

[SOURCE: IEC 60050-904:2014/AMD3:2019 (IEV 904-04-01), modified — In the definition the term “an item” has been replaced by “a product” and note 1 to entry has been deleted]

3.6.2

maintenance

process to retain a product in, or restore it to, a state in which it can perform as intended

[SOURCE: IEC 60050-192:2015 (IEV 192-06-01), modified — In the definition the term “combination of all technical and management actions intended” was replaced by “process”, the term “item” was replaced by “product” and the term “required” was replaced by “intended”, and the Note to entry has been deleted]

3.6.3

repair

process of returning a faulty product to a state where it can fulfil its intended use

[SOURCE: EN 45554:2020, modified — In the definition “condition” was replaced by “state”]

3.6.4

refurbishing

reconditioning

industrial process to return or improve a product or part within the limits of its original design

Note 1 to entry: Original design include form, functionality, performance and safety aspects.

Note 2 to entry: Refurbishment can result in extended lifetimes.

Note 3 to entry: The identity of the product or part shall be maintained (e.g. serial or type number).

3.6.5

remanufacturing

industrial process to create a product by combining different parts from used products and including, where necessary, new parts

Note 1 to entry: Remanufacturing also occurs when at least one change is made which influences the safety or original design of an existing product.

Note 2 to entry: The product shall be given a new identity (e.g. serial or type number).

3.6.6

reuse

operation by which a product or part having reached the end-of-use is used again

Note 1 to entry: When the product or part is reused for another purpose, it is called repurpose.

Note 2 to entry: Normal, regular or sporadic use is not considered as reuse.

[SOURCE: IEC 60050-193:2024² (IEV 193-06-10)]

3.6.7

upgrade

upgrading

process to enhance the functionality, aesthetics, or performance of a product

Note 1 to entry: An upgrade to a product can involve changes to its software, firmware or hardware (e.g. adding memory).

Note 2 to entry: An upgrade to a product can involve addition or replacement of parts.

Note 3 to entry: Upgrade takes place within the limits of the original design of the product.

[SOURCE: IEC 60050-193:2024² (IEV 193-06-15)]

3.7 Abbreviated terms

CE	Circular economy
CRM	Critical raw material
ECD	Environmentally conscious design
ErP	Energy-related product
FMEA	Failure mode and effect analysis
GHG	Greenhouse gas
ICT	Information and communication technology
ME	Material efficiency
SDG	Sustainable development goal

4 Principles and concepts in support of circular product design

4.1 Circular product design core principles

The core principles that lead to a circular designed product are:

- Circular economy becoming part of the environment, social, and governance (ESG) policy of the organization, ensuring management understanding and early contribution and commitment of all relevant business functions in accordance with the ECD principles of the EN IEC 62430:2019, Clause 4.
- Considers the whole life cycle of the product taking a “life cycle thinking” approach in accordance with the ECD principles of the EN IEC 62430:2019, Clause 4.
- Based on circular business targets chosen by the organization for the product, product designs are optimized following the design principles for narrowing, slowing and closing the flows.
- Create and promote sustainable circular systems (e.g. reverse logistics, repair systems) that enable product and material recirculation and support and educate customers to contribute to closing the loop.
- Managing trade-offs is the solution to achieve a circular product design, and so helping organizations with difficult decisions e.g. durability vs. using less material.

The organisation should adopt these principles in such way that avoids adverse environmental impacts. See Annex A for more information.

4.2 Design principles for narrowing, slowing, and closing material flows

4.2.1 General

Resource depletion and scarcity and increasing production of waste and pollution represent major challenges today and are the focus of different legislations such as ESPR [4] and ESRS [32]. The efficient use of resources is central in this document. See Annex A for more information.

The linear ‘take-make-dispose’ economic model is reaching its limits, and initiatives to develop alternative economic models are emerging. The circular economy strives for an industrial system that is restorative and regenerative by design and where resources are managed within technical and biological cycles [31]. The circular economy is based on three principles [31], driven by design:

- eliminate waste and pollution;
- circulate products and materials at their highest value; and
- regenerate nature.

Products and components can flow in technical cycles with activities to reuse, recover, restore or reutilize resources within existing or new products. Products and materials should be kept in the technical cycles as long as possible. Closing the biological cycle means that biodegradable materials which cannot be kept or reused in the technical cycles are broken down by microorganisms at the molecular level and thus can be used by living systems. These materials should not be detrimental to the water, soil or biodiversity of the ecosystem in which these were introduced. In this way these are restored into the biosphere and can contribute to the regeneration of natural systems.

As part of the circular economy, material efficiency can be increased through the three principles of slowing down, narrowing, and closing material flows [33]. Slowing and closing the flows are fundamental principles toward the cycling (circulation) of materials. These are distinct from the other approach of narrowing the flows, which focus ultimately on overall reduction of the material use.

NOTE These principles are intended as source of inspiration for circular product design.

While not exhaustive, Figure 1 presents a schematic representation of these three principles along with representation of a linear flow for comparison. Examples of strategies which can be implemented that contribute to these three principles are given in Annex B.

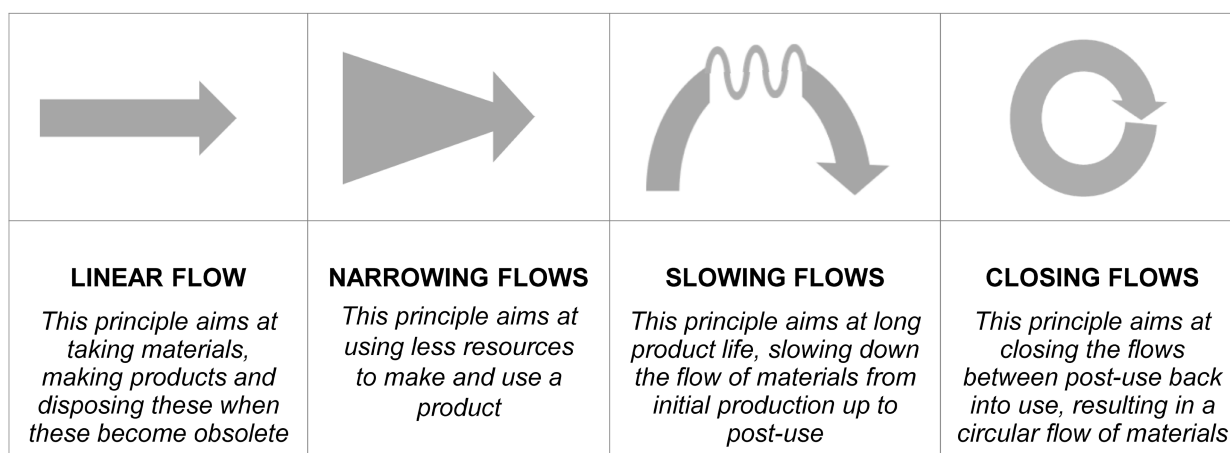


Figure 1 — Principles of narrowing, slowing and closing material flows

The principles of narrowing, slowing, and closing material flows should not be considered in isolation. Assessing trade-offs will help inform the decision (see 6.5).

4.2.2 Narrowing material flows

The principle for narrowing material flows involve strategies using less materials (and energy) to deliver the same or equivalent function to the user. It also involves strategies such as intensifying the use of products through sharing services. It involves making trade-offs between durability and the types and quantities of materials utilized.

The principle of narrowing material flows is different from slowing flows, as it does not influence the speed of the flow of products and does not involve any service flows (e.g. repair). Narrowing material flows has been applied successfully within a linear business model, and existing strategies can be used in conjunction with other circular strategies.

Examples of strategies for narrowing material flows can be found in B.1.

4.2.3 Slowing material flows

This principle is aimed at using products, components and materials longer through the design of long-life goods (increased reliability and durability) in combination with product-life extension strategies such as maintenance, repair, hardware or software upgrade or software update, and refurbishment. With such strategies, the utilization period of products is extended, resulting in a slowdown of the flow of materials by reducing the need to replace existing products or by decreasing the need for new products.

The ultimate goal of this principle is to reuse products again and again, which needs complementary activities like planning circular systems around the product including reverse logistics or to develop new business models to rethink ownership.

Examples of strategies for slowing material flows can be found in B.2.

4.2.4 Closing material flows

Closing the material flows refers to activities that bring post-consumer waste back into the economic cycle. Recycling is the most common strategy to close the material flows. Activities such as remanufacturing and repurpose also allow for closure of the loop by creating (new) products from already used products or parts.

Lately, the use of renewable content is becoming popular to close the material flows. However, there are a number of criteria which should be considered so that the biodegradable material may go back into the

biosphere at the end-of-life and close the biological cycle. A final step to close the biological cycle is the safe return to the biosphere through activities like biodegradation, anaerobic digestion or composting of the material. This asks that the material can be safely returned to the biosphere and used by living systems. Those materials should only be returned into the biosphere when all precautions have been taken to avoid negative effects to the environment.

EXAMPLE Not all biodegradable plastic degrades in marine environment; semi-degraded biodegradable material is even more difficult to recover from the sea, and when recovered more difficult to recycle.

Recycling of biological materials should be the preferred solution to close material flows if the remaining quality and functionality of that material after use is still acceptable. Biodegradability should be applied when there is no way of collecting products and keeping them in the technical cycle while avoiding environmental pollution. Materials should be kept in the technical cycle as long as possible.

NOTE Whether a material gets recycled in practice depends on the availability of recycling processes, technology, and infrastructure as well as the stakeholders' understanding and awareness.

Examples of strategies for closing the material flows can be found in B.3.

4.3 Material value hierarchy

The material value hierarchy represents the concept of keeping the value of materials as high as possible in the economy. It is intimately related to one of the principles of the circular economy, namely circulate products and materials at their highest value. The material value hierarchy is also a good model to represent material efficiency, that is defined as a degree of performance (which includes satisfaction of the user needs, durability and material recovery) in relation to the materials used (utilized or consumed) to make or use the product.

Figure 2 shows the material value hierarchy. This hierarchy represents value loss (or additional resources needed) when moving from up to down the ladder.

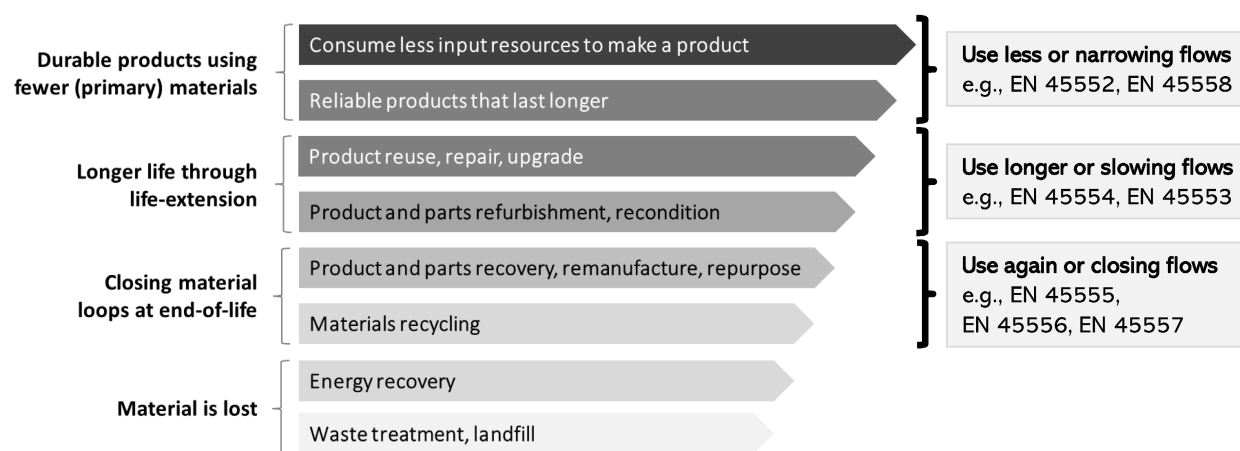


Figure 2 — Material value hierarchy

The material value hierarchy can be used as support by organizations that are making the transition to circular economy. Having a good understanding on how the value of materials evolve when applying different circular solutions helps organizations to make a more conscious choice of the circular business targets and related circular design strategies. Organizations can use the material value hierarchy as source of inspiration, as relevant.

Material value hierarchy and use less or narrowing flows strategies

The hierarchy depicted in Figure 2 shows what strategies can be best applied to hold the value of materials in the economy. In the first shown strategy, use less and longer, less value is lost if fewer inputs (or no input at all) of resources are used to make a product. Creating the virtual equivalent will not reduce the resource consumption to zero, as often the demand on energy increases, but is likely to reduce it considerably.

Additionally, when products are made, they are able to retain (preserve) more value when they are made in such a way that they have very long useful lives.

Organizations should take into account trade-offs with other important aspects. For instance, consuming less material to design a product could impact its durability; or for safety reasons a product may be chosen not to be (easily) repairable. Therefore, organizations need to consider the different strategies of this figure and analyse the trade-offs with other aspects that are relevant when defining their circular goals, circular business targets, and circular product design strategies.

Material value hierarchy and use longer or slowing flows strategies

As there are plenty of reasons not to make products able to last forever (no technology available, none or not enough durable materials available, safety aspects, users not interested to keeping a product for long due to fashion aspects, etc.), the best next approach is to design and develop products and parts that are able to have their lives extended over and over again (use longer strategies).

- Within the various lifetime extension strategies, reusing a product “as is” would result in the least loss of value (from the material perspective). Being able to upgrade parts would potentially involve some material loss that is associated with e.g. the parts replacement, but on the other hand, that would make that product more attractive for reuse.
- The longer the products are used and reused, greater the chance repairs are needed. Repairing asks for resources (worn parts need to be replaced, expertise and other resources are needed to perform the repair, etc.). Those resources are to be included in the overall value loss accountancy linked to the product when it is repaired.
- When the owner starts losing its interest in the product for example because the functions are no longer sufficient, an effective next strategy to bring the product back to use is refurbishing. Refurbishing will lead to more value loss compared to repair, as it is likely to involve repairs itself, but also cleaning, bringing aesthetics to the initial condition, as well as a new sales, delivery, and installation. This means that refurbishing requires extra resources for its execution and is lower in the ladder of value loss than repair.

Material value hierarchy and use again or closing flows strategies

For products that have reached their end-of-life, the obvious next step is recycling. However, for some products, there is a significant residual quality or functionality still present in the whole of the product or in some of the parts, which makes it possible to give a new life through remanufacturing, repurposing, or parts recovery (recover and use again strategy).

- The processes involved in remanufacturing or repurposing, however, go beyond that of refurbishing. Here not only cleaning, repair and aesthetics management is needed, but also parts that are close to worn-out will need to be replaced by new, design and development on how to fit the parts together to make the new product are likely needed, and last, thorough assessment and/or testing of the parts will need to guarantee that such remanufactured or repurposed product will last a full new life in the market. This is why these are at a lower level in the hierarchy compared to previous strategies.
- Sometimes the residual quality of the product in its totality is insufficient to give it a new life. However, some parts might still be of enough quality to be reused in e.g. repair of existing products. Therefore, parts recovery is an important activity at the end-of-life of the product.
- A last, but important activity for closing the material flows at end-of-life of the product is recycling. Ideally, all products should be recycled at the end-of-life. Although there could be reasons why products cannot be recycled, e.g. no recycling technology for certain materials available, avoid safety incidents with contaminated products.

Following the material value hierarchy of Figure 2, if products are incinerated (with or without energy recovery) or discarded into landfill, there is a significant loss of value, and the materials are literally “lost” for the economy partly as residues in the land and partly as emissions into the biosphere, e.g. CO₂). Such strategies belong to a linear economy and, where possible, should be avoided.