How Standardization for Ecodesign and Circular Economy Contributes to Sustainability

by Thierry Cormenier and Martial Patra

Executive summary

The circular economy impacts all applicative domains and fields. Every activity sector, every industry, and every administration try by different means to initiate actions with the objective of dramatically reducing resource extraction and waste production. To this end, many actions can be taken now without waiting for new technologies or new products. Sustainability can only be achieved through more global approaches such as lifecycle thinking and environmentally conscious product design, which is used in increasingly digital systems. This paper describes why and how international standardization bodies work, so that each country and organization can have tools that aggregate everyone's experience, and so that the environment can benefit from the performance of digital technology and not suffer it as a constraint.

A note from the IEC TC111 chair

IEC Technical Committee (TC) 111 prepares horizontal International Standards which are key in helping to ensure electrical and electronic products are designed with the environment in mind.

In our globalized world, it is more essential than ever to develop harmonized and internationally recognized standards to guarantee a fair playing field between the different stakeholders, from raw or second-hand producers of materials, goods and products, down to the end-user.

Environmental standardization mitigates products' impact on human health as well as on resource depletion or water pollution. Standards are also essential tools in the fight against e-waste, while aiding manufacturers to meet legislative requirements on toxic substances control.

When assessing the level of hazardous substances in a product, it is of the utmost importance to use the same international standard to describe the test method for measuring potentially toxic substance content. This will help improve the product's recycling and end-of-life management, in a circular economy perspective.

Standards provide a basis for trustful, harmonized, and easy-to-understand communication about the various ways products affect the environment. Improved transparency helps customers make the right buying decision and improve green procurement.

For all these reasons, IEC technical committee 111 is the environmental committee of the International Electrotechnical Commission (IEC). We work with international experts, scientists, and engineers from all around the world for the benefit of everyone.

Christophe Garnier
IEC TC111 Chairman

Foreword

How are international standards driving the race for a greener planet?

Increasingly people, organizations, economic or engineering systems, as well as companies, cities, and governments, feel concerned about global warming and want to be involved in solutions that control and stabilize its effects. Achievement must be at a value that is acceptable for every citizen and for society overall. The United Nations has clearly defined sustainability objectives but achieving the sustainability goals and their interdependencies' stability is complex and must use holistic approaches.

The environmental aspects of standardization framework have been considered up to now under safety aspects for protecting citizens, with the focus on substances and chemicals (RoHS directive or Reach regulation in Europe). This ensures that human safety will be included and ensured.

Twenty years ago, environmental considerations and constraints were lower because they only addressed the end of the ecosystem's life through recycling and focused on hazardous and highly concerning substances. Therefore, they highlighted loopholes. The upstream phases of the life cycle had to be reconsidered under circular economy[1] to better focus on addressing scarcity of resources, minimizing emissions, and transforming waste into resources, while continuing to improve the safety of goods and services.

Materials circularity, established from material efficiency assessments, is part of a more global and long-term objective, which is the neutrality of human interactions with the planet so that nature can maintain its rights and recover its stability.

Sustainability can only be achieved through minimizing the environmental footprint by optimizing each ecosystem. An ecosystem should be a controlled system aiming to reach the stability of its targets in the shortest time, contributing to sustainability. Because a system can be technical, economic, social, or other, we can consider that each sustainable development goal (SDG[3]) is an answer of a respective ecosystem that has interdependencies with adjacent SDG ecosystems. To support this objective, standards offer tool boxes to be referenced by coming regulations as it will be necessary for example to answer the challenges of the European Green Deal[2].

The stability of the global environmental ecosystem or different ecosystems represented by each SDG is necessary. Resource and waste management and emissions reductions, demonstrated by the need for circularity, cannot be dissociated from other socio-economic ecosystems, hence the notion of a circular economy, as reported by Mr. Frans Vreeswijk, IEC General Secretary and CEO:

"In the developed world, our linear economic model whereby products are manufactured, used and then discarded is increasingly and rightfully challenged by one that encourages the development and use of products that last longer, can be more easily repaired and upgraded. IEC work provides the methodologies and requirements that encourage a circular economy, allowing societies to reduce waste and make better use of limited natural resources. On the other side of the spectrum, developing economies are looking to the UN sustainable development goals (SDG[3]) to overcome poverty and hunger, increase access to energy and clean water, better health and greater opportunities for economic development."

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[1] https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy

[2] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[3] https://www.un.org/development/desa/disabilities/envision2030.html

[3] https://unstats.un.org/sdgs/report/2019/The-Sustainable-Development-Goals-Report-2019.pdf

If we look in Europe, a significant initiative under the European Ecodesign Directive is – after setting standards for the energy efficiency of energy-related products (ErP) – the deployment of nine new horizontal standards. These standards specifically target the assessment of ErP's material efficiency through their ability to address circularity, as part of a broad program for sustainability within objectives defined for 2030[4]. This paper is a long-term vision that will be implemented through societal and market demand and the associated regulations' evolution supported by the standardization framework.

The material efficiency standardization program of the European Union (EU) ends when many initiatives start in various regions (Europe, China, Japan, USA, etc.). This is why it is necessary to review the fundamentals, which are based on existing international standards, particularly on the process of product design. It enables each stakeholder in the race to achieve a greener planet to complete their toolbox.

Introduction

Holistic approaches

The concern about CO_2 reduction and the lack of natural resources requires system competencies and a holistic view. This document will review the fundamentals of a system's behavior to show how the current and coming regulations and standards could contribute.

As usual, product design must meet functional needs, but for some of them, their needs are still limited to the use and regulation constraints with an aim of short-term profitability. This is why the results of functional analyses (see page 13) must consider the widest interdependencies of the SDGs and customer needs in order to optimize the design under constraints.

When longer product life span is the expected result of optimization, the life cycle assessment must take into consideration all environmental and operating conditions in accordance with this life span. This is why material efficiency assessments must be formalized using standards that optimize resources use. System approaches maximize the dependability performance when the goal is to minimize the product's and system's environmental footprint.

Based on standardization work dealing with the assessment of material efficiency for circular economy, this document gradually leads the reader towards optimizing the minimization of the environmental footprint, using trade-offs along the life cycles of products and systems. This optimization also involves the contribution of digitization and data migration throughout the life cycle, requiring the resolution of interoperability problems between life phases or between tools used over a same life phase.

System stability is addressed by systems engineering applied to life cycle management. That approach is already widely documented but needs to be structured to be more accessible, better understood, and better deployed in different processes, where materials, parts, and products are perceived as subsystems. Each subsystem will have to deliver all the useful information needed to derive all the possible benefits at each life phase, including minimizing the environmental footprint.

[4] https://ec.europa.eu/commission/sites/beta-political/files/rp_sustainable_europe_30-01_en_web.pdf

European Commission standardization request

Closing the loop with material efficiency

The European Commission published a standardization request (Mandate M/543)[5], which is a mandate offered to the European standardization organizations (CEN, CENELEC, and ETSI) for drafting a set of ecodesign horizontal standards to support material efficiency aspects for a more circular economy. The objective of the standardization work is linked to the following three objectives:

a) Extending product lifetime
b) Ability to re-use components or recycle materials from products at end-of-life
c) Use of re-used components and/or recycled materials in products

The CEN, CENELEC, and ETSI standardization organizations agreed in early 2016 to prepare horizontal standards that address the material efficiency topics described in the M/543 mandate. The standards should be applicable to electro-technological (energy-related product or "ErP," managed by CENELEC) and non-electro-technological (ErP managed by CEN) products that are already covered by different regulations under the application of the Ecodesign Directive[6], as well as for information technology (equipment managed by ETSI). The material efficiency topics considered are:

- The definition of parameters and methods relevant for assessing durability, upgradability, and ability to repair, re-use, and re-manufacture products
- Provision of guidance on how standardization deliverables for assessing durability, upgradability, ability to repair, and re-manufacture of products can be applied to product-specific standards
- The ability to access or remove certain components, consumables, or assemblies from products to facilitate repair, remanufacture, or reuse
- The reusability/recyclability/recoverability (RRR) indexes or criteria
- The ability to access or remove certain components or assemblies from products to facilitate their extraction at the end-of-life for ease of treatment, recycling, and recovering
- The method to assess the proportion of re-used components and/or recycled materials in products
- The use and recyclability of critical raw materials (CRM) to the EU, listed by the European Commission
- The documentation and/or marking regarding information relating to material efficiency of the product, taking into account the intended audience (consumers, professionals, or market surveillance authorities)

These different aspects of material efficiency feed the three main principles of circularity and are also consistent with some of the sustainable development goals defined by the United Nations (in particular, Goal 12: Responsible consumption and production) if material is generic and includes materials, parts, and product. The three main pillars of circularity are well described by the Ellen MacArthur Foundation. Taking these 3 pillars with small changes we could summarize them as follows:

1) Design and manufacture out waste and pollution
2) Keep materials, products, and systems in use
3) Regenerate natural systems

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[5] COMMISSION IMPLEMENTING DECISION M/543 of 2015/12/17 on a standardization request to the European standardization organizations as regard Ecodesign requirements on material efficiency aspects for energy-related products in support of the implementation of Directive 2009/125/EC of the European Parliament and of the Council.
https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564

6 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0125

Examples on ErPs related to these 3 pillars are detailed as follows:

1. Design and manufacture out waste and pollution:
   - Circular, environmentally consciously designed products for main system use cases:
     - Avoid hazardous substances
     - Avoid GHG emissions
     - Use recycled materials and optimize raw material extraction
     - Improve energy savings and energy efficiency of:
       - Motors
       - Variable speed drive (VSD)
       - Pumps
       - Power transformers
       - Electronic displays
       - Power supplies
       - Batteries, etc.
     - Identify the material efficiencies benefit based on circularity (maintain, repair, reuse, update, and upgrade)
     - Identify the environmental benefits of interoperable digitization
       - Identification of substances at end of life
       - Identification of aging of used parts or products
   - Identify the lowest environmental footprint of the product within a system, associated with reference lifetime defined under conditions of use

2. Keep materials, products, and systems in use:
   - Optimize the product and system dependability:
     - Identify and comply with the conditions of use to reach the expected durability (maintenance and repair)
     - Improve the conditions of use to extend the expected durability
       - Example: The main difference between a professional and a domestic device with the same function is the impact of the conditions of use on the product design.
     - Minimize the environmental footprint by managing the trade-off between the ownership or rent of product, related to the acceptable reliability and durability
   - Reuse

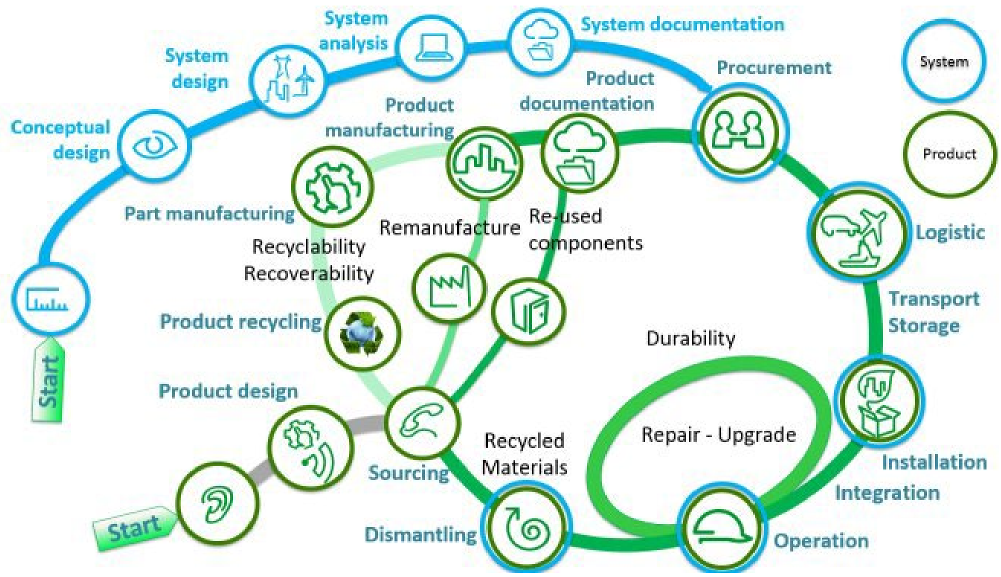
3. Regenerate natural systems:
   - Remanufacture
   - Refurbish
   - Recycle
   - Recover

These three principles are assessed all along the products' and systems' lifecycles as shown in Figure 1. What is important to consider is that the optimized environmental footprint for effective circularity requires a trade-off among items of the three main functions.

Trade-offs can be managed if the physical (environmental and operating conditions) and digital mission profiles of the product within its system are defined. In addition, the risk assessments help to classify the functions by importance. Health and safety are always the priority.

Figure 1

Basic circularities of a product's lifecycles, considering the surrounding system



Durability of materials, parts, and products

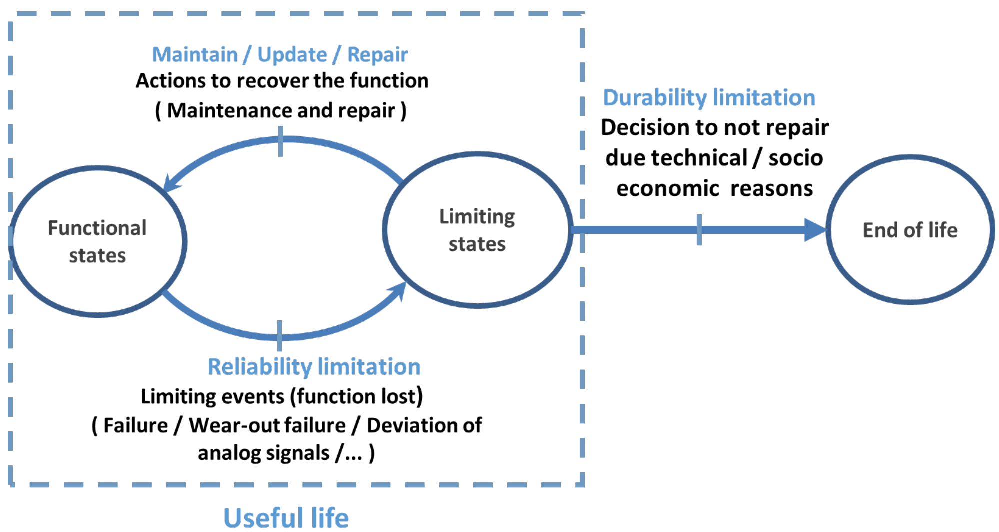
The importance to keep materials, parts, products and systems in use needs to focus on durability during the use life phase (operation in Figure 1).

The durability is the ability to function as required under defined conditions of use, maintenance, and repair, until a limiting state is reached; the limiting state is reached when a limiting event appears. Materials, parts, and product limiting events and limiting states are identified by the functional analysis and, if any, completed by a failure mode and effects analysis of the materials, parts, and product.

Figure 2 shows the limitations which can be met by materials, parts, and product and the ability to recover a functional state.

Figure 2

Main events and state relations during the use phase



An accurate mission profile defining operating and environmental conditions contribute to a robust design. The identification of stresses of materials, parts, and product, for a time duration, all having their aging laws, contributes to the robustness of the design.

The dependability assessments help to manage the trade-off on the material circularities. If any, maintenance actions must be considered when assessing durability. The durability of the materials, parts, and product can be different. To extend the lifespan during the use phase, all aspects increasing the loops from the limiting state to the functional state shall be considered for the product and the parts, while the environmental footprint must stay lower than those of the use of a new part or product.

Beyond the use life phase, lifespan extension must be considered in other life phases promoting the re-use, remanufacture, refurbish, recycling, and recovery, if any.

Recycling & Use of recycled materials

To regenerate naturals systems based on recycling, some prerequisites should be identified as follows:

Recycling

The recycling life phase appears after the end of life when there is no remaining ability to re-use, remanufacture, or refurbish.

The main objective of recycling should be to re-process material for use at the same level of application as the original material. Maximization of material recycling requires design strategies. The results of product functional analyses may lead to the search for innovative materials combining several functions. As for the functional analysis of the product, the functional analysis of the materials must cover the entire materials life cycle. For materials combining multiple functions, the preferred methodologies of recycling materials based on product and part disassembly, and based on material separation, dissolution, or any other techniques of such materials, may require innovation at the design, manufacturing, and end-of-life stages.

Use of recycled materials

To benefit from material efficiency, the use of recycled materials must be promoted, otherwise previously used materials would be transformed into waste.

Recycled materials are materials covering several properties (mechanical, electrical, thermal, chemical, environmental, etc.) aiming to be as close as possible to identical to, or better than, the original materials.

Emerging regulations or specifications mention minimum requirements in terms of a percentage of recycled material(s). Regulatory requirements related to the use of certain substances can immediately halt the use of recycled materials. When necessary according to environmental footprint risk analysis, a trade-off should be found when these regulations cover the same region, such as the definition of a maximum percentage of recycled material to manage a transition, aiming to avoid waste.

If there is no maximum rate of use of previously allowed materials, manufacturers are faced with a narrowed scope of recyclable materials. The current regulation of substance is not the same as those applicable when the original materials had been used (e.g., REACH is updated every six months). We understand that we cannot comeback to regulation applicable 30 years ago. It is the reason why a time of validity would be welcome to give time enough to manage a maximum rate during a transition period to maximize the material circularity.

The traceability and the knowledge of materials are necessary especially before the material life phase dealing with separation(s). When materials contain polymer, its identification should be in accordance with ISO 1043 standard, or with the ISO 1629 standard for rubbers, or the ISO 18064 standard for thermoplastic elastomers. Thermosetting materials are often considered as non-recyclable even though their inorganic part could be recovered and directly reused.

For all purposes of material circularities as described above, a standardization joint technical committee CEN CENELEC JTC 10 “Energy-related products - Material Efficiency Aspects for Ecodesign” was established in 2016 between CEN and CLC for drafting a set of ten standards and technical reports (EN 4555x series). The following documents are already published or still under development by European experts and members of the working groups:

- EN 45550: Terms and definitions related to material efficiency of ErP
- EN 45552: Method for assessment of durability (including reliability)
- EN 45553: Method for assessment of ability to remanufacture
- EN 45554: Methods for assessment of ability to repair, reuse, upgrade
- EN 45555: Methods for assessing the recyclability and recoverability
- EN 45556: Method for assessing the proportion of reused components
- EN 45557: Methods for assessing the recyclability and recoverability
- EN 45558: Method to declare the use of critical raw materials
- EN 45559: Methods for providing material efficiency information

Using simplified product and applicative system lifecycles, Figure 3 shows how the set of material efficiency horizontal standards covers the assessment along these lifecycles and interactions between their different steps. The brightness of the color shows their contribution to material efficiency.

A horizontal standard is generic with fundamental principles, concepts, terminology, or technical characteristics that are relevant to a number of technical committees and of crucial importance to ensure the consistency of the body of standardization documents.

The standard’s defining methodology of assessments will be considered by product technical commitees through associated standards. Any assessment should be associated to the threshold defined by regulations or user specifications to complete a verification or a validation.

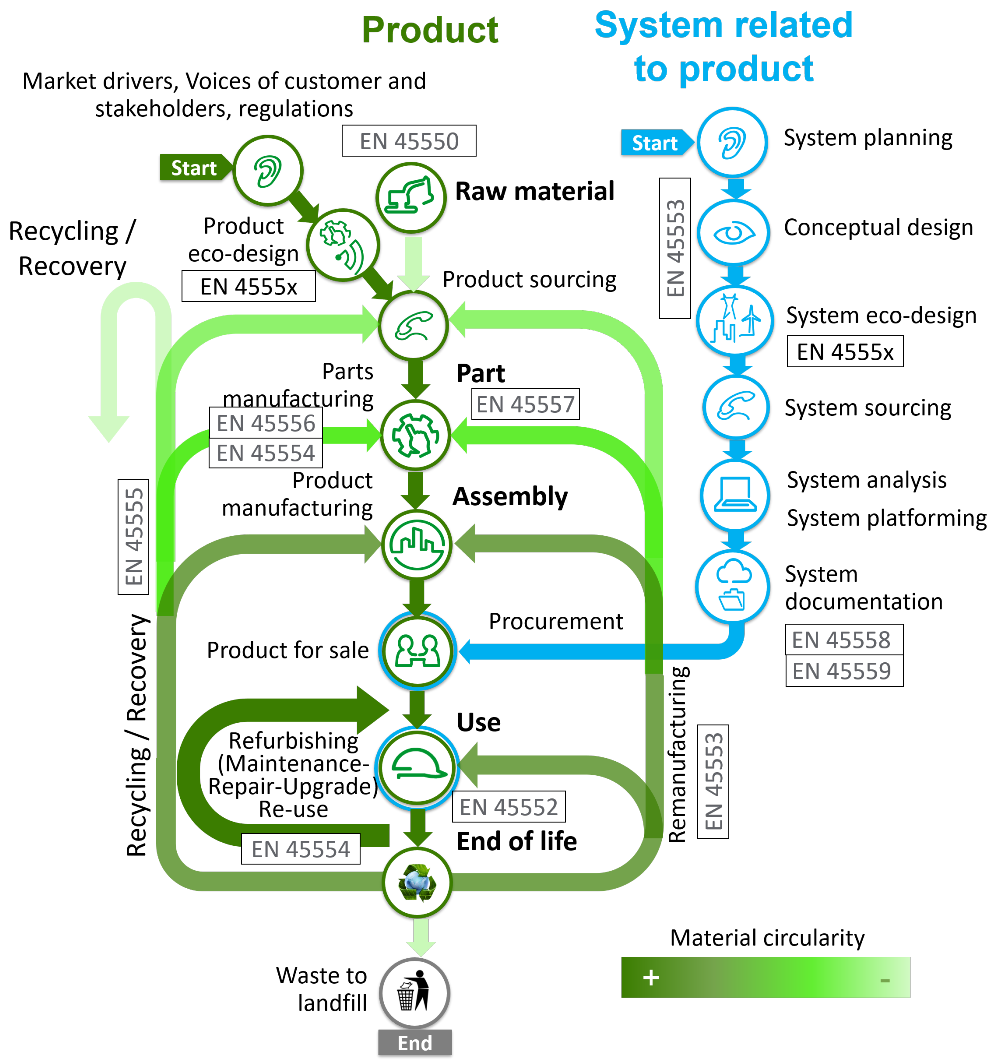


Figure 3

Product and system lifecycles in a circular model covered by EN 4555x series

EN 4555X standards series

Detailed description and purpose of the horizontal EN 4555x standard series

A set of material efficiency standards covering the assessment of ErP

It is important to note that the EN 4555x standard series describes methodologies and provides requirements only for the assessment of the distinct material efficiency aspects of ErP (left side of Figure 4) but does not provide requirements for a material-efficient environmentally conscious design[7] (ECD) or for global circular economy aspects. These considerations are considered today at a worldwide level within the IEC/TC 111 Committee with reference to the IEC Guide 109[8] (environmental aspects) in collaboration with ISO/TC 207 (environmental management).

[7] Environmental conscious design (ECD): covered by the joint working group "JWG ECD" for developing the standard IEC/ISO 62430: Environmental Conscious Design (ECD) - Principles, requirements and guidance. The JWG ECD is established between IEC/TC 111 Committee (Environmental standardization for electrical and electronic products and systems) and ISO/TC 207 Committee (Environmental Management).

[8] IEC/Guide 109: edition 3.0 of 2012-06: Environmental aspects – Inclusion in electrotechnical product standards.

To optimize the products' and systems' environmental footprint, it is critical to link and evaluate the interaction of all these aspects of material efficiency as well as other aspects (like digitization, energy consumption, or energy savings' capability) for reaching an optimized design for circularity[9], as shown on the right side of Figure 4. The right part of the Figure 4 needs trade-offs between items. However, there is no possible compromise with trade-offs for health because safety is the highest level of importance, followed by primary functions and associated regulation such as REACH, RoHS, or others. The environmental functions (circularity, resource use, and environmental impact) should be introduced in early stages of the classification of functions, with the understanding that minimizing the environmental footprint of the product operating in a system, for an expected life span and defined environmental and operating conditions, should be the target.

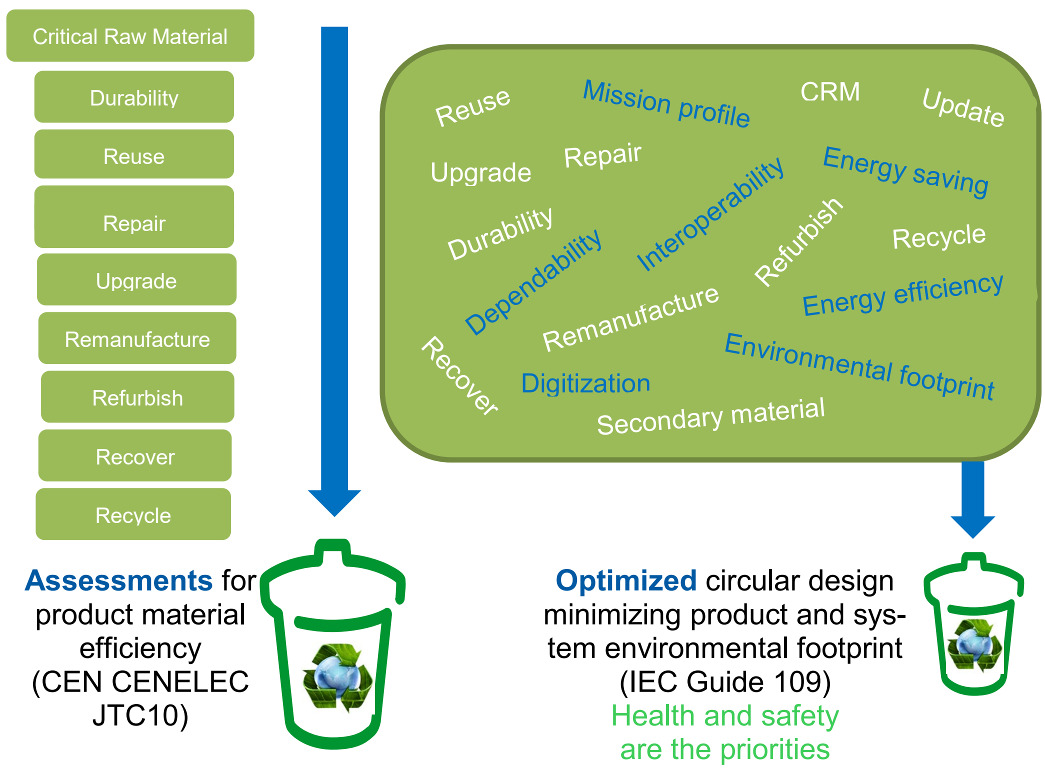


Figure 4

Material efficiency assessment versus design optimization for circularity and environmental footprint

The EN 4555x European standards, detailed in appendix A, are horizontal (considered as generic documents) because they do not apply to any particular ErP but provide a common, agreed upon methodology for assessing all various ErPs. These documents cover IT and household appliances, such as washing machines, water heaters, televisions, batteries, and other products dedicated to the business-to-consumer market. They also apply to more industrial ErP equipment, such as electric motors, variable speed drive systems, pumps, ventilation units, compressors, power transformers, electronic displays, power supplies, and batteries or others products dedicated to the business-to-business market.

[9] CIRED: 25th International Conference on Electricity Distribution: Madrid, 3-6 June 2019. "MATERIAL EFFICIENCY FOR CIRCULAR ECONOMY: FROM ASSESSMENTS TO OPTIMIZATIONS". By Thierry Cormenier - Schneider Electric – France.

Even if some of these material efficiency standards could be directly used for assessing ErP equipment, they should, by nature, be used as a reference to develop product-specific standards.This is in order to address the assessment of material efficiency aspects in a more specific way because their relevance is linked to the mission profile and use cases of ErPs, all of which are different.

Horizontal and product-specific standards

Horizontal and product specific standards derived from EN 4555x series

From the short descriptions of the EN 4555x horizontal standards for assessing material efficiency aspects applicable for ErP (see Appendix A), it is more than likely that the standards will need to be adapted to the specificities of each product, system, or piece of equipment. Consequently, every standardization product committee at the European level (CEN and CENELEC) or at the international levels (IEC and ISO) would consider the benefits of preparing and drafting a unique document or a complete set of similar standards for the assessment of ErP's material efficiency covered by their scope.

Guidelines that explain how to assess each material efficiency topic and the way to use each individual document has been embedded within each EN 4555x standard. Consequently, the CEN-CLC/JTC 10 committee cancelled the project EN 45551, which was expected to become a general guideline for that purpose.

Nevertheless, creating a general guideline to support the standardization work of each ErP technical committee has been considered very useful. Then, if agreed upon by the European CEN-CLC Ecodesign Coordination Group (CEN-CLC/Eco-CG), material efficiency guidance should be drafted for use by technical committees' product-oriented standards for ErP to write product-specific standards.

Minimize the environmental footprint using system engineering

How to optimize environmental footprint reduction

The need to accelerate efforts for a greener and more sustainable world, both quantitatively and qualitatively, requires considering any ecosystem as a whole. Each improvement on distinct items is necessary but can be much more efficient if a system approach is considered. This section explains how to support future roadmaps of standardization bodies like IEC, ISO, IEEE and any others, to cover a broader spectrum for better efficiency of any environmentally conscious design initiative.

Functional analysis

Functional analysis is a process that identifies, describes, and classifies the functions of a product in a system.

To prioritize design choices within the framework of an environmentally conscious design (ECD), a functional analysis that involves all the stakeholders encountered during the product's life cycle in its system should be carried out, especially when facing trade offs. The identification and description of functions can be performed using Figure 5 and the ISO/IEC/IEEE 24748-1:2018 standard (system life cycle management), while the classification of functions can be carried out in accordance with functional analysis system techniques (FAST) or equivalent methodologies.

Based on risk assessment and application failure mode analysis, dependability requirements should be defined to identify the dependability functions. The standards

IEC 60300-1 (Guide on methodology for dependability management), IEC 60300-3-4 (Application guide – Guide to the specification of dependability requirements) and IEC 62347 (Guidance on system dependability specifications) can be used to identify the methodology and guide the specification. During the life cycle, the dependability review should be conducted in accordance with the IEC 62960 standard (Dependability reviews during the life cycle).

Product functional analysis

A functional analysis can be carried out for systems, products, parts, and materials as shown in Figure 5. This should be applied for each life phase of the object covered by the functional analysis of either the system, the product, the parts, or the materials, and identify all interdependencies. Products, parts, and materials can also be considered as a system as soon as multiple functions and technologies are combined. The functional analysis system technique is a methodology that transforms the user specification into a technical specification when functions are classified by importance.

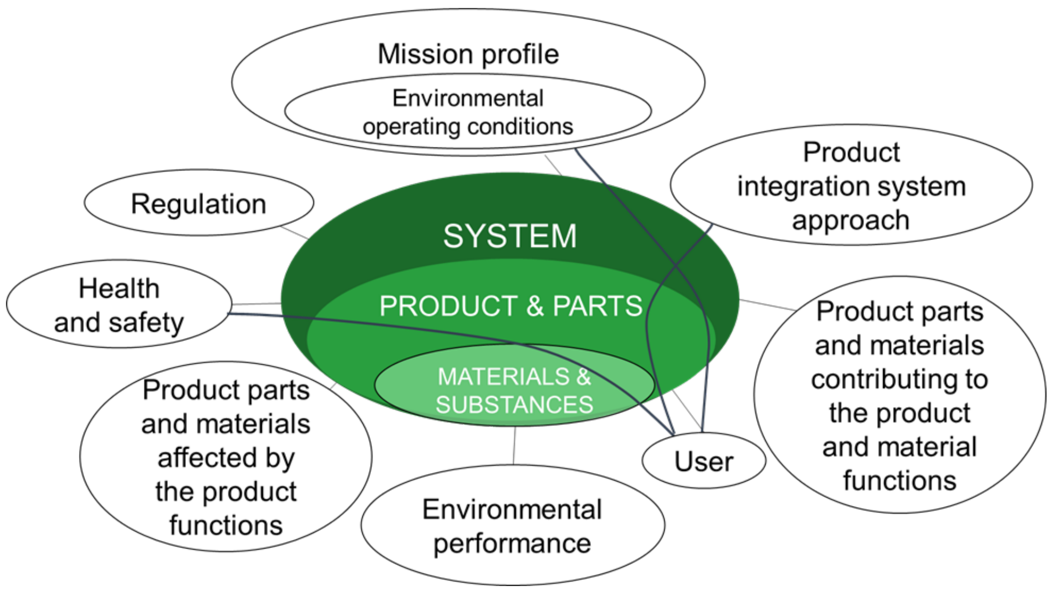


Figure 5

Example of structure to initiate functional analysis for either systems, products, parts, or materials

The functional analysis that answers the question "what for" allows user functions to be defined, while technical functions are identified by answers to the question "how to" the user functions shall be designed and implemented. However, there are several steps that must answer the question of "how to" when the functional analysis system technique is conducted in detail. Due to the several steps on "how to," the first step on "how to" is arbitrarily defined by "what to do," which should later be followed by several steps of "how to" to continue a detailed design process that defines the product design strategy, the environmental design strategy, the material efficiency strategy, as show in Figure 6a, and then the technical specifications. An example of the life cycle system approach applied to material efficiency is shown in Annex Table 2.

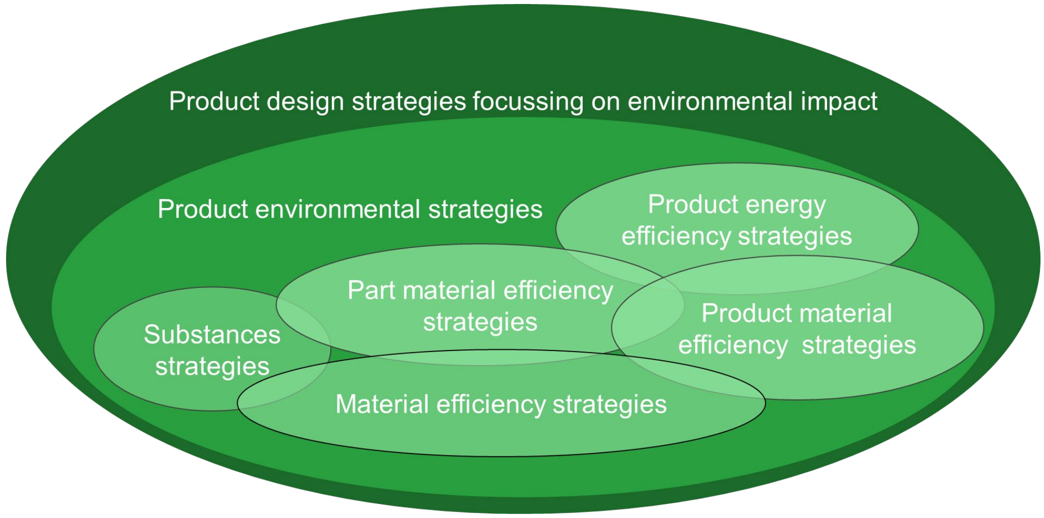


Figure 6a

Hierarchy of the different strategies

Figure 6a helps to identify how the implementation methodology could be derived from the main pillars (1, 2, 3 described page 5) and the first implementation initiative from the CEN CENELEC JTC10 deliverables as detailed Figure 6b.

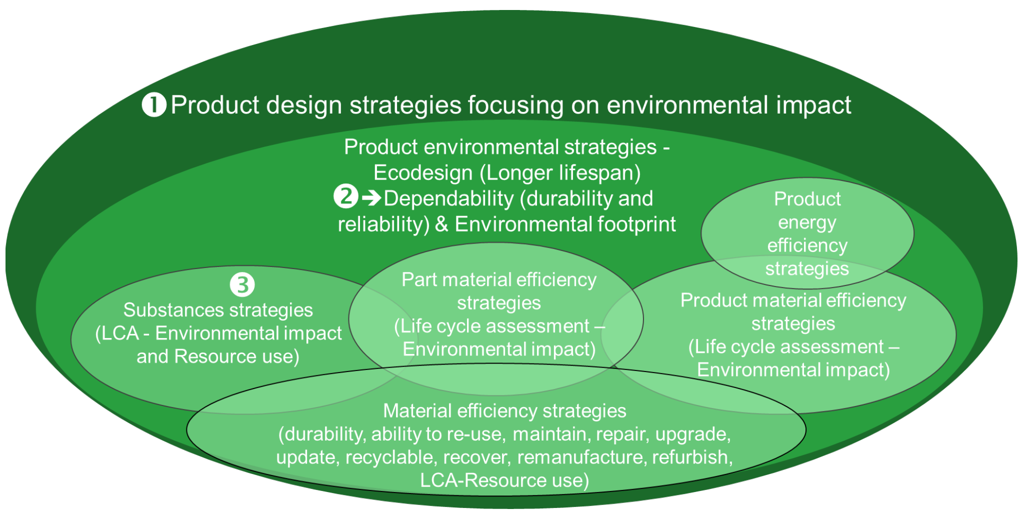


Figure 6b

Main pillars of material circularity (1, 2, 3) and CEN CENELEC JTC10 deliverables

To specify the implementation of theses strategies, reference standards could be applied from the ISO and IEC 62430 environmentally conscious design and the IEC 60300-3-4 Dependability management – Part 3-4: Application guide – Guide to the specification of dependability requirements.

To initiate functional approaches of the system and of the product, Table 1 gives examples of system influencing factors under each influencing condition along the life cycle to identify the needed functions.

The main user functions' approaches related to "what for" and their relations with environmentals aspects are described within Figure 7.

Table 1

Main influencing factors and conditions to identify functions and how they will be fulfilled

System influencing factors:
What for? To identify **how** to conduct an environmentally conscious design

Segments & Architecture	Process	Task requirements	Interacting system
Data centers	Input / output	Nature of tasks	Boundary
HealthCare	Modes	Scope	Protocol
Oil & Gas	Stages	Duration	Interference
Mine, Mineral, Metals	Cycles	Sequence	Dependency
Hotels	Failure modes	Mode of Operation	Interoperability
Banking Finance	Generation	Start-up	Cyber-security
Water Wastewater	Transmission	Normal operation	Dependability
Utilities: Private, Public, Renewable	Distribution	Emergency operation	Grid-codes
Food & Beverage	Micro-grid	Shut-down	Availability Redundancy

Service conditions and Impacts: **How** to be sustainable?		Project constraints: **How** to innovate & to be compliant?	Specificities of the operations. **How** to operate?	
Environment	Environmental	Project	Human interaction	Support services
Temperature	End of life	Economic constraints	Health and safety	Preventive Maintenance
Humidity	Hazardous substances	Regulatory constraints	Command authorized	Documentation
Vibration	Footprint	Technical novelty	Unauthorized Interaction	Technical support
Shock	Circularity	Novelty of operation	Job-defined interaction	Spare parts
Pressure	Energy efficiency	Complexity	Training	Special tools
Radiation (EMC)	Decarbonization	Number of systems	Skills	Maintenance access
Pollutants	Radiation (EMF)	Segment certification	Interfaces	Levels of support
Storage	Disturbances others (Noise...)	Time constraints		Repair
Transports				Condition-based-maintenance

IEC Guide 109: Environmental aspects – Inclusion in electrotechnical product standards

The IEC Guide 109 supports the integration of environmental requirements into product standards. This document already incorporates a system approach, but it has not yet been sufficiently deployed. This is why, at the IEC plenary meeting held in Shanghai in October 2019, ACEA (Advisory Committee of Environmental Aspect) in charge of Guide 109, invited the IEC Technical Committees to join this horizontal committee in order to improve Guide 109 and to better consider some specificities.

Figure 7 describes some adaptations on Figure 1 of the IEC Guide 109, dealing with the relationship between provisions in product standards and the environmental aspects and impacts associated with the product during its life cycle.

Why are these adaptions necessary? IEC 62430: 2019 Environmentally conscious design – Principles, requirements and guidance does not specify the mission profile as an input of the ecosystem that influences the product life span, the main input of the life cycle assessment (LCA), especially the annexes on how to apply and select environmental conscious design.

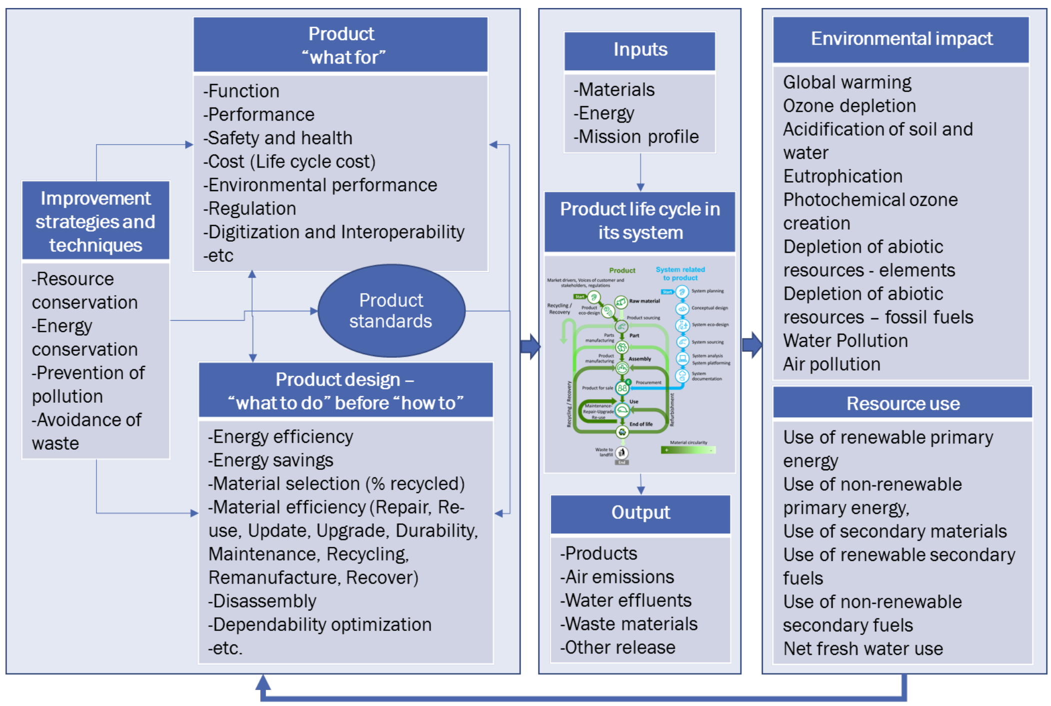


Figure 7

Relationship between provisions in product standards and the environmental aspects and impacts associated with the product during its life cycle

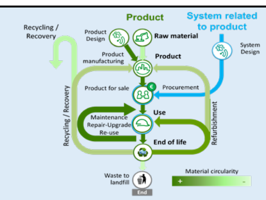
ISO/IEC/IEEE system approach

How should life cycle management be addressed?

System approaches that address product life cycles in a system are covered by a series of standards, such as the “ISO/IEC/IEEE 24748-1 Systems and software engineering — Life cycle management — Part 1: Guidelines for life cycle management.” They should be considered at an early stage of the life cycle. This standard is appropriate for describing a man-made system. It can be used to describe an ecosystem related to products, services, or any human activities that interact with the environmental aspects.

Figure 8 of this document summarizes the relationship with other series of standards as described Figure 10 of the ISO/IEC/IEEE 24748-1 standard, which describes how to conduct any adaptation by domains (activities, business model, services, etc.), by disciplines (technologies), and specialties (human, health, safety, security, interoperability, usability, dependability (availability, maintainability, reliability, etc.), and environmental impacts). These “-ilities” requirements are referred to as “critical quality characteristics.” These characteristics determine how well the product meets its specified requirements in a specific area selected for focus.

The ISO/IEC/IEEE 24748-1 standard is associated with ISO/IEC/IEEE 15288, which deals with system life cycle processes.

<table>
<tr><td rowspan="2">Guidance</td><td colspan="2">ISO/ IEC/IEEE 24748-1
(Life cycle management)</td><td rowspan="2">
</td></tr>
<tr><td colspan="2">ISO / IEC / IEEE 24748-2 ; ISO/ IEC / IEEE 24748-3
Application in specific context</td></tr>
<tr><td rowspan="2">Conformance</td><td>ISO/IEC/IEEE 15288
(Systems)
System life cycle processes

ISO/IEC/IEEE 12207
(Software systems)</td><td>ISO 9001
ISO 14001 - ISO 14009
IEC Guide 109
ISO/IEC/IEEE 24748-4
ISO 50001
IEC 60300 / IEC 62960
IEC 61508
IEC 62430
ISO/IEC 27000
ISO 55001-002
ISO/IEC 15408
ISO/IEC 15504
Etc.</td><td>Quality management systems – Requirements
Environmental management systems - Circularity
Environmental aspects – Inclusion in product standards
Systems engineering - Life cycle management
Energy management systems
Dependability management and review during lifecycle
Functional safety of safety-related systems
Environmental conscious design
Information technology - Security techniques
Asset management — Systems — Requirements
Information technology - Security techniques
Information technology - Process assessment</td></tr>
<tr><td>System</td><td colspan="2">Specialty</td></tr>
</table>

Figure 8

ISO/IEC/IEEE 24748-1 relationship to detailed process standards

Ecosystem for sustainability

How to maximize the efficiency of standards dealing with environmental aspects

A simple way to express a system would be to represent an analog macro model of a system (summarized in Figure 9) that represents the ecosystem seeking optimization and stability. It could be summarized as follows for each block of the schema:

1. “Input” summarizes the outer control system.
2. “Correction” is usually the amplifier of a signal (decision) from the difference of the values respectively representing the need and the target.
3. “Assessments” represent an image of the system in a certain situation, like feedback from sensors.
4. “Actuators” are the enablers of the control (decision).
5. “Stable ecosystem” represents any system contributing to the sustainable development goals (SDGs).

The time constant of climate change is very long, and the model and each system is very complex, so it is difficult to summarize them by this single schema. There are several actions that assume to control the system as an open loop system and use assessment methods instead of control systems.

Figure 9 shows which block of the schema influences the system to reach the target. It illustrates any ecosystem and its stability for sustainibility. The curves from IPCC[10] show several scenarios that are assumed about decarbonization or greenhouse gas emission reduction and their influence on global warming, which are associated with SDG 13 (climate change). Few initiatives on standardization exist such as the PAS 2060: 2014 “Specification for the demonstration of carbon neutrality”, which highlights that different approaches could be met. It is why detailed CO_2 impact methodology should be verified by a third party and explained with deep transparency[11].

For example, even with the EU regulation in force requiring the controls of the SF6 handling, Schneider Electric invested substantially to replace SF6 with air in their medium voltage switchgear ranges. The choice of alternative gases has not been retained due to the inability to answer SDG n°3 (Health) because the exemption of toxicity has not been demonstrated. The use of air in this range answers to the SDG n°13 (Climate action). The ability to upgrade by combining on the same range of MV equipment the old ones using SF6 and the new ones using air, answers to the SDG n°12 (Responsible consumption and production).

Like Figure 9, Figure 10 specifies the relevant standards for use. IEC 62430:2019 standard applicable for ISO and IEC products is the last publication dealing with environmentally conscious design. It is co-published under the dual ISO and IEC logos. The material efficiency will be considered through a technical report, which in progress.

Every ecosystem model to reach each SDG is complex. To solve environmental issues and to control respective ecosystem models, the digitization must be introduced or more deployed along the product and system life cycles (See Figure 12). It is why the EU Green Deal specifies “*accessible and interoperable data are at the heart of data-driven innovation*” and asks “*European scientific and industrial excellence to develop*

[10] https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter12_FINAL.pdf
[11] https://www.se.com/ww/en/about-us/sustainability/climate-change/

a very high precision digital model of the Earth." The EU Commission will support work to unlock the full benefits of digital transformation to support the ecological transition.

The next chapter dealing with digital twins will present an initiative to solve interoperability issues for the benefit of the environment. The EU Commision said "an immediate priority will be to boost the EU's ability to predict and manage environmental disasters. To do this, the Commission will bring together European scientific and industrial excellence to develop a very high precision digital model of the Earth". To optimize any results when facing unknown complex models, adaptive controllers referring to digital twins should be investigated as presented in Figure 11.

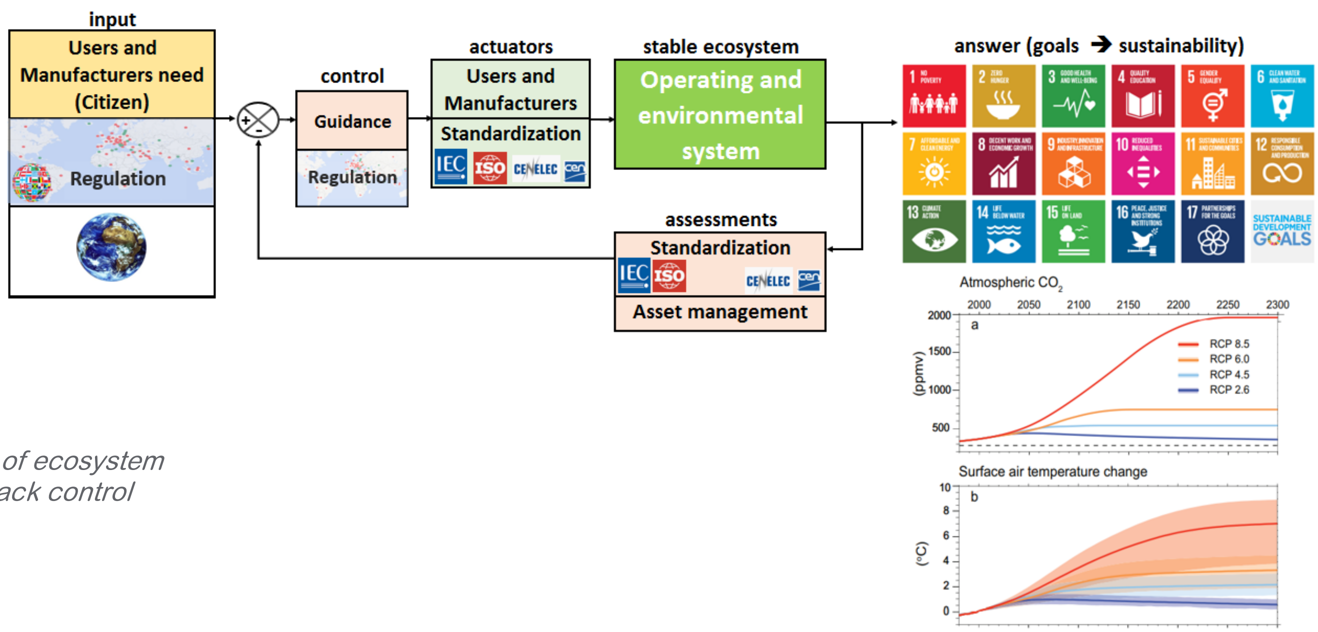


Figure 9

Example of ecosystem as feedback control system

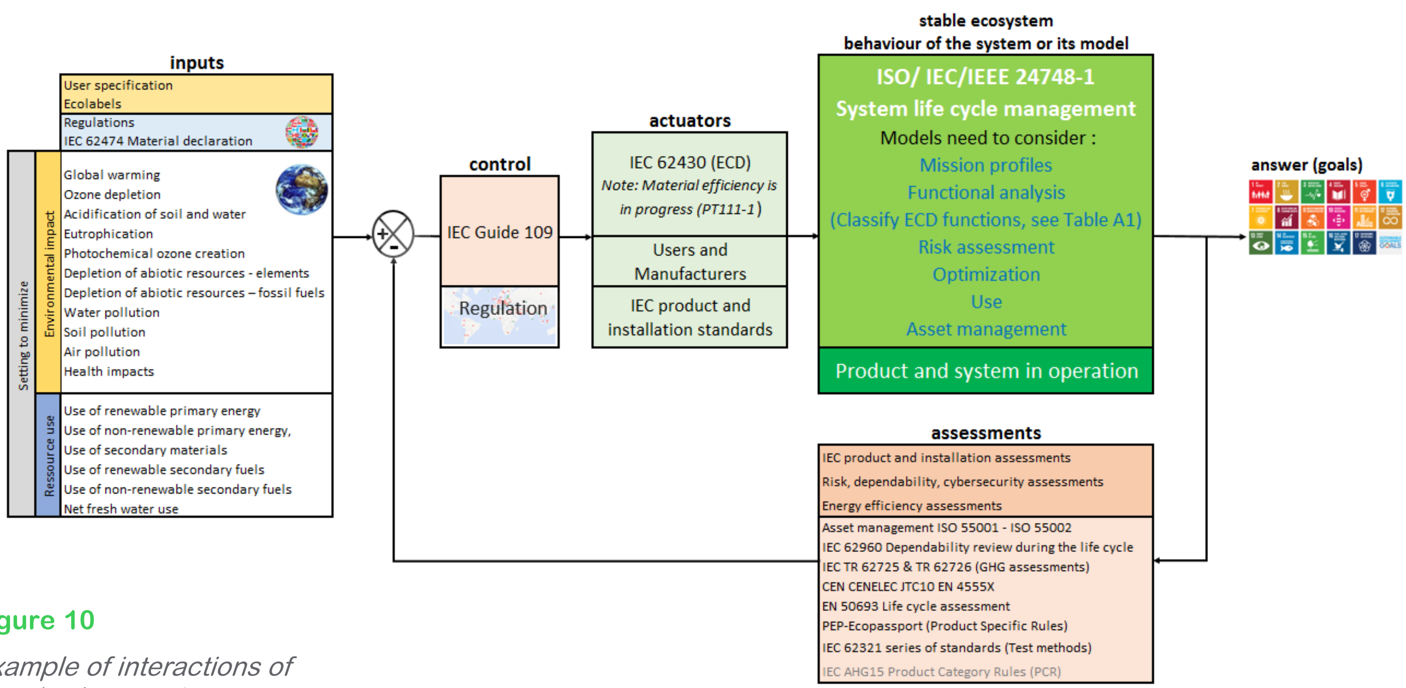


Figure 10

Example of interactions of standards targeting sustainability

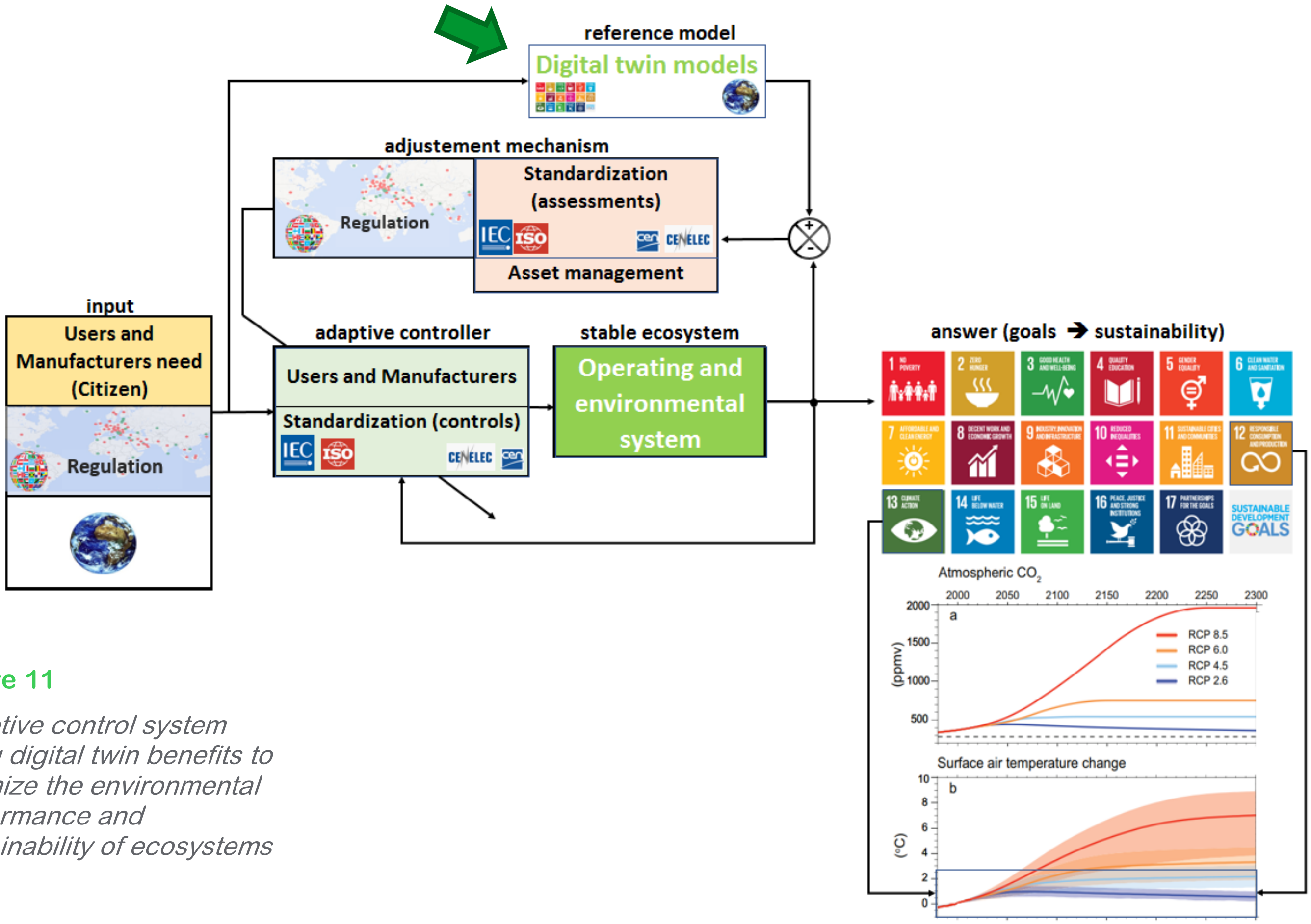


Figure 11

Adaptive control system using digital twin benefits to optimize the environmental performance and sustainability of ecosystems

Digital twins

How environmental aspects benefit from digital transformation

heaFor digital transformation to occur, information exchanges (digital properties, digital twins) along product and system circular life cycles, are necessary (as shown in Figure 12) and as specified in clause A3 of IEC 62430: 2019.

The benefits of data migration are the identification of the products, its parts and materials, their environment, and the operating conditions of the system. The digital twin includes the instructions for use.

Digital twins are digital representations of a physical device or system in their circular environments. Digital twins must rely on product data. Numerical twins are already widely used in general, and increasingly used with circular economy, but they are mostly "static" between phases. Digital twins are distributed over the entire product and system life cycles, starting even before the existence of the product, on both the manufacturer and customer sides. Within the same phase of life, several digital twins contribute to the customer's digital experience and its system asset management.

However, there are several systems, processes, and respective data models that prevent communication from machine to machine, between two adjacent life phases, or between two devices or software within the same life phase. It is time- and energy-consuming to manage the data along the life cycle for all stakeholders. Consequently the product life cycle assessments should consider the environmental impact of the digitization. This will confirm the real benefit of the digitization avoiding green washing.

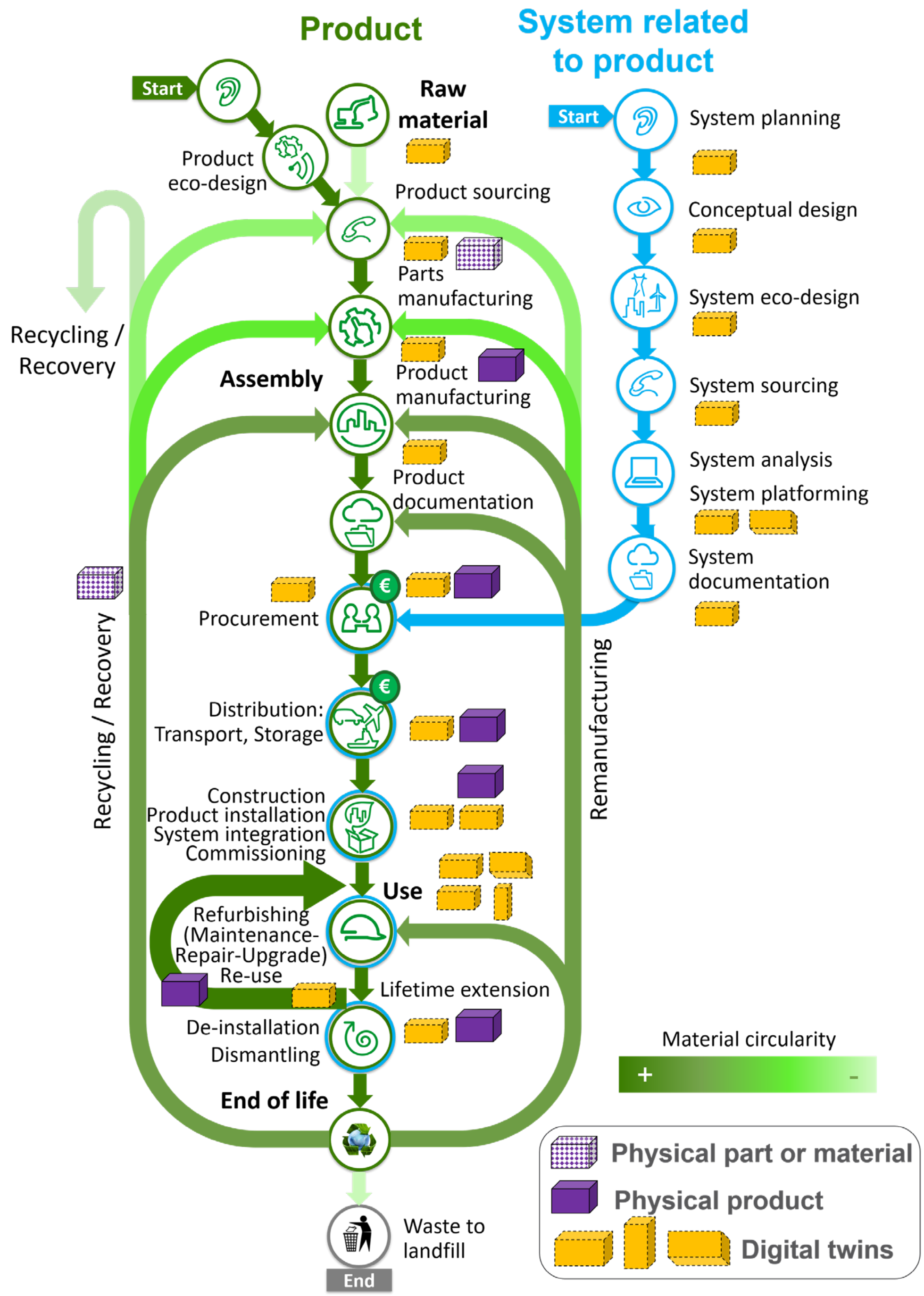


Figure 12

Example of material circularities showing real materials, parts, and product and their digital twins

Data migration

How to improve interoperability along the life cycle

Figure 12 shows the data migration along the circular life cycle while Figure 13 simplifies the life cycle only to show the reference documents of data models for different segments. This figure introduces the limitation of the data migration due to the interoperability issues between the data models and processes.

These issues are also valid for various uses cases and application domains. The properties could be re-used and/or harmonized if they are integrated within the IEC common data dictionary (IEC CDD) [12].

All gaps and overlaps of Figure 13 reflect a multiplicity of data platforms where the data are mainly static, mainly associated with only one life phase, and unable to be used by sofware providers during simulation stages or by manufacturing tools providers.

As a first step, a product's or service catalog's data should be developed to be integrated within IEC CDD, and at the same time within a pivot platform such as eCl@ss [13], which enables the transformation of the product's properties and structure to other models. The use of eCl@ss is not limited to the procurement life phase. That is only the origin of its creation, but its capability might be extended to other life phases if relevant product or service properties are filled. This has been demonstrated for the low voltage electrotechnical devices [14] as recognized by the IEC.

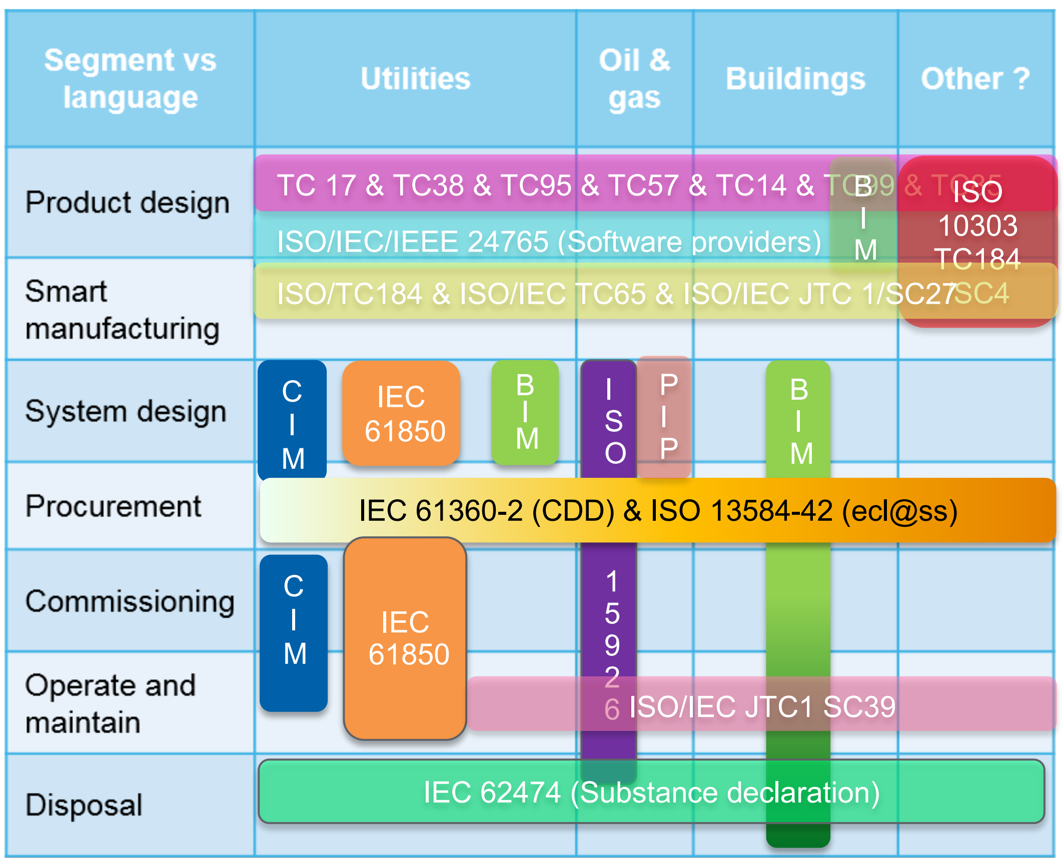


Figure 13

Example of data models that should be harmonized with IEC CDD reducing the environ-mental impact through data management.

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[12] IEC CDD: https://cdd.iec.ch/cdd/iec61360/iec61360.nsf/TreeFrameset?OpenFrameSet

[13] https://www.eclass.eu/en.html

[14] https://www.iec.ch/dyn/www/f?p=103:46:4703621703714::::FSP_ORG_ID,FSP_LANG_ID:4036,25

Future of MEErP for EU regulation

When a system approach focuses on life cycle cost analysis

The European Commission's most recent workshop (2019-05-28) on the MEErP (the regulatory Methodology for Ecodesign of Energy-related Products) was dedicated to the reinforcement of aspects of circular economy in the methodology, and particularly how to consider the way material efficiency can be assessed from the regulation point of view for implementation in future ecodesign regulations for ErP.

The potential contradictions have been identified and discussed. As an example the discussions raised potential links between material efficiency, energy efficiency, energy savings, and the relations between the design constraints to achieve these performance and the life cycle costs.

General consideration for dependability specifications, including life cycle cost analysis (LCCA) and its optimization seeking extremum, such as least life cycle cost analysis (LLCCA), are respectively covered by the IEC 60300-3-3 "Dependability management – Part 3-3: Application guide – Life cycle costing" standard and the IEC 60300-3-4 "Application guide – Guide to the specification of dependability requirements" standards. The IEC 60300-3-4:2007 Figure 1 shows the objectives project costs versus system reliability near to that it was presented during the MEErP workshop.

In particular, consideration of the least life cycle cost analysis (LLCCA) was discussed during this workshop[15] to determine an effective trade-off among three objectives:

- the cost that impacts manufacturers (and customers) when ErP are put on the market
- the cost (and related energy savings) that impacts the users during the ErP life operation
- the societal cost (meaning the impact on the environment for air, water, ground, and biodiversity), on human health, and employment (another UN Sustainable Development Goal)
- etc.

Figure 14 shows, by combination of the three above cost factors, the equivalent overall life cycle cost (LCC) reached for optional payback periods. Among other optimizations, studies on costs should start to carefully consider the LCC ranking for establishment of the best regulatory proposals including material efficiency aspects.

[15] European Commission workshop on "The future of the MEErP" in Brussels on 2019-05-28: Presentation of "Design options ranking and the inclusion of material efficiency aspects" by Davide Polverini (European Commission: DG GROW Unit C1: Clean technologies and products).

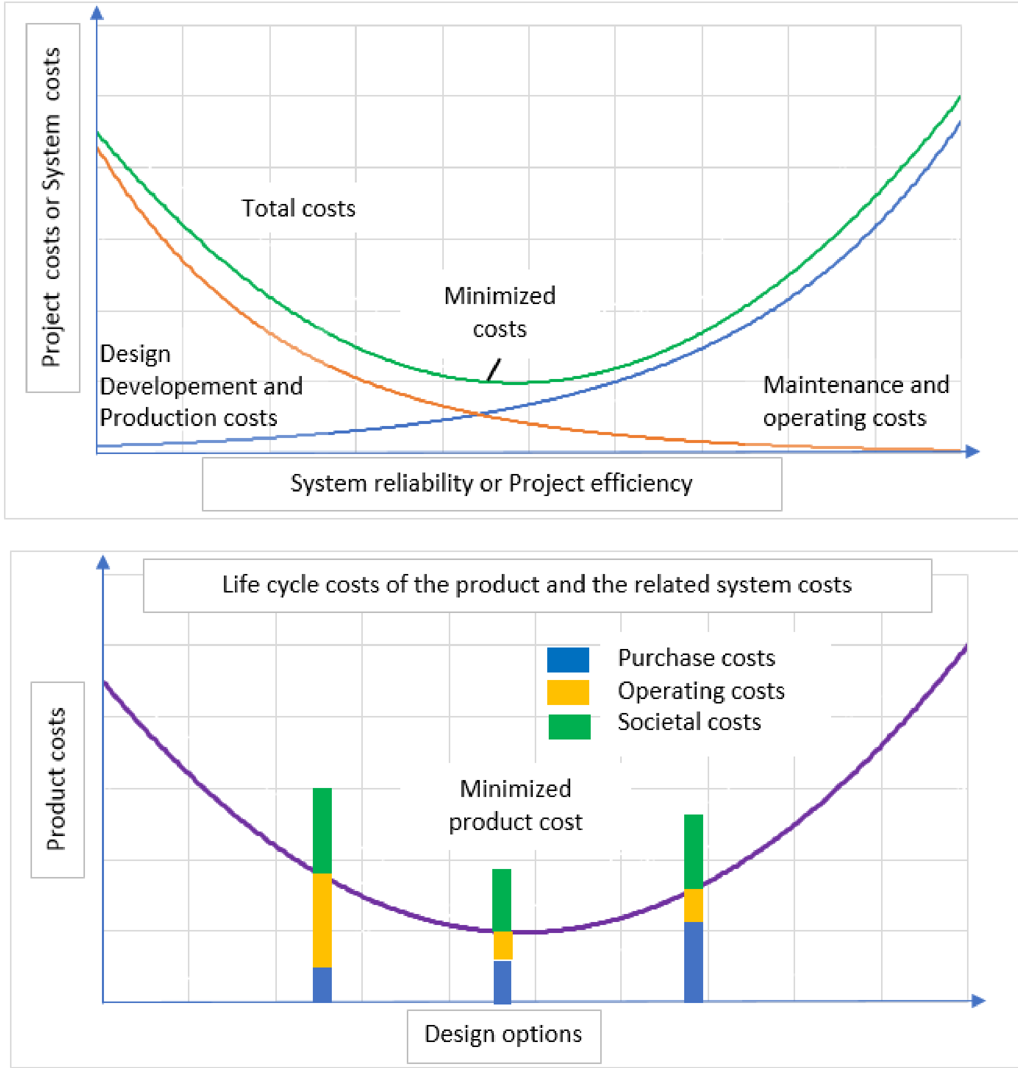

Figure 14

Ranking of ErP least life cycle cost (LLCC) considering design options

It has long been said that the overall benefit for energy savings is obtained through the extended product approach at the applicative sector level (as described in the EN IEC 61800-9-1 standard), particularly for motor power drive systems (PDS). For instance, pumps, fans, and compressor systems use motors and VSDs at the most efficient system operating point of the equipment. The energy efficiency performance objective to reach for motors impacts the type of materials and their quantity in the motor. If material efficiency objectives are so stringent that any new energy efficiency requirement for better performance of motors cannot be reached anymore, then compliance with regulations could become impossible.

Therefore, trade-offs between energy efficiency performance and material efficiency aspects should be carefully considered. And further ErP preparatory studies to be conducted by the European Commission should consider LLCCA for optimization of requirements in regulations.

An analogous approach is valid for power transformers where the energy efficiency is obtained with additional material and where the lifespan is over 30 years.

Product to service

Retrofitting and new business model transforming waste into resources

Retrofitting electrical distribution switchboards[16] (circuit breakers, contactors, load break switches, and protection relays) can take place during the use phase to extend the equipment's life span in accordance with material efficiency for circular economy.

Retrofit solutions reduce the environmental impact of the ecosystem compared to simply installing new products. These solutions include:

- Updating switchgear housings and accessories
- Maximizing the durability of cables and wires
- Maximizing the equipment's durability by upgrading it with sensors and connecting it to a platform:
    - Embedded analytics support the maintenance strategy
    - Deep analyses assess the product's aging related to its physical (design) and statistical (on field, mission profile) behavior.
- Upgrading any obsolete active components
- Avoiding additional civil work

For the equipment's owner, retrofit solutions are not only economical, but also faster to install, meaning less production downtime and fewer risks during installation. Top equipment manufacturers ensure resource circularity through their commitment to minimizing the environmental impact of a customer's installation. This happens by managing product life cycle well and doing more with fewer resources, while helping protect their health, safety, and the environment.

Figure 15 shows what a circular process would look like, showing supperposed failure patterns (time dependant, time constant, etc.) defined within the IEC 60300-11 Dependability management – Part 3-11: Application guide – Reliability centred maintenance and successive potential re-uses depending of the reliability requirements. The conditional probability of failure depends on the technology used and associated physical properties. As an example, the main car rental companies apply this kind of model. This enables them to more easily renew a fleet with greener products or equipment.

[16]. Schneider Electric - White paper "How Retrofit Services for Electrical Distribution Contribute to the Circular Economy" - 2018 Giovanni Zaccaro.

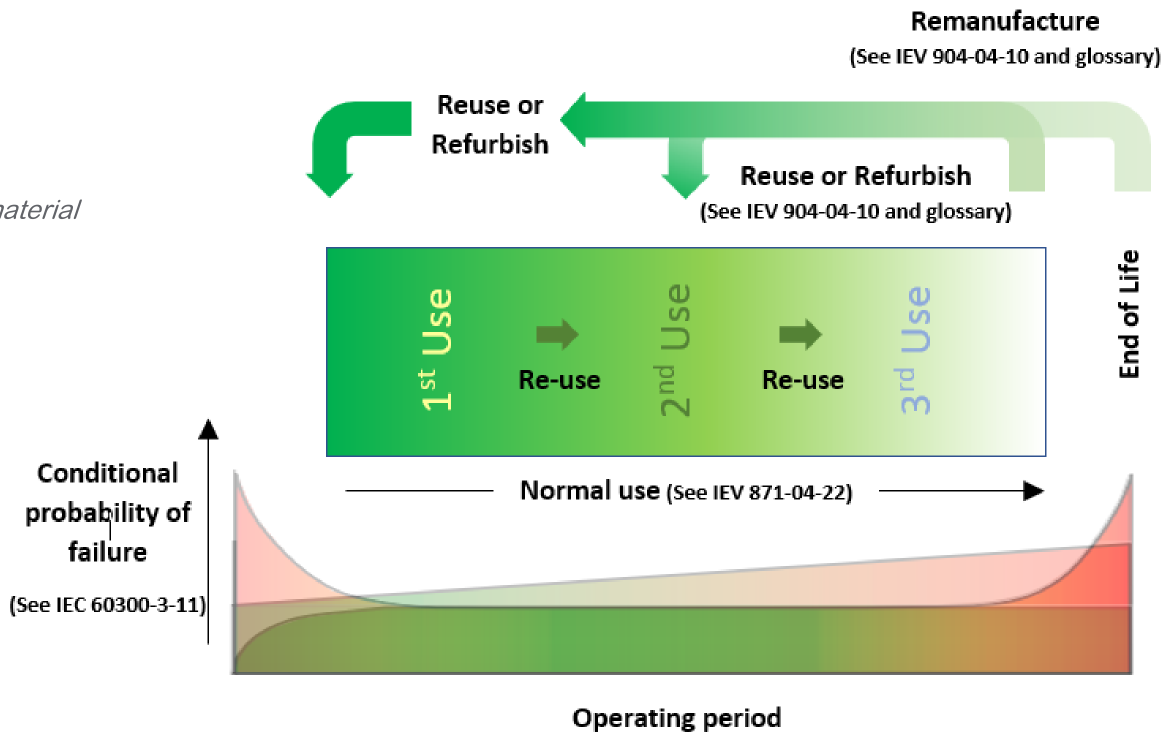

Figure 15

How to manage material circularities and dependability

Conclusion

Standardization on material efficiency assessments has been launched as an emergency need for circular economy. However, the sustainability of the ecosystems, as defined by UN sustainability goals, is broader. In this white paper, there has been a special focus on global approaches based on system engineering that covers life cycle management and supports SDGs number 12 (responsible consumption and production) and 13 (climate action). The aim is to bring stability to any ecosystem.

These approaches are documented by many standards from technical committees such as the horizontal committees IEC TC 56 (Dependability), IEC TC111 (Environmental standardization for electrical and electronic products and systems) and product and system committees covered by the technical ISO/IEC JTC1/SC7 liaised with IEEE for publications. Active liaisons and contributions on global standards need to structure the approaches described in this paper to make them more accessible and better implemented in different processes where materials, parts, products, and systems will have to be perceived as an ecosystem. Each ecosystem must deliver all the useful information needed to derive all the possible benefits of digitization, at each life phase, including minimizing the environmental footprint. To do this, the energy loss caused by the non-interoperability of the subsystems not only in each of the life phases but also in its communication with the system must be identified, minimized, or even eliminated.

Appendix A

Detailed content of EN 4555x series

Described below are the material efficiency status, covered topics, strength, improvement, opportunity, and threats for each EN 4555x horizontal standard. 02/2020: All standards are finalized except EN 45553 (Remanufacture) and EN 45550 (definitions), which are still in process.

All documents are expected to be used and deployed through product standards by the product and product-group standardization committees.

EN 45550 (Technical Report), Definitions related to material efficiency

This is a collection of common terms used in different EN 4555x standards.

Strength: This document summarizes all definitions used by the EN 4555x series of standards.

Weakness: This document should have been prepared before to engage the work on the EN 4555x series of standards, to ensure a common understanding for each term used.

Opportunity: This can be improved with the following definitions based on exsiting IEC and ISO standards to feed dual logo environmentally conscious design standards IEC and ISO 62430. In addition, this would help the product and product-group standardization committees.

See definitions for material, material efficiency and material circularity from different sources.

Threat: To not be recognized as reference document for definition dealing with material efficiency for circular economy, not being unique for all EN 4555x series of standards and external to CEN CENELEC.

EN 45552, General method for the assessment of the durability of energy-related products

The user of this horizontal standard, that should be an ErP product standardization Technical Committee, shall consider and select the functions that are required for ErPs. Technical committees must focus on the environmental and operating conditions issued from the ErP mission profile, which becomes the input for the reliability and the durability of the product, keeping in mind that any environmental footprint assessment is always linked to an expected life span.

For example, Figure 2 and Figure 16 shows the limiting events and actions that make the product or system move from functional states to limiting states and finally to the end of its life.

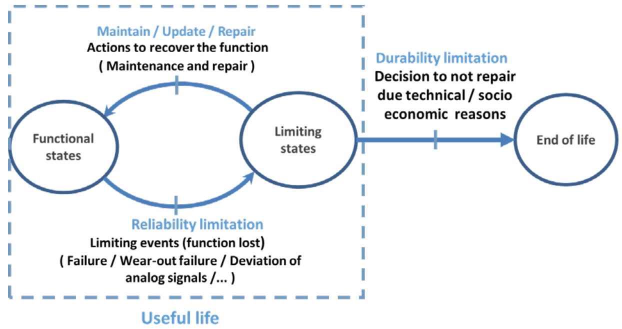

Figure 16

Limiting events and actions affecting the ErP operating status

Status: This standard was approved 01/2020.

Strength: A functional approach is developed, such as the introduction of the environmental and operating conditions influencing any product aging.

Weakness: The environmental performance assessed by LCA was not considered as a secondary function. The functional analysis process was not detailed enough to support the product and product-group technical committees. Risk assessment is missing. The reliability assesment methodology is not detailed enough, being out of scope of the mandate M/543.

Opportunity: It is a good foundation, used as tool for the material efficiency for any environmentally conscious design (See IEC PT111-1 deliverable Q3 2020).

Threat: Missunderstanding of the reliability which is not detailed enough compared to the available documents from IEC TC56, without additional recommendations.

Additional recommendations for the readers of the EN 45552:

- The methodologies dealing with reliability assessment are not sufficiently detailed compared to what has been developed for durability assessment. This is linked to the fact that the European mandate was on durability assessments and not on reliability assessments, even though these two performances of dependability are linked.
- The reliability assessment methods do not integrate repair actions.
- Maintenance is considered only as preventive and predictive while corrective maintenance is considered as a repair action.
- Fatigue, wear, and any deviations of signals are considered as limiting events and need maintenance action(s) on the part(s) or on the product to transform their limiting state into a functional state.
- Attention shall be paid between normal use (use, transport, and storage life phases) and intended use (use phase).
    - There is no established inclusion between durability and reliability. Each can be assessed separately, but there will be no acceptable reliability without acceptable durability to the users of a product and vice versa. IEC 62308 includes durability in an overall assessment of reliability, which is often the case. The risk is that insufficient knowledge in reliability assessment reduces the assessment of durability based on MTTF and/or endurance tests, which would be wrong. This is the reason why EN 45552 refers to IEC 62308 Equipment reliability – Reliability assessment methods and aging tests in accordance with IEC 62506 Methods for product accelerated testing types B and C.

EN 45553, General method for the assessment of the ability to remanufacture energy-related products

This standard describes how to assess the ErP's ability of ErPs to be remanufactured. Remanufacturing is an industrial process that produces a product from used products or used parts. The remanufacturing process can affect the safety, original performance, purpose, or type of product. The EU mandate M/543 did not refer to refurbishment. This could be because the mandate aims to define assessments that are applicable to energy-related products while refurbishing is more often used for goods that cannot be remanufactured and when only parts of the goods can be refurbished, such as power transformers above 4MA and buildings.

EN 13306:2017, which specifies maintenance terminologies, considers refurbishment a maintenance action.

The current status of the document is an enquiry for a new formal vote, where some modifications should be implemented such as:

- Remanufacture process has no link with "significant change."
- Remanufacture process applies when "at least one change is made which influences the safety, original performance, purpose or type of the product."

EN 45554, General methods for the assessment of the ability to repair, reuse, and upgrade energy-related products

This standard is generic. It provides options that allow for the selection of assessment types (semiquantitative, quantitative, or qualitative assessment are possible) and criteria as appropriate for each product-group. It allows the user to identify the ErP prioritized parts that could possibly be repaired, re-used, or upgraded.

Status: This standard has been formally voted positive 10/2019.

Strength: This standard is the main standard to extend the lifespan of the parts and products when a limiting state is reached.

Weakness: This document to measure the importance of the material circularity enablers during the use phase should have used the functional analysis methodology. This document should have been refered to standards dealing with parts and products dependability optimization using maintenance (corrective, preventive, predictive).

Opportunity: The product and product-group standardization committees could take the opportunity to refer to the functional analysis and to the dependability standards to define the priority parts (See EN 45552).

Threats: To limit the lifespan extension without the predictive maintenance improving the reliability and durability.

EN 45555, General methods for assessing the recyclability and recoverability of energy-related products

This standard takes into account the end-of-life treatment processes found in reality, to assess the recyclability/recoverability of an energy-related product, and certain parts/materials of it. In addition, the recyclability/recoverability of critical raw materials are considered.

This standard provides a general methodology for selecting the potential end-of-life treatment scenario for materials, parts, and products that are being considered for recyclability and recoverability. The assessment of an ErP is based on the definition of a representative end-of-life treatment scenario and takes into account the design characteristics affecting the recyclability and recoverability.

Status: Published 11/2019.

Strength: The end-of-life scenario has to be representative in terms of product-related representativeness, technological representativeness, temporal representativeness, and geographical representativeness. The methodology is based on factual and measurable values (mass-based approach) even if the Annex C introduces potential calculation based on environmental impacts.

Weakness: The standard defines the methodology and is still too general.

Opportunity: Thanks to a common and representative scenario, comparison becomes possible. The working group in charge of this document should accompany in more depth the product and product-group standardization committees with dedicated scenarios.

Threat: Not enough data collected to define a representative end-of-life treatment scenario at the European scale.

Additional recommendations for the readers of the EN 45555:

- Informative Annex B provides an example with values and diagram to facilite the understanding of the standard.

EN 45556, General method for assessing the proportion of reused components in energy-related products

It is clear that this standard will be derived from product specific standards for determining the ratio for re-used components. Product committees, such as those for motors, VSDs, pump systems, power transformers, electronic displays, power supplies, and batteries should define the assessment criteria attached to each re-used component by considering the mission profile of the ErP. In particular, specific criteria should be attached to “active components” that cannot be similar to criteria for “passive components.”

Status: This standard was approved and was published on 2019-06-07.

EN 45557, General methods for assessing the recyclability and recoverability of energy-related products

This standard provides a methodology to assess the recycled content of parts of the ErP or complete ErP for all materials or for a specific selection of materials. It requires to clearly distinguish the pre-consumer and post-consumer content even if the calculation of a total recycled content is possible. The total recycled materials content shall always be stated in conjunction with the corresponding pre-consumer and post-consumer content.

Status: This standard was approved 01/2020.

Strength: The standard describes as clearly as possible the distinction between “circulating material,” pre-consumer material, and post consumer material.

Weakness: The standard is intended for ErPs but the recycled content assessment methods are mainly a stake for product and product-group standardization committees aiming to integrate recycled materials and to assess them. To obtain consistent evaluations, the same boundaries (pre- or post-consumer) should be resource management considerations from design to manufacture life phases.

Opportunity: This shared vision of assessing the recycled content could be communicated when product and product-group standardization committees will integrate such requirements. In addition, this standard could help to improve the design stage of the product or parts.

Threat: Currently there is no global methodology bringing reliable, accurate, and reproducible methods. Without trustable and easy-to-implement chain of custody, communication and comparison of recycled content could remain difficult.

Additional recommendations for the readers of the EN 45557:

- Annex A gives a further generic method for assessing the recycled materials content for material supply chain. Guidance on specific materials (plastic, metals, and glass) are also available.
- Within informative Annex B, an example with values and diagram facilitates the understanding of the standard.

EN 45558, General method to declare the use of critical raw materials in energy-related products

This standard can be applied directly to each different ErP because it provides a standardized format for reporting the use of critical raw material (CRM) in ErP by directly applying the EN/IEC 62474 standard for declaration. Regulated CRM are considered in the way that specific regulatory [17] requirements are set for them (in Europe, a list of 27 CRMs was published in 2017, including CRM like antimony, cobalt, heavy rare earth elements, tantalum, gallium, natural rubber or graphite, etc.). Non-regulated CRM can be also considered through this standard.

Status: This standard was approved and published on 2019-03-01.

Opportunity: The IEC 62474 structure is accessible through the IEC website under XML format and an Excel file for developpers. However, the material definition of the EN 45558-IEC 62474 deviates from the IEC CDD definition (see note 4 of the material definition in the following section of this paper, proposed within the SWOT as the opportunity for the EN 45550); The IEC CDD is very important for the digital transformation to migrate the data of the materials, parts, and products along their life cycles.

EN 45559, Methods for providing information relating to material efficiency aspects of energy-related products

This standard provides a common methodology for producing information on ErP covered by the EN 4555x series. It also describes a generic methodology for product-oriented technical committees that should create a communication strategy for their specific products like motors, VSDs, pumps, or any other ErP.

Status: This standard was approved and published on 2019-03-01.

Strength: EN 45559 defines input for communication which can be used as a common list of properties for the material efficiency.

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[17] Communication from the European Commission on the 2017 list of Critical Raw Materials (CRM) for the EU. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017DC0490&from=EN

Weakness: Many communicated inputs depend on the conditions of assessments and the conditions of the aging of materials, parts, and products. Not all conditions are communicated. Reliability is missing from the input list while the EN 45552 introduced defines reliability assessment method. There is no list of precautions for the users of products to extend the lifespan of the materials, parts, and products. For example, information about the variation of lifespan between normal service conditions, special service conditions, even under harsh environments, should be provided to identify the robustness of the life cycle assessment (LCA).

Opportunity: The set of properties for material efficiency can be introduced in each new catalog data such as some are exisitng within the IEC Common Data Dictionary to take all the benefits from the digitization. Example: Which properties of a part should be within a catalogue data if we would improve the traceability of a part which has been reused three times and now expected to be recycled soon?

Threat: Greenwashing, if the relevant information associated to the various assessements are missing. For example to assess a global environmental performance relevant information would be:

- the energy efficiency
- the environmental footprint
- the mission profile of the materials, parts, and products affecting their aging

The potential communicated inputs of the EN 45559 are related to the dependability of the materials, parts, and products, and to the material circularity strategy, both aiming to minimize the environmental footprint.

Example of material efficiency

Table 2

Example of a life cycle system approach applied to material efficiency

Life cycle stage	Purpose
Concept	• Identify stakeholders' needs (Resource availability, product need, etc.) • Identify the mission profile of the materials (conditions and associated duration, product self-heating, etc.) • Identify the mission profile of the parts and product (environmental and operating conditions and associated durations, etc.) • Identify how to answer to the product dependability, optimization minimizing its environmental footprint, and the contribution from material efficiency. • Explore concepts (new sustainable materials, reused material, etc) • Propose viable solutions
Design	• Refine material requirements (mechanical, electrical, thermal, chemical, EMC properties, etc) • Create solution description • Build new material, if any, parts and product • Verify and validate materials, parts and product
Manufacturing	• Manufacture materials, parts and product • Process modification, if any • Process innovation • Inspect and test

Life cycle stage	Purpose
Use	• Operate materials to satisfy parts' needs • Operate parts to satisfy products' needs • Operate product to satisfy users' needs • Material conservation (durability) • Ability to be maintained and/or repaired (service) • Ability to update or upgrade (improvement) • Ability to identify the material, parts and product ageing and past conditions
Support	• Provide sustained product capability (to reuse, to remanufacture, to refurbish)
Retirement	• Provide sustained material capability (to recycle, to recover, to dispose) • Provide sustained product capability (to reuse parts, to recycle, to recover, to dispose) • Store

Glossary

Dependability (of an item)
Ability to perform as and when required

Note 1 to entry: Dependability includes availability (192-01-23), reliability (192-01-24), recoverability (192-01-25), maintainability (192-01-27), and maintenance support performance (192-01-29), and, in some cases, other characteristics such as durability (192-01-21), safety, and security.

Note 2 to entry: Dependability is used as a collective term for the time-related quality characteristics of an item.

(Source: IEV 192-01-22)

Durability (of a part or a product)
Ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached

Note 1 to entry: The degree to which maintenance and repair are within the scope of durability will vary by product or product group.

Note 2 to entry: The user of this document has to define the criteria for the transition from limiting state to end-of-life (EoL). For more information see Figure D.1. (See Figure 16 of this document)

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: CEN CENELEC JTC10 EN 45552 (2020))

Functional analysis
Process that identifies, describes, and classifies the functions of a material(s), part(s), product(s) and system

Note 1 to entry: Material, part, and product are considered as a sub-system of the upper element.

(Source: CEN CENELEC JTC10 EN 45552 (2020))

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: CEN CENELEC JTC10 EN 45552 (2020))

Limiting state
Condition after one or more limiting event

Note 1 to entry: A limiting state can be changed to a functional state by maintenance or repair of the ErP.

Note 2 to entry: A limiting state can change to EoL-status, if maintenance or repair is no longer viable due to socio-economic or technical reasons.

(Source: CEN CENELEC JTC10 EN 45552 (2020))

Material
Substance or mixture of substances within a product or product part

Note 1 to entry: Materials can be divided into two categories:

- materials that are intended to become part of products, e.g. raw materials, auxiliary materials, intermediate products;
- materials that do not become part of products or neither be a part or a product, e.g. cleaning solvents and chemical catalysts, which often are referred to as operating materials

Note 2 to entry: Some types of materials can be classified into either category, depending on their use. Water is one such material. In some cases, water can become part of a product (e.g., bottled water), while in other cases it can be used as an operating material (e.g., water used in an equipment washing process).

Note 3 to entry: Energy carriers like fuels or steam can be identified as materials, at the discretion of the organization.

(Source: IEC 62474 2018 3.15 and ISO 14051:2011 3.10 and EN 45558:2019 modified)

NOTE 4 to entry: IEC Common Data Dictionary definition of material: Substance that is a chemical element or a compound in its natural state or obtained by any production process, including any additive necessary to preserve the stability of the products and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition, or a preparation, that is a mixture or solution composed of two or more substances

Material efficiency
Ratio or other quantitative relationship between an output of performance, systems, products, or service, and an input of material or product parts or products

(Source: ISO 14052 3.3 modified)

Material circularity
Combination of activities aimed at minimizing resources and wastes by generating circular flows of materials, parts, or products

Note 1 to entry: Repair, reuse, and update help extend the lifespan of materials, parts and products during the use phase.

Note 2 to entry: Refurbishing, remanufacture, and reuse help extend the lifespan of materials, parts and product recover a normal use.

Note 3 to entry: A product achieved by material circularity can't be declared as a new product because along the previous life of the product there was certainly regulation changes and the aging of part(s) even if technical performance is kept.

Note 4 to entry: Recycling and recovery help extend the lifespan of materials for other uses after the ultimate end of life of parts or products.

Recovery
Operation of any kind, the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy

Note 1 to entry: Recovery operations include material recovery and energy recovery.

(Source: Directive 2008/98/EC, modified by moving the last sentence of definition to Note 1 to entry)

Recycling
Recovery operation of any kind, by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes excluding energy recovery

Note 1 to entry: Recycling includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

(Source: Directive 2008/98/EC, modified by moving the last sentence of definition to Note 1 to entry)

Refurbishing
General process of service activities covering maintenance, repair, upgrade which are operated during the use phase, to restore parts or a product to original intended use

Note 1 to entry: Changes should not need type tests and should be verified by predetermined routine and/or functional tests.

(Source: IEV 904-04-09 modified)

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: CEN CENELEC JTC10 EN 45552 (2020))

Remanufacturing
Manufacturing industrial process after the end of life, which creates a product from same used parts or product

Note 1 to entry: changes should not need type tests and should be verified by routine tests in accordance with the current product standard.

(Source: IEV 904-04-10 modified)

Repair
Process of returning a faulty product to a condition where it can fulfil its intended use

(Source: CEN CENELEC JTC10 EN 45552 (2020))

Reuse/re-use
Process by which a product or its parts, having reached the end of their first use, are used for the same purpose for which they were conceived

Note 1 to entry: Reuse after second or subsequent usage is also considered as reuse, but normal, regular or sporadic use is not considered as reuse

(Source: CEN CENELEC JTC10 EN 45554 (2020))

Upgrading
Process of enhancing the functionality, performance, or capacity of a product

Note 1 to entry: Upgrade may involve changes to the software, firmware and/or hardware.

(Source: IEV 904-04-11 modified; Source: IEC 62075:2012, definition 3.23 modified)

Acronyms

B2B	"Business-to-Business" economic market
B2C	"Business-to-Customer" economic market
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CLC	European Committee for Electrotechnical Standardization
CRM	Critical raw material
ECD	Environmental conscious design. See [8].
ErP	Energy-related product
ETSI	European Telecommunications Standards Institute
IEC	International Electrotechnical Commission: International Standards and Conformity Assessment for all electrical, electronic and related technologies
ISO	International Organization for Standardization
LLCC	Least Life Cycle Cost
MEErP	Methodology for Ecodesign of Energy-related Products
PDS	Power drive system
VSD	Variable speed drive

About the authors

Thierry Cormenier graduated from the Conservatoire National des Arts et Métiers in 1992 with a degree in engineering in Automation. As a senior expert since 2009, he joined Schneider Electric in 2010. Previously he was in R&D at IBM and in engineering in ANSALDO now NIDEC ASI, then he held several management positions in the engineering department of the Medium Voltage Equipment in GEC ALSTHOM, ALSTOM and AREVA. From 2001 to 2014, he was an IEC member of TC17/SC17C/MT29 in relation with his function of R&D director for HV/LV prefabricated substations. He is convener of the TC17C/SC17C/ MT19 dealing with the classification of HV switchgear used in special conditions. He is a member of several organizations of standardization and professional associations such as IEC (TC17, TC99, TC111), CENELEC, CEN CENELEC JTC10, T&D Europe, and Gimelec, publishing numerous articles throughout his career. Currently, as expert, Thierry is supporting customers, R&D on MV activities, and is working on standardization, focusing on environmentally conscious design, material efficiency, circular economy, system life cycle management and product durability, when digital technologies benefit environmental footprint reduction for power systems.

Martial Patra graduated as an engineer in electronics and microwaves from the university Pierre & Marie Curie of Paris. He has been a Schneider Electric senior expert since 2008. He is now responsible for standardization activities in safety, environmental and power electronics' purpose of the overall industrial Automation business. At a European standardization level, he is currently Chairman of the CEN-CENELEC Ecodesign Coordination Group (CEN-CLC Eco-CG), serving as a focal point concerning standardization issues relating to energy-related products covered by the Ecodesign Directive. In this position, he takes part in horizontal standardization work of CEN-CLC JTC 10 for preparing Material Efficiency standard EN 4555x series. Since 2008 he has also been Secretary of the CENELEC TC 22X Committee for Power Electronics in Europe, and at international standardization level, after 9 years spent in the office as Chairman, he is currently Vice Chairman of IEC/SC 22G Committee for Adjustable speed electric drive systems incorporating semiconductor power converters, managing this Committee worldwide. He is also IEC/TC 22 or SC 22G Liaison Officer with other Committees (TC 31 & 65) and member of EU professional "Cemep" (Task force for Circular Economy).