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Recommendation

ITU-T L.1023 (08/2023)

SERIES L: Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

E-waste and circular economy

Assessment method for circularity performance scoring

ITU-T L-SERIES RECOMMENDATIONS

Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

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Recommendation ITU-T L.1023

Assessment method for circularity performance scoring

Summary

Recommendation ITU-T L.1023 outlines an assessment method for circularity scoring of information and communication technology (ICT) goods.

The assessment method consists of three steps:

1) Setting the relevance and applicability (R) of each circularity indicator for the ICT goods at hand.
2) Assessing the margin of improvement (MI) of each circularity indicator.
3) Calculating the circularity score (score) from 0 to 100% for the ICT good at hand for all three circularity aspects. This includes:
   – Using a predefined value matrix to identify the % score from 0 to 100 for each combination of R×MI.
   – Calculating the average of the included circularity indicators for the ICT good at hand separately for all three circularity aspects: product durability, ability to recycle, repair, reuse, and ability to upgrade from equipment and manufacturer level.

History*

Edition	Recommendation	Approval	Study Group	Unique ID
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Keywords

Circularity aspect, circularity indicator, circularity score, ICT goods, product durability, recycling, repair, reuse, upgrade.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Assessment method for circularity performance scoring

1 Scope

Realization of the circular economy requires incorporating elements in product design that support the reduction of material use, reuse, recycling and recovery of products, product parts, components and materials to circulate them in the value chain for as long as possible. This Recommendation contains a three-step methodology to identify an information and communication technology (ICT) good's circularity in three dimensions via three circularity aspects: first, the ICT good durability; second, the ICT good ability to be recycled, repaired, reused and upgraded; and third, the manufacturers ability to recycle, repair, reuse and upgrade the ICT good put into the market. The three aspects are then divided into indicators for circular product design. The circularity indicators are then assessed at four levels, both from how well circularity has been achieved, the margin of improvement, and the relevance and applicability of each indicator for the ICT good at hand. The margin of improvement (MI) score and relevance score are then combined and translated into a score for each indicator. The average of applicable indicators for each circularity aspect are calculated as the total circularity score for each circularity aspect.

This Recommendation is intended for the circularity assessment of a single product (like phones, computers, servers, chassis, boards, modules, etc.) at a time. Whereas circularity assessment of whole equipment systems – and of organizations' overall circularity performance based on e.g., shipped products per year – are out of scope of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T L.1015] Recommendation ITU-T L.1015 (2019), *Criteria for evaluation of the environmental impact of mobile phones.* https://www.itu.int/rec/T-REC-L.1015-201905-I

[ITU-T L.1020] Recommendation ITU-T L.1020 (2018), *Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks*. https://www.itu.int/rec/T-REC-L.1020-201801-I

[ITU-T L.1021] Recommendation ITU-T L.1021 (2018), *Extended producer responsibility – Guidelines for sustainable e-waste management*. https://www.itu.int/rec/T-REC-L.1021-201804-P

[ITU-T L.1022] Recommendation ITU-T L.1022 (2019), *Circular economy: Definitions and concepts for material efficiency for information and communication technology*. https://www.itu.int/rec/T-REC-L.1022-201910-I

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 ICT goods [b-ITU-T L.1410]: Tangible goods deriving from or making use of technologies devoted to or concerned with:

– the acquisition, storage, manipulation (including transformation), management, movement, control, display, switching, interchange, transmission or reception of a diversity of data;

– the development and use of the hardware, software, and procedures associated with this delivery; and

– the representation, transfer, interpretation, and processing of data among persons, places, and machines, noting that the meaning assigned to the data is preserved during these operations.

NOTE – [b-ETSI TS 103 199] used the word "equipment" instead.

3.1.2 component [b-ETSI TR 103 679]: Part of a product that cannot be taken apart without destruction or impairment of its intended use.

3.1.3 product part [b-ETSI TR 103 679]: Sub-unit of a product.

NOTE – HDD is an example of a product part within a computer.

3.1.4 upgrade [b-EN 45554]: Process of enhancing the functionality, performance, capacity or aesthetics of a product.

3.1.5 reliability [b-EN 45552]: Probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event.

3.1.6 material [b-ETSI TR 103 679]: Substance or mixture of substances within a product or product part.

3.1.7 substance [b-ETSI TR 103 679]: Chemical element and its compounds in the natural state or obtained by any production process, including any additive necessary to preserve the stability of the product and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the declarable substance or changing its composition.

3.1.8 product [b-ETSI TR 103 679]: Good or service.

3.1.9 primary packaging [b-Directive 94/62/EC]: Primary packaging or sales packaging is the packaging conceived so as to constitute a sales unit to the final user or consumer at the point of purchase.

NOTE 1 – Primary packaging excludes *grouped packaging or secondary packaging* (i.e., packaging used outside of primary packaging to group multiple product units, to replenish the shelves at the point of sales and to protect the primary packaging) and *transport packaging or tertiary packaging* (i.e., packaging conceived so as to facilitate handling and transport of a number of sales units or grouped packagings in order to prevent physical handling and transport damage).

NOTE 2 – Adopted from *Article 3* of [b-Directive 94/62/EC].

3.1.10 circular economy [ITU-T L.1020]: A circular economy is restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times while reducing waste streams. A concept that distinguishes between technical and biological cycles, the circular economy is a continuous, positive development cycle. It preserves and enhances natural capital, optimises resource yields, and minimises system risks by managing finite stocks and renewable flows, while reducing waste streams.

NOTE – The definition is based on [b-EMF], and amended.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 expected durability: The time a customer (the user of the ICT good) can expect the product to last.

3.2.2 expected average durability: The time a customer (the user of the ICT good) can expect the product to last including warranty returns and other early failures.

NOTE – Expected average durability is lower than expected durability.

3.2.3 priority part: A part having a high likelihood of needing repair, replacement or upgrading.

3.2.4 circularity: Degree of alignment with the principles for a circular economy.

3.2.5 circularity assessment: Evaluation and interpretation of results and impacts from a circularity measurement.

3.2.6 circularity measurement: Process to help determine the circularity performance through collection, calculation or compilation of data or information.

3.2.7 circularity performance: Degree to which a set of circularity aspects align with the principles for a circular economy.

NOTE – The Circularity Scores between 0 and 100 obtained by the framework outlined in this Recommendation are examples of circular performance.

3.2.8 circularity indicator: Metric used to measure one or more circularity aspects.

NOTE – The PD_n, $3RUe_n$ and $3RUm_n$ outlined in this Recommendation (e.g., PD1) are examples of circularity indicators.

3.2.9 circularity aspect: Element of an organization's activities or solutions that interacts with the circular economy.

NOTE – The PD, 3RUe and 3RUm outlined in this Recommendation are examples of circularity aspects.

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

NOTE 1 – New and/or used parts can be used during refurbishment.

NOTE 2 – The definition is based on [b-EN 303 808] and amended.

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

NOTE 1 – The product created by the remanufacturing process may be considered a new product when placing on the market.

NOTE 2 – The definition is based on [b-EN 303 808] and amended.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3Rue Ability to Recycle, Repair, Reuse, and Upgrade, Equipment level

3Rum Ability to Recycle, Repair, Reuse, and Upgrade, Manufacturer level

CE Circular Economy

CRM Critical Raw Material

CS Circularity Score

DfD Design for Disassembly

DfR	Design for Recycling
DfRe	Design for Remanufacturing
DfX	Design for X
EAD	Expected Average Durability
ED	Expected Durability
EEE	Electrical and Electronic Equipment
HDD	Hard Disc Drive
ICT	Information and Communication Technology
LCA	Life Cycle Assessment
MI	Margin of Improvement
MR	Material Recycling
PD	Product Durability
R	Relevance
RFP	Request for Procurement
sEEE	Small Household Electrical and Electronic Equipment

5 Conventions

Colours are used in the appendices of this Recommendation to graphically indicate circularity scores ranging from very good to very bad.

6 Background

The principles of circular economy (CE) emphasize optimizing resource yields at all stages of a product's lifecycle [b-ITU-T L.Sup.28], [ITU-T L.1015], [ITU-T L.1021], [ITU-T L.1022].

CE ultimately aims to make products without causing or incentivizing additional extraction of Earth's resources. This means using recycled and renewable material, prioritizing efficient use of materials and recovery of wastes, designing products to be durable to maximize their useful life and finally, where necessary, contributing materials back to the market for making new products.

This requires incorporating elements in product design that support the reduction of material use, reuse, recycling, and recovery of products, product parts, components and materials to circulate them in the value chain for as long as possible. To achieve this objective, circularity indicators that aim to reduce, reuse, recycle and recover should be considered, and integrated from the early stages of product design.

To date, in ITU-T the standardization of implementation of CE principles has largely focused on waste management models, such as integrating extended producer responsibilities [ITU-T L.1021] into business practices, rather than evaluating indicators to incorporate circular elements into product design. Multiple design for X (DfX) approaches exist including design for disassembly (DfD), design for recycling (DfR), and design for remanufacturing (DfRe).

The present methodology incorporates some selected parameters of the CENELEC series of product material efficiency standards [b-CENELEC].

However, material efficiency is complicated to quantify since it depends on multiple indicators, such as recycled content, recycling compatibility, software, data, maintenance and spare parts, product durability, and in general all the aspects of ability to repair, reuse, and upgrade. These indicators and the guidance for their assessment are presented in Table 4. Hence, in the application of the complete methodology outlined in this document, various important aspects of material efficiency will be considered and incorporated into the circularity scoring.

Moreover, the present methodology differs from the product circularity indicator [b-PCI].

However, the methodology outlined in this Recommendation is not to be confused with methods which aim to measure circularity from a materials flow and organizational perspectives, such as those under development by the Ellen MacArthur Foundation [b-EMF] or the World Business Council for Sustainable Business [b-WBCSD]. The reason is that the methodology presented in this Recommendation is semi-quantitative and does not use absolute material flows (from e.g., LCA) for calculating the final score.

While not all indicators described in this Recommendation might neither work for all ICT good categories nor specific ICT goods, they are applicable to improve ICT good circularity if they are applied at the early stage of product design. For example, the circularity performance scores obtained with this Recommendation for different concepts may be compared (along with other eco-metrics) in the concept stage in the product development process [b-Andrae2016].

Therefore, this Recommendation is intended to be a guideline and methodology for designers of ICT goods to align product design to the most relevant indicators. This use of this Recommendation can result in increased circularity of ICT goods in self-improvement. Hence, this Recommendation is intended to assess and improve the circularity of ICT goods at hand and the results are not intended to be used in comparative assessment of separate products.

7 The methodology

The methodology contains a three-step approach to support product designers in determining the most relevant indicators to be incorporated in their product design. Bovea and Pérez-Belis [b-Bovea] proposed which existing DfX guidelines are most relevant in product design from a circular economy perspective for small household electrical and electronic equipment (sEEE). [b-AndraeVaija] proposed a new method based for ICT goods inspired by [b-Bovea]. These DfX guidelines proposed by [b-Bovea] and used for ICT goods by [b-AndraeVaija], are then reorganized and adopted further to the specificities of ICT goods based on CE principles as shown in Table 1, adapted from Table I in [b-AndraeVaija]. Additional indicators have been added and several have been removed compared to the original lists [b-Bovea], [b-AndraeVaija] in order to align with metrics included in the CENELEC product material efficiency standards [b-CENELEC] and EPEAT [b-EPEAT] and to reflect the variety of products in the ICT industry.

Noticeably, the far-left column of Table 1 – Circularity Aspects – contains a list of circular principles that put all the indicators into different aspects. The description of each aspect is as follows:

1) Product durability (PD): It includes indicators related to promoting the life span and durability of products by adapting their design and studying the possibility of upgrading software to a new version and service support by ensuring the product can be used for as long as possible by the first user or subsequent users.

2) Ability to recycle, repair, reuse, upgrade (3RUe) – equipment level: It includes indicators related to the product's structure and access to its priority parts for repair, connecting systems to facilitate disassembly and reassembly, spare parts, diagnostic and information availability. It relates to:

   – Possibilities to refurbish the ICT good;

   – Possibilities to reuse product parts and components within the ICT good (after first use) in refurbishment of similar or other ICT goods;

– Facilitate the identification, separation and recycling of materials. Addresses separate collection of products for better recycling and development of designated recycling technologies.

3) Ability to recycle, repair, reuse, upgrade (3Rum) – manufacturer level:

It includes indicators related to the manufacturer ability (on company level) to facilitate recycling, repair, reuse and upgrade. These requirements are not directly connected to the equipment, but to the infrastructure and support to be developed or supported by the manufacturer. It relates to:

– Availability of service support in terms of information, infrastructure and spare parts.

In summary, each group contains a set of indicators that directly address the group's topic. Each indicator is also assigned to a code with the group's initials followed by a numerical number.

The proposed method is in principle unlimited regarding the number of groups and indicators. For example, new indicators for scratch resistance for example for metals, glass, etc. can be added and margin of improvement (MI*)* levels defined. Also new groups can be added accordingly. Appendix III contains an example of a potential new indicator for 3Rue.

Table 1 – Circularity aspects and circularity indicators for circular product design of relevance for circular ICT

Circularity aspect	Code	Circularity indicator
Product durability	PD1	Software and data support
	PD2	Scratch resistance
	PD3	Maintenance support
	PD4	Robustness
	PD5	Battery for portable ICT goods
	PD6	Data security
Ability to recycle, repair, reuse, upgrade – equipment level	3Rue1	Fasteners and connectors
	3Rue2	Diagnostic support
	3Rue3	Material recycling compatibility - Plastic parts
	3Rue4	Material recycling compatibility - Metal parts
	3Rue5	Recycled/renewable plastics
	3Rue6	Recycled metals
	3Rue7	Material identification
	3Rue8	Hazardous substances
	3Rue9	Critical raw materials
	3Rue10	Packaging recycling
	3Rue11	Technical performance product mass-based material efficiency
Ability to recycle, repair, reuse, upgrade – manufacturer level	3Rum1	Service offered by manufacturer
	3Rum2	Spare parts distribution
	3Rum3	Spare parts availability
	3Rum4	Disassembly information

Table 1 – Circularity aspects and circularity indicators for circular product design of relevance for circular ICT

Circularity aspect	Code	Circularity indicator
	3Rum5	Collection and recycling programmes
	3Rum6	Environmental footprint assessment knowledge available to improve the equipment material efficiency

The proposed methodology involves three main steps that shall be followed:

1) The first step is to estimate the relevance (R) of each indicator to the ICT good at hand based on relevance characteristics such as customer relevance or life cycle assessment (LCA) calculation.

2) The second step involves determining the margin of improvement (MI) of each indicator based on the degree to which the indicator is met. (See Table 4 for guidance on how to determine MI for each indicator) for the ICT good category.

NOTE – The order of steps 1 and 2 is somewhat flexible. The determination of MI can be done separately from R. For example, the customers (e.g., telco operators) can determine the R from their perspective and the manufacturers (of the original ICT equipment) determine the MI and R from their perspective.

3) The third step involves determining the circularly score (score) for each aspect of the product at hand.

Through the third step it will be possible to determine the indicators most critical for each aspect improving the ICT good circularity.

The following clauses give a detailed description of each step. Appendix I reports example applications of the assessment methodology.

7.1 Step 1 – Estimate the relevance (R) of each circularity indicator to the product at hand

The level of relevance of each circularity indicator might appear somewhat ambiguous as there are many bases which can be used to determine relevance. However, if the basis is clearly set, defining R is not difficult.

R evaluates the degree of relevance of each indicator for a product category according to its function, life span, durability, performance, etc. R is defined based on four grades (see Table 2) and the option to set R to 0 when an indicator is not applicable to the product under investigation. The R of an indicator is considered *HIGH* when the significance (i.e., to the customer, to the cost, to the environment, the LCA score, etc.) of scoring well for the MI for that indicator is essential when taking into account the tasks, life span, durability, performance and other features that characterize the product category to which the product belongs. Conversely, the R of the indicator is considered *LOW*. *Very HIGH* and *Very LOW* are the highest and lowest R grades, respectively.

In summary, R for each indicator given in Table 1 can be identified in a number of ways. One way is to assess R based on customer preferences (See examples in Appendix I.).

Table 2 – Description of levels of relevance (R) of circularity indicators

Code	Grade of R	***Description*** when taking into account the functions, life span, durability, performance, etc. of the product category.
R4	Very HIGH {4}	The positive effect (for customer, environment etc.) of the indicator at hand will be *VERY HIGH*. NOTE – For example, gateways could have R=4 for 3Rue1 as easily removable and reusable fasteners enable a cost-effective refurbishing business model giving positive economic and green benefits.
R3	HIGH {3}	The positive effect (for customer, environment, etc.) of incorporating the indicator at hand will be *HIGH*.
R2	LOW {2}	The positive effect (for customer, environment, etc.) of incorporating the indicator at hand will be *LOW*. NOTE – For example, gateways could have R=2 for 3Rum4 as disassembly information is not essential for end user.
R1	Very LOW {1}	The positive effect (for customer, environment, etc.) of incorporating for the indicator at hand will be *Very LOW*. NOTE – For example, keyboards could have R=1 for PD6 as these devices usually do not store data that is considered to be private and needs secure data deletion.
R0	Not applicable {0}	The indicator is not applicable to the product at hand. NOTE – A zero rating will result in the category not being included. This can be useful when the category cannot be applied, e.g., PD5 (Battery for portable goods) is not applicable to stationary products or products without batteries. There may be indicators which are applicable to the product at hand which are inappropriate for evaluation due to technical reasons. For such cases the rationale for choosing R0 shall be clearly motivated.

R will be closely linked to the type of ICT good and the business model.

7.2 Step 2 – Evaluation of the margin of improvement (MI) for a product design

This step is to evaluate the margin of improvement (MI) of a specific circular indicator found in Table 1 for a product design.

MI evaluates the level of compliance of the circular indicators. It assesses to what extent a product design has incorporated circular design into the product in terms of a specific circularity indicator of a circularity aspect. It is expressed as the margin of improvement; how close it is to the best-known practice.

MI is defined based on four grades (Table 3). If the criterion for an MI-level for a certain circular indicator is not met, the MI of that product design will be *very High*, and grade 4 will be assigned. Conversely, if a product design fully meets the criterion for an MI-level for a certain circular indicator, the MI will be *very Low*, and grade 1 will be assigned. The lower the MI, the higher possibility of a better score.

Table 3 – Description of MI levels for each circular indicator

Code	Grade of MI	Description
MI4	Very HIGH {4}	The criterion for the MI-level for the circular indicator is not met in the product design. The MI of that aspect will be Very HIGH.
MI3	HIGH {3}	The criterion for the MI-level for the circular indicator is slightly met in the product design. The MI of that aspect will be HIGH.
MI2	LOW {2}	The criterion for the MI-level for the circular indicator is fairly met in the product design. The MI of that aspect will be LOW.
MI1	Very LOW {1}	The criterion for the MI-level for the circular indicator is fully met in the product design. The MI of that aspect will be VERY LOW.

Table 4 gives hints on how to define the criteria for MI levels for the indicator of any ICT good. Each criteria for each MI level shall refer to entities which are verifiable and/or measurable.

Table 4 – Guidance for identification of MI level for each circular indicator

Circularity aspects	Circularity indicator	Hints to defining the criteria for MI levels for the indicator of any ICT good	Scoring level (1-4)
Product durability	PD1: Software and data support	Availability of software and firmware updates & upgrades.	MI = 1 – Software and firmware updates and upgrades availability can be categorized as long-term (class A, i.e., for a duration of time that reflects the expected maximum useful life of the product, cf. [b-EN 45554]). Criterion for fulfilling MI = 1.
			MI = 2 – Software and firmware updates and upgrades availability can be categorized as mid-term (class B, i.e., for a duration of time that reflects the expected average useful life of the product, cf. [b-EN 45554]).
			MI = 3 – Software and firmware updates and upgrades availability can be categorized as short-term availability (class C, i.e., available during a period of two years after the time of sale of the product, cf. [b-EN 45554]).
			MI = 4 – No information on duration of availability (class D, cf. [b-EN 45554]) is provided on software and firmware updates and upgrades availability.
	PD2: Scratch resistance	Resistance of housing parts subject to be scratched.	MI = 1 – Plastic scratch resistance equal or greater than 2H regarding [b-ASTM D3363 – 05].
			MI = 2 – Plastic scratch resistance equal or greater than H regarding [b-ASTM D3363 – 05].
			MI = 3 – Plastic scratch resistance equal or greater than HB regarding [b-ASTM D3363 – 05].
			MI = 4 – Plastic scratch resistance lower or equal to B regarding [b-ASTM D3363 – 05].
	PD3: Maintenance support	Availability of consumables, wear-out parts expected to be replaced periodically. Availability of maintenance infrastructure.	MI = 1 – Consumables and wear-out parts expected to be replaced periodically can be categorized as publicly available (class A in [b-EN 45554]) or as available to independent maintenance service providers (class B in [b-EN 45554]).
			MI = 2 – Consumables and wear-out parts expected to be replaced periodically can be categorized as available to manufacturer-authorized maintenance service providers (class C in [b-EN 45554]).
			MI = 3 – Consumables and wear-out parts expected to be replaced periodically can be categorized as available to the manufacturer only (class D in [b-EN 45554]).
			MI = 4 – Consumables and wear-out parts expected to be replaced periodically can be categorized as not available (class E in [b-EN 45554]).

Table 4 – Guidance for identification of MI level for each circular indicator

Circularity aspects	Circularity indicator	Hints to defining the criteria for MI levels for the indicator of any ICT good	Scoring level (1-4)
			No maintenance infrastructure are offered by manufacturer.
	PD4: Robustness	**Examples of standards which can be considered** (to be assessed depending on the type of equipment and the environment in which the product is intended to be used). ETSI EN 300 019-x-y series; for environmental requirements (temperature, humidity, rain, mechanical, etc.). IEC 60721-3-X series for environmental requirements (temperature, humidity, rain, mechanical, etc. requirements). [b-ETSI ES 201 468] or ITU-T K.20/21/44/45 for robustness to electromagnetic voltage transients [b-IEC 61960-3] Electrical test acceptance criteria. Battery protection software.	MI = 1 – The product's design features have better characteristics than the minimum requirements for the environmental class in which the product is intended to be used and comply to the enhanced requirements (Example: a product intended to be used in non-weather protected location and satisfies the requirements of class 4.1E (extended severity level) of [b-EN 300 019-1-4] instead of class 4.1 (minimum severity level) and complies to the enhanced requirements of ITU-T K.20/21/45).
			MI = 2 – The product's design features characteristics comply to the minimum requirements for the environmental class in which the product is intended to be used. (Example: a product intended to be used in non-weather protected location and satisfies the requirements of class 4.1 of [b-EN 300 019-1-4] and complies to the basic requirements of ITU-T K.20/21/45).
			MI = 3 – The product's design features characteristics comply to most of the minimum requirements for the environmental class in which the product is intended to be used. (Example: a product intended to be used in non-weather protected location and satisfies the requirements of class 4.1 of [b-EN 300 019-1-4] but does not comply to the basic resistibility requirements of ITU-T K.20/21/45).
			MI = 4 – The product's design features characteristics do not comply to several of the minimum requirements for the environmental class in which the product is intended to be used. (Example: a product intended to be used in non-weather protected location and does not satisfy to the chemical active substances (corrosion) requirements of any class of [b-EN 300 019-1-4] and does not comply to the basic resistibility requirements of ITU-T K.20/21/45).
	PD5: Battery for portable ICT goods	Battery longevity for portable ICT goods. [b-IEC 62620] may be applicable to measure capacity.	MI = 1 for Li: Battery pack is chargeable to > 80% of its original design capacity after 300 cycles.
			MI = 2 for Li: Battery pack is chargeable to > 70% of its original design capacity after 300 cycles.
			MI = 3 for Li: Battery pack is chargeable to > 60% of its original design capacity after 300 cycles.
			MI = 4 for Li: Battery pack is chargeable to < 60% of its original design capacity after 300 cycles.
	PD6: Data security	Data management:	MI = 1 – Personal data can be erased, and password can be reset by user. Features are built-in and easily accessible.

Table 4 – Guidance for identification of MI level for each circular indicator

Circularity aspects	Circularity indicator	Hints to defining the criteria for MI levels for the indicator of any ICT good	Scoring level (1-4)
		Personal data to be deleted without compromising the functionality of the device. NOTE – The classification can be undertaken in alignment with [b-EN 45554].	MI = 2 – Personal data can be erased, or password can be reset with external software, freely available solutions.
			MI = 3 – Erasure of personal data and password reset is possible on request using services of the manufacturer.
			MI = 4 – Neither the personal data nor password can be manipulated by the user.
Ability to Recycle, Repair, Reuse, upgrade – equipment level	3Rue1: Fasteners and connectors	Fasteners, connectors and tools used to disassemble parts that are likely to need replacement during the expected lifetime of the product are reusable/removable per [b-EN 45554]. NOTE – Circularity assessment of whole equipment systems are out of scope of this Recommendation. It addresses single products like chassis, boards, modules, phones, computers, servers, etc.	MI = 1 – Fasteners and connectors can be categorized as reusable (class A, i.e., an original fastening system that can be completely re-used, or any elements of the fastening system that cannot be re-used are supplied with the new part for a repair, re-use or upgrade process, cf. [b-EN 45554]) and using no tools, basic tools or product specific tools (classes A-C as defined in [b-EN 45554]).
			MI = 2 – Fasteners and connectors can be categorized as removable (class B, i.e., an original fastening system that is not reusable, but can be removed without causing damage or leaving residue which precludes reassembly (in case of repair or upgrade) or re-use of the removed part (in case of re-use) for a repair, re-use or upgrade process, cf. [b-EN 45554]) and using no tools, basic tools or product specific tools (classes A-C as defined in [b-EN 45554]).
			MI = 3 – Fasteners and connectors can be categorized as removable or reusable using proprietary tools.
			MI = 4 – Fasteners and connectors can be categorized as neither removable nor reusable (class C, i.e., an original fastening system which is neither removable nor reusable, as defined as in MI = 1 and MI = 2, for a repair, re-use or upgrade process, cf. [b-EN 45554]).
	3Rue2: Diagnostic support	Diagnostic support classification by necessary interface.	MI = 1 – Interface can be categorized as an intuitive interface (Class A) – cf. [b-EN 45554].
			MI = 2 – Interface can be categorized as a coded interface with public reference table (Class B) or as a publicly available hardware / software interface (Class C) – cf. [b-EN 45554].
			MI = 3 – Interface can be categorized as a proprietary interface (Class D) – cf. [b-EN 45554].
			MI = 4 – Diagnostic is not possible with any type of interface (Class E) – cf. [b-EN 45554].

Table 4 – Guidance for identification of MI level for each circular indicator

Circularity aspects	Circularity indicator	Hints to defining the criteria for MI levels for the indicator of any ICT good	Scoring level (1-4)
	3Rue3: Material recycling compatibility – Plastic parts	Materials compatibility for joint recycling. NOTE – Refers to plastics used in the ICT good itself.	MI = 1 – All of the following requirements shall be fulfilled; 1) Plastic parts > 25 g do not contain metal inlets or fasteners that are moulded, heat or ultrasonically inserted or glued-in and cannot be separated by breaking off from the plastic part or with commonly available tools. 2) Plastic parts > 100 g do not have an adhesive, coating, paint or finish that is not compatible with recycled. NOTE – Plastic parts with > 25% post-consumer recycled content and printed-circuit boards are exempt. Requirement does not apply to parts where such measures are required for safety, legal or technical requirements. 3) Plastic parts > 25 g are comprised of a single resin or combination of resins compatible for recycling and are separable by hand or with commonly available tools from other plastic parts > 25 g and not compatible for joint recycling. NOTE – Printed circuit boards, wires and cables, connectors, electronic, optical, acoustic, sealings, ESD and EMI components are excluded.
			MI = 2 – Two of the requirements specified for MI = 1 are fulfilled.
			MI = 3 – One of the requirements specified for MI = 1 is fulfilled.
			MI = 4 – None of the requirements specified for MI = 1 is fulfilled.
	3Rue4: Material recycling compatibility – Metals parts	Materials compatibility for joint recycling. NOTE – Refers to metals used in the ICT good itself.	MI = 1 – All of the following requirements shall be fulfilled. 1) In metal parts with weight > 25 g, metals are kept separable for easy recycling, particularly the materials intended for different end-of-life treatment. 2) Data on used alloys is available. 3) Metal parts with weight > 25 g do not have such adhesive, coating, paint, or finish that is not compatible with recycling.
			MI = 2 – Two of the requirements specified for MI = 1 are fulfilled.
			MI = 3 – One of the requirements specified for MI = 1 is fulfilled.
			MI = 4 – None of the requirements specified for MI = 1 is fulfilled.
	3Rue5: Recycled/renewable plastics	Use of recycled plastics. NOTE – Refers to plastics used in the ICT good itself.	MI = 1 – Total content of recycled and biobased plastics 75-100%.
			MI = 2 – Total content of recycled and biobased plastics 50-75%.
			MI = 3 – Total content of recycled and biobased plastics 25-50%.
			MI = 4 – Total content of recycled and biobased plastics 0-25%.
	3Rue6: Recycled metals	Use of recycled metals. NOTE – Refers to metals used in the ICT good itself excluding printed circuit boards, wires and cables, connectors, electronic, optical, acoustic, sealings, ESD and EMI components.	MI = 1 – Combined total recycled metals content in at least two predominant metals by mass is 75-100%. NOTE – Predominant metal means that this metal is used in biggest amount (by mass) in the product. When analyzing recycled metal content for these predominant metals in a product, the reference point shall be the mass of these same metals.
			MI = 2 – Combined total recycled metals content in at least two predominant metals by mass is 50-75%.
			MI = 3 – Combined total recycled metals content in at least two predominant metals by mass is 25-50%.
			MI = 4 – Combined total recycled metals content in at least two predominant metals by mass is 0-25%.

Table 4 – Guidance for identification of MI level for each circular indicator

Circularity aspects	Circularity indicator	Hints to defining the criteria for MI levels for the indicator of any ICT good	Scoring level (1-4)
	3Rue7: Material identification	Materials identification according to ISO 11469.	MI = 1 – Markings to identify base materials as per [b-ISO 11469], [b-ISO 1043-1] (plastics), [b-ISO 1629] (rubbers) [b-ISO 18064] (thermoplastic elastomers), as well as fillers and reinforcing materials (ISO 1043-2), plasticizers (ISO 1043-3) and flame retardants (ISO 1043-4)
			MI = 2 – Markings to identify base materials as per [b-ISO 11469], [b-ISO 1043-1] (plastics), [b-ISO 1629] (rubbers) and [b-ISO 18064] (thermoplastic elastomers)
			MI = 3 – Markings to identify plastics as per [b-ISO 11469] and [b-ISO 1043-1].
			MI = 4 – No markings to identify materials on any part.
	3Rue8: Hazardous substances	Reduction of bromine and chlorine. NOTE – This circular indicator is not applicable to ICT infrastructure equipment.	MI = 1 – Each plastic part in the product exceeding 0.5 g shall not contain greater than 1 000 ppm chlorine or greater than 1 000 ppm bromine at the homogeneous level [b-IEEE 1680.1]. Test methods such as IEC 62321-3-1 and 62321-3-2 are recommended. [b-IEEE 1680.1]. NOTE – Parts which exceed 25% post-consumer recycled content may contain a maximum of 5 000 ppm chlorine and a maximum of 5 000 ppm bromine [b-IEEE 1680.1]. Power cords – in jurisdictions where PVC-free power cords have not been approved by safety agencies for use in the product – are exempted. [b-IEEE 1680.1].
			MI = 2 – Each plastic part in the product exceeding 25 g shall not contain greater than 1 000 ppm chlorine or greater than 1 000 ppm bromine at the homogeneous level. [b-IEEE 1680.1]. NOTE – Parts which exceed 25% post-consumer recycled content may contain a maximum of 5 000 ppm chlorine and a maximum of 5 000 ppm bromine. [b-IEEE 1680.1]. Printed circuit boards, cables and wiring, fans and electronic components are excluded. [b-IEEE 1680.1].
			MI = 3 – Parts exceed the concentrations of 1 000 ppm chlorine or 1 000 ppm bromine, but the manufacturer has carried out a hazard assessment and no viable alternative substances have been identified. [b-IEEE 1680.1]. NOTE – Notes as for MI = 1 and MI = 2 apply here as well.
			MI = 4 – The bromine and chlorine based substances content is unknown.
	3Rue9: Critical Raw Materials	Declaration of Critical Raw Materials Content. NOTE – CRMs are different for each region. Examples of defined CRM include L.1100 and the list of CRM for the EU [b-EU-CRM]. Each product has to choose the appropriate CRM list.	MI = 1 – Based on the CRM content assessment, the location of the CRM in the ICT good is available to improve recyclability.
			MI = 2 – An assessment according to EN 45558 has been carried out on all of the CRMs present in the product.
			MI = 3 – Indicative weight range assessment of at least two CRMs present in the product. NOTE – Example for servers in Table I.2-1.
			MI = 4 – The CRM content is unknown.

Table 4 – Guidance for identification of MI level for each circular indicator

Circularity aspects	Circularity indicator	Hints to defining the criteria for MI levels for the indicator of any ICT good	Scoring level (1-4)
Ability to Recycle, Repair, Reuse, upgrade – manufacturer level	3Rue10: Packaging recycling	Material recycling aspects included in the primary packaging.	MI = 1 – All the aspects of material efficiency are considered for the primary packaging, by fulfilling all of the following five requirements: 1) Elimination of elemental chlorine as a bleaching agent used to bleach virgin or recovered fibres subsequently used in product packaging. 2) Elimination of the use of expanded polystyrene in product packaging. 3) Packaging is designed in a way that it allows reuse, recycling or recovery. 4) Sum of the concentrations of intentionally added lead, cadmium, mercury and hexavalent chromium present in primary packaging shall not exceed 100 ppm by mass. 5) Minimum used 30% recycled content by mass of plastic and fibre-based materials.
			MI = 2 – Three or four of the requirements for MI = 1 for packaging material efficiency are fulfilled.
			MI = 3 – One or two of the requirements for MI = 1 for packaging material recycling are fulfilled.
			MI = 4 – None of the requirements for MI = 1 for packaging material recycling are fulfilled.
	3Rue11: Technical performance product mass based materials efficiency.	Technical performance per product mass. NOTE – The background of the indicator is that material efficiency could be defined as the ratio between the performance of a system and the input of materials required [b-Cordella].	MI = 1 – Technical performance per product mass used improved > 15% in between product at hand and previous corresponding product model.
			MI = 2 – Technical performance per product mass improved > 10% in between product at hand and previous corresponding product model.
			MI = 3 – Technical performance per product mass improved > 5% in between product at hand and previous corresponding product model.
			MI = 4 – Technical performance per product mass not improved in between product at hand and previous corresponding product model.
	3Rum1: Service offered by manufacturer	Duration of Repair, Reuse, upgrade services	MI = 1 – RRU service availability can be categorized as long-term (class A, i.e., a repair, re-use or upgrade service, which the manufacturer offers for a duration of time that reflects the expected durability of the product, cf. [b-EN 45554]). NOTE – Expected durability is the time a customer (the user of the ICT good) can expect the product to last.
			MI = 2 – RRU service availability can be categorized as mid-term (class B, i.e., a repair, re-use or upgrade service, which the manufacturer offers for a duration of time that reflects the expected average durability of the product, cf. [b-EN 45554]). NOTE – Expected average durability includes warranty returns and other early failures and is therefore lower than expected durability.
			MI = 3 – RRU service availability can be categorized as short-term (class C, i.e., a repair, re-use or upgrade service, which the manufacturer offers for two years after the time of sale of the product, cf. [b-EN 45554]).
			MI = 4 – No RRU service availability is offered.
	3Rum2: Spare parts	Availability of spare parts to	MI = 1 – Spare parts are publicly available or available to independent repair service providers (Class A and Class B, as defined in [b-EN 45554]).

Table 4 – Guidance for identification of MI level for each circular indicator

Circularity aspects	Circularity indicator	Hints to defining the criteria for MI levels for the indicator of any ICT good	Scoring level (1-4)
	distribution	different categories of persons/ organisations	MI = 2 – Spare parts are available to manufacturer-authorized repair service providers or available to the manufacturer only (Class C and Class D, as defined in [b-EN 45554]) in all the markets where the product is sold by the manufacturer.
			MI = 3 – Spare parts are available to manufacturer-authorized repair service providers or available to the manufacturer only (Class C and Class D, as defined in [b-EN 45554]) in limited markets where the product is sold by the manufacturer.
			MI = 4 – Spare parts are not available (Class E, as defined in [b-EN 45554]).
	3Rum3: Spare parts availability	Duration of spare parts availability	MI = 1 – Spare parts availability can be categorized as long-term (class A, i.e., a repair, re-use or upgrade process, for which the required spare part(s) is/are available for a duration of time that reflects the expected durability of the product category, cf. [b-EN 45554]).
			MI = 2 – Spare parts availability can be categorized as mid-term (class B, i.e., repair, re-use or upgrade process, for which the required spare part(s) is/are available for a duration of time that reflects the expected average durability of the product, cf. [b-EN 45554]). NOTE – Expected average durability (EAD) is lower than expected durability (ED) as EAD takes into account the failure rate and warrant returns while ED refers to the duration of the product (the time a customer (the user of the ICT good) can expect the product to last).
			MI = 3 – Spare parts availability can be categorized as short-term (class C, i.e., repair, re-use or upgrade process, for which the required spare part(s) is/are available during a period of two years after the time of sale of the product, cf. [b-EN 45554]).
			MI = 4 – No information on duration of availability is provided for spare parts (class D, i.e., repair, re-use or upgrade process, for which the required spare part(s) is/are available at the time of sale, but for which the duration of availability cannot be determined, cf. [b-EN 45554]).
	3Rum4: Disassembly information	Classification of information availability by comprehensi-veness	MI = 1 – Information is publicly available (class A, i.e., repair, re-use or upgrade process, for which the relevant information is available to all interested parties, cf. [b-EN 45554]).
			MI = 2 – Information is available to independent repair service providers (class B, i.e., repair, re-use or upgrade process for which the relevant information is available to any self-employed professional, as well as any legally established organization, providing repair services, cf. [b-EN 45554]).
			MI = 3 – Information is available to manufacturer-authorized repair service providers (class C, i.e., repair, re-use or upgrade process, for which the relevant information is available to service providers authorized by the product manufacturer to offer repair services, cf. [b-EN 45554]).
			MI = 4 – Information is available to the manufacturer only (class D, i.e., repair, re-use or upgrade process, for which the relevant information is available to the product manufacturer, cf. [b-EN 45554]).
	3Rum5: Collection and recycling programmes	Designated collection and recycling programs.	MI = 1 – A designated collection program for refurbish, remanufacturing, repair and a designated selective, recycling program for specific parts of ICT goods (e.g., specific recycling process able to recover Germanium from optical fibre, Tantalum from Tantalum capacitors or Indium from LCD/OLED displays, etc.) is available.

Table 4 – Guidance for identification of MI level for each circular indicator

Circularity aspects	**Circularity indicator**	**Hints to defining the criteria for MI levels for the indicator of any ICT good**	**Scoring level (1-4)**
			MI = 2 – A designated collection program for refurbish, remanufacturing, repair and a designated recycling program is available for specific ICT goods (e.g., IT and telecommunications equipment for European WEEE handled by smelters to recovers precious metals).
			MI = 3 – A designated collection or a designated recycling program is available.
			MI = 4 – Neither designated collection nor designated recycling program is available.
	3Rum6: Environmental footprint assessment knowledge	Knowledge on the equipment environmental footprint	MI = 1 – An [b-ISO 14040] / [b-ISO 14044] or [b-ITU-T L.1410] compliant life cycle assessment (LCA) has been carried out on the ICT good and the results are made available on demand.
			MI = 2 – A simplified environmental footprint assessment (e.g., screening LCA, environmental footprint assessment on one environmental indicator such as carbon footprint, etc.) has been carried out on the ICT good and the results are made available on demand.
			MI = 3 – An environmental footprint assessment on a similar type of ICT good has been studied and the results are made available on demand.
			MI = 4 – Neither an environmental footprint assessment have been done on the ICT good, nor an environmental footprint assessment on a similar type of equipment are made available on demand.

7.3 Step 3 – Calculating the circularity score (Score) of the product

To identify the circular indicators that are most important to be incorporated into a product design, it is necessary to calculate the circularity score (score).

The values assigned to and used to calculate the score of an ICT good, which allow designers to identify which of the circularity indicators of the main circularity aspects listed in Table 1 are most important to be incorporated, more so than others in their product design in order to improve its circularity.

Once the R and MI values for the *ith* circularity indicator are decided following steps 1 and 2, it will be possible to calculate the score of an ICT good for each circularity aspect using (1):

$$Score = R_i \times MI_i \tag{1}$$

For instance, if a product has a very bad performance of the circular indicator, then its MI is very high (Table 3). Therefore, a numerical value of 4 is assigned. If this circular indicator is very relevant, or belongs to a circularity aspect that is very relevant for this product category/type, then the numerical value of 4 (Table 2) is assigned to R. In this case, the theoretical score for this product is 4(R) × 4(*MI*) = 16.

In another instance, if a product has a rather good performance of the circular indicator, then its MI is high (Table 3). Therefore, a numerical value of 3 is assigned. If this circular indicator belongs to a circularity aspect that is of very low relevance for this product category/type, then its R is very low and the numerical value of 1 (Table 2) is assigned. In this case, the theoretical score for this product is 1(R) × 3(*MI*) = 3.

However, the present method aims to reward circularly designed ICT goods with high % values and less circularly designed ICT goods with low % values.

NOTE – 0% is the worst score that can be obtained when using the present Recommendation for circularity performance calculations and 100% the best possible score.

This requires some development of the scoring as described in Appendix II and [b-AndraeVaija] – compared to the baseline method [b-Bovea].

Figure 1 shows the translation of R and MI combinations to values between 0% and 100%.

		R			
		1	**2**	**3**	**4**
MI	**1**	55	75	90	100
	2	50	60	70	80
	3	40	35	30	15
	4	25	20	10	0

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Figure 1 – Matrix with values for *MI* and *R* combinations

With the score determined, it will then be possible to identify the circular indicators for improving a product's circularity. For instance, if the score of ICT good A is 0% in the PD category (i.e., Very High $MI = 4$ and Very High $R = 4$), it means that it is very urgent to redesign the product by improving the circular indicators from the PD circularity aspect found in Table 1. Conversely, if the score of ICT good A is 100% in the 3Rue circularity aspect (i.e., Very Low *MI* and Very High *R*), it means that no urgent action is needed to improve the product design from an 3Rue standpoint.

In addition, at this stage it is possible to review the list of circular indicator applied to the ICT good. Indeed, some of them might not be relevant ($R = 0$), due to the ICT good design or business model, whereas some might be missing in order to describe the effort needed to improve its circularity. For example, for an ICT good that will undergo a refurbishment process during its lifespan it could be interesting to consider the scratch resistance (PD2) of the housing parts, as they might be reused as spare parts.

The scale used by the score assessment method represents the level of circularity for a particular product design (including manufacturer services) and the urgency to incorporate different circular indicator. They are graded differently depending on the average *Score* at circularity aspect level.

These average total scores on circularity aspect level are obtained by calculating the average of the scores for the circularity indicator contained in the circularity aspect.

For instance, the PD contains six circular indicators. Again, PD1, PD2,…PD6 are obtained by finding the scores between 0 and 100 for each R×MI combination in Figure 1. Thus, the average score for PD is equal to: $\frac{PD1+PD2+PD3+PD4+PD5+PD6}{6}$. Non-relevant circular indicators shall be removed from the average calculation. For example, if *PD6* is not relevant, the average score for PD is equal to: $\frac{PD1+PD2+PD3+PD4+PD5}{5}$.

The scores obtained by the assessment method in the present document provide designers with a clue of a product's circularity performance, allowing them to improve the circular indicators and circularity aspects that have the lowest scores.

Table 5 shows how e.g., a designer may interpret the score for each circularity aspect.

Table 5 – The level of urgency of score for each circularity aspect

Circularity score in %	Urgency level explanation
81-100	Does not require any urgent actions
61-80	Does not require very urgent actions
41-60	Efforts should be made to improve, but not so urgent
21-40	It is urgent to improve
0-20	It is very urgent to improve

Appendix I illustrates an application of the present methodology to one ICT good. The most important circularity indicators for the ICT goods can be obtained by sorting all included circularity indicators values from each circularity aspect, e.g., 1) PD1, 2) 3RUe7, 3) 3RUm1, etc.

Appendix I

Examples of application of the methodology

(This appendix does not form an integral part of this Recommendation.)

I.1 5G active antenna radio

This clause presents an example of ITU-T L.1023 methodology applied to assess the circularity scoring of a 5G active antenna radio. A 5G active antenna radio is a remote radio head unit that is placed at the top of a cell tower which consolidates radio frequency (RF) electronics, power amplifiers, baseband, and signal filters, backhaul opto-communications hardware (HW), an antenna array and a protective radome for transmitters/receivers. The top two predominant metals are aluminium and copper which have combined recycled content of just less than 50%. The plastic part (radome) also consists of just below 50% of recycled content. Both metals and plastic parts are kept separate for easy recycling according to design for environment guidelines.

5G methodology

The assessment methodology of circularity scoring involves 3 steps: (1) estimation of *relevance* (R) of each criterion, (2) determining *margin of improvement* (MI) and (3) calculating the *circularity score* based on the values from previous two steps (1&2).

NOTE – The order of steps 1 and 2 is somewhat flexible. The determination of MI can be done separately from R. For example, the customers (e.g., telco operators) can determine the R from their perspective and the manufacturers (of the original ICT equipment) determine the MI and R from their perspective.

The scoring is based on three circularity aspects: (1) *Product durability*, (2) *Ability to recycle, repair, reuse and upgrade at equipment level* and (3) *Ability to recycle, repair, reuse and upgrade at manufacturer level and 23 circularity indicators* presented in Table 4 of the main body of this Recommendation. The circularity aspects and circular indicators are also displayed in Table I.1-1.

Table I.1-1 – Empty table with the 23 circularity indicators distributed in the three circularity aspects to be filled for the circularity score assessment

Circularity aspects	Circularity indicators	Relevance (R)	Margin of improvement (MI)
Product durability	PD1: Software and data support		
	PD2: Scratch resistance		
	PD3: Maintenance support		
	PD4: Robustness		
	PD5: Battery for portable ICT goods		
	PD6: Data security		
Ability to recycle, repair, reuse, upgrade – equipment level	3Rue1: Fasteners and connectors		
	3Rue2: Diagnostic support		
	3Rue3: Material recycling compatibility -Plastic parts		
	3Rue4: Material recycling compatibility -Metal parts		
	3Rue5: Recycled/renewable plastics		
	3Rue6: Recycled metals		

Table I.1-1 – Empty table with the 23 circularity indicators distributed in the three circularity aspects to be filled for the circularity score assessment

Circularity aspects	Circularity indicators	Relevance (R)	Margin of improvement (MI)
	3Rue7: Material identification		
	3Rue8: Hazardous substances		
	3Rue9: Critical raw materials		
	3Rue10: Packaging recycling		
	3Rue11: Technical performance product mass-based material efficiency		
Ability to recycle, repair, reuse, upgrade - manufacturer level	3Rum1: Service offered by manufacturer		
	3Rum2: Spare parts distribution		
	3Rum3: Spare parts availability		
	3Rum4: Disassembly information		
	3Rum5: Collection and recycling programmes		
	3Rum6: Environmental footprint assessment knowledge publicly available		

These steps are further explained for the circularity score assessment of 5G active antenna radio in the following sections.

Determining relevance R

5G active antenna radio is a business-to-business (B2B) product which is usually installed in the customer premises. For circular goods, the manufacturer needs to consider the whole lifecycle of a product from design and production and is usually also collecting the product after the use. Therefore, functionality, life span, durability, performance, circulation of material and components and environmental impact of the product have been considered to assess the value for *R*.

For instance, 5G active antenna radios could be used for extended lifetime with maintenance supports and software upgrade possibility together with repair and refurbishment during their life cycle. Thus, software and data support, maintenance support, spare parts availability, disassembly information, and collection and recycling programs are of high importance for the product circularity. Likewise, the product is mostly placed in outdoors environments in height, hence robustness is another important factor. Thus, these aspects are considered as significantly important, hence relevance (*R)* is 4 for these circularity indicators. Similarly, from an environmental sustainability and circularity point of view, other factors such ase material identification, material recycling compatibility, recycled/renewable content present in both plastic and metal parts, fasteners and connectors, declaration of critical raw materials (CRMs), package recycling, and environmental footprint assessment knowledge are important factors. Positive effects of those aspects are high for circularity of this product; hence the respective circularity indicators are all considered as having a high or very high relevance (R = 3 or 4) for the circular scoring.

Some other aspects such as scratch resistance, data security and the battery for portable ICT goods are not relevant at all because of the nature of the product, i.e., aesthetic beauty is not the priority or requirement for network infrastructure goods, the product does not store any customer information or sensitive data and it does not contain any battery. Furthermore, Table 4 indicates that the hazardous substance criterion is not applicable for network infrastructure goods. Therefore, R of these indicators is 0 (i.e., not relevant at all) and hence the respective MI levels scoring is labelled as N/A in Table I.1-2 for the 5G active antenna radio and are not considered as an assessment criterion.

Determining margin of improvement MI level

The scoring of MI is done with the help of predefined scoring levels which have some requirements to be assessed based on Table 4 of the main body text. However, for some of the indicators such as PD4-Robustness, it is up to the practitioner to define the environment in which the product is intended to be used and then apply the applicable tests defined in the relevant standards. For 5G active antenna radio, from the example standards presented in Table 4 for the robustness indicator, [b-ETSI 300 019-2-4] for the product intended to be used in non-weather protected location and [b-ITU-T K.21] for assessing the resistibility to the electromagnetic voltage transient are used. Depending on the operator's installation, either [b-ITU-T K.21], which is relevant for installation in customer premises or [b-ITU-T K.45], which is relevant for installation in the access and trunk networks is to be used for this category of network equipment. For this example, [b-ITU-T K.21] is used. MI levels are defined on Table 4 for the PD4 robustness indicator. For the product in this example, MI is 2, as it complies with all the minimum requirements of the product environmental class standard [b-EN 300 019-1-4] and the basic requirements of [b-ITU-T K.21] for electromagnetic voltage transient, however it does not show any superior characteristics than the minimum requirement.

Some examples of the required test type for the environmental class standards [b-EN 300 019-1-4] test class are air temperature test, humidity test, rain test, vibration test, shock test, earthquake test, etc. [b-ITU-T K.21] includes resistibility requirements and test procedures for surges due to lightning, short-term induction from adjacent AC power lines or railway systems, earth potential rise due to power faults, direct contacts between telecommunication lines and power lines, electrostatic discharges, etc.

The rest of the circularity indicators are assessed according to the MI levels described in Table 4 of the main body text and displayed in Table I.1-2.

NOTE – The robustness test requirements are different depending on the product type and use environment. Consumer goods like mobile phones can have completely different requirements for water/dust resistance etc. compared to the network infrastructure equipment presented as an example here.

Circularity score

The circularity score of each circularity indicator is calculated according to its *R* and *MI* results, combined with the matrix presented in Figure 1 (*Score* matrix with values for *MI* and *R* combinations). For instance, for the circularity indicator PD1 (software and data support), according to the assessment carried out, the results are R = 4 (most relevant) and MI = 1 (low improvement potential). According to Figure 1 from the main body text, this combination of R and MI gives a score of 100. The same process is applied to identify the scores of the other circularity indicators (according to their R and MI) and the results are displayed in Table I.1-2.

Table I.1-2 – R, MI, and circularity score for all relevant indicators for the 5G active antenna radio

Equipment: 5G active antenna radio				
Circularity aspects	**Circularity indicators**	**Relevance (R)**	**Margin of improvement (MI)**	**Circularity score**
Product durability	PD1: Software and data support	4	1	100
	PD2: Scratch resistance	0	N/A	N/A
	PD3: Maintenance support	4	2	80

Table I.1-2 – R, MI, and circularity score for all relevant indicators for the 5G active antenna radio

Equipment: 5G active antenna radio				
Circularity aspects	**Circularity indicators**	**Relevance (R)**	**Margin of improvement (MI)**	**Circularity score**
	PD4: Robustness	4	2	80
	PD5: Battery for portable ICT goods	0	N/A	N/A
	PD6: Data security	0	N/A	N/A
Ability to recycle, repair, reuse, upgrade – equipment level	3Rue1: Fasteners and connectors	4	1	100
	3Rue2: Diagnostic support	3	3	30
	3Rue3: Material recycling compatibility – Plastic parts	4	1	100
	3Rue4: Material recycling compatibility – Metal parts	4	1	100
	3Rue5: Recycled/renewable plastics	4	3	15
	3Rue6: Recycled metals	4	3	15
	3Rue7: Material identification	4	1	100
	3Rue8: Hazardous substances	0	N/A	N/A
	3Rue9: Critical raw materials	4	1	100
	3Rue10: Packaging recycling	3	2	70
	3Rue11: Technical performance product mass-based material efficiency	3	2	70
Ability to recycle, repair, reuse, upgrade - manufacturer level	3Rum1: Service offered by manufacturer	4	1	100
	3Rum2: Spare parts distribution	3	2	70
	3Rum3: Spare parts availability	4	1	100
	3Rum4: Disassembly information	3	3	30
	3Rum5: Collection and recycling programmes	4	1	100
	3Rum6: Environmental footprint assessment knowledge	3	1	90

NOTE – The data presented in this example is not real data but rather examples.

Circularity aspect level is calculated in the next step by calculating the average of the circularity indicator scores within the same circularity aspects. For instance, the circularity aspect level score of all the relevant PDs (product durability indicators) for the 5G active antenna radio (from Table I.1-2) is shown in Table I.1-3.

Table I.1-3 – Circularity score of all PDs

PDs	Score
PD1	100
PD2	N/A
PD3	80
PD4	80
PD5	N/A
PD6	N/A

All the non-relevant circular indicators shall be removed from the average calculation. For example, PD2, PD5 and PD6 are not relevant, hence they are removed from the calculation. The average score of all PDs is equal to:

$$\frac{PD1 + PD3 + PD4}{3}$$

Thus, the score for product durability (PD) is equal to:

$$\frac{100 + 80 + 80}{3}$$

$$= 86.67 \sim \mathbf{87\%}$$

The scores of other circularity aspects are calculated in the same way and the results are shown in the Table I.1-4.

Results

The circularity score results for the circularity aspects can be presented in table form as shown in the Table I.1-4. The result shows how different circularity aspects perform compared to each other. We can see that the 5G active antenna radio has a higher circularity score for the "Product durability" and "Ability to recycle, repair, reuse, upgrade at manufacturer level", i.e., 87% and 82% respectively. The most improvement potential lies in the "Ability to recycle, repair, reuse, upgrade – equipment level" which has circularity score of 70%. Observing from the circularity indicators scores, the circularity aspect – "Ability to recycle, repair, reuse, upgrade at equipment level" could be improved by better diagnostic support and using more renewable and recycled content (in both plastic and metal parts) during the production stage. The circularity score of an individual circularity indicator provides the areas which require or do not require any actions to improve the circularity of the product with the respective level of urgency. Thus, this gives the areas to focus on and prioritize.

Table I.1-4 – Circularity score results for all circularity aspects

Equipment: 5G active antenna radio	
Circularity aspect	**Circularity score**
Product durability	87%
Ability to recycle, repair, reuse, upgrade – equipment level	70%
Ability to recycle, repair, reuse, upgrade – manufacturer level	82%

The circularity score results can also be presented and analysed in any other format to better comprehend the scoring and for better graphical illustration. For instance, a radar chart can be used for better visual communication and comprehension. Figure I.1 shows the results of the 5G active antenna radio in a radar chart.

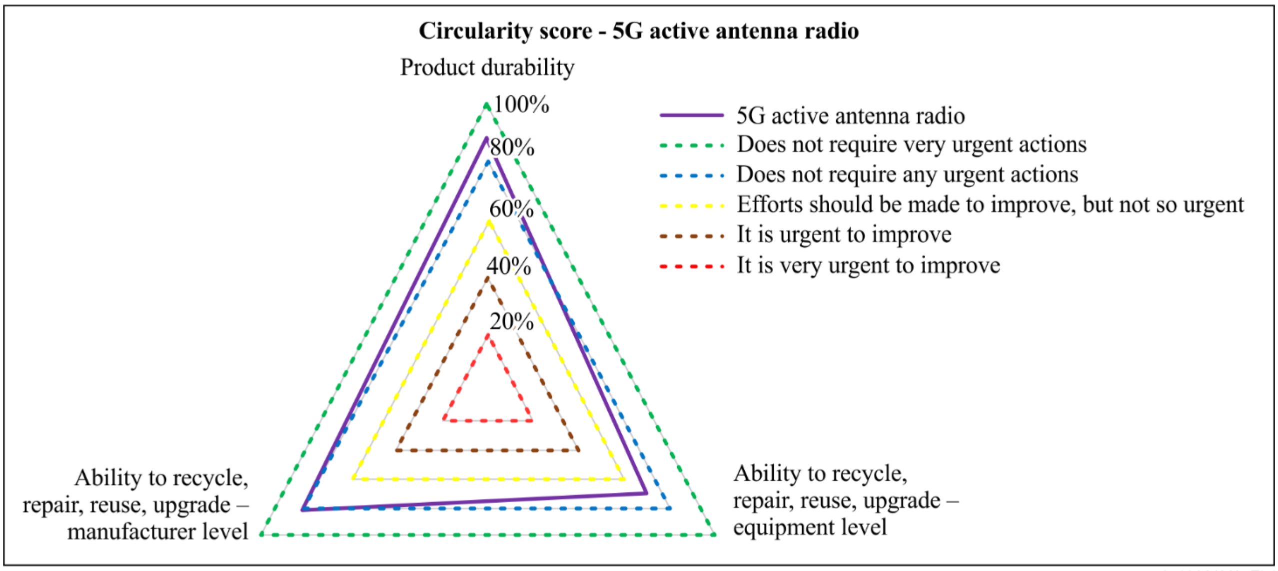

Figure I.1 – Radar chart for the 5G active antenna radio results according to circularity aspect scores from Table I.1-4

I.2 Server example

Table I.2-1 shows another suggestion for 3Rue9 *MI* levels for servers.

Table I.2-1 – Suggestion for 3Rue9 MI levels for CRMs in servers

3Rue9: Critical raw materials	Declaration of critical raw materials content	MI = 1 – Based on the CRM content assessment, the location of the CRM in the ICT good is available to improve recyclability. Based on the CRM content assessment, design efforts have been carried out to substitute CRM and the results have been published.
		MI = 2 – An assessment according to [b-EN 45558] has been carried out on all of the CRMs present in the product.
		MI = 3 – Indicative weight range (less than 5 g, between 5 g and 25 g, above 25 g) at component level, of the at least two critical raw materials is available (cf. [b-EU 2019/424] for servers).
		MI = 4 – The CRM content is unknown.

Appendix II

Rationale for scoring tables

(This appendix does not form an integral part of this Recommendation.)

The first step of the approach is to fill a matrix of combinations with some pertinent values. To facilitate this process, 5 levels from A (the best score) to E (the worst score) are considered. Figure II.1 shows the completed matrix.

		R			
		1	**2**	**3**	**4**
MI	**1**	C	B	A	A
	2	C	B	B	A
	3	C	D	D	E
	4	D	D	E	E

L.1023(20)_FII.1

Figure II.1 – A to E matrix for MI and R

The progression is linear from the lowest score to the highest (for example with the best scoring located in the top-left corner and the worst one in the bottom-right).

Then each level in a range of 20% is translated as followed:

– A = [100%; 80%]

– B = [80%; 60%]

– C = [60%; 40%]

– D = [40%; 20%]

– E = [20%; 0%]

Once again, the matrix is filled with appropriate score for each letter (Figure II.2).

		R			
		1	**2**	**3**	**4**
MI	**1**	55	75	90	100
	2	50	60	70	80
	3	40	35	30	15
	4	25	20	10	0

L.1023(20)_FII.2

Figure II.2 – 0% to 100% matrix for *MI* and *R*

Then a formula is derived that combines MI and R to reach the % scores in Figure II.2. As the progression of the scores in Figure II.2 is not linear the resulting equation (II.1) allowing calculation of each cell score is rather complex.

$$Score\ for\ MI, R\ combination$$

$$= \left(\left(\frac{1}{3} \times \boldsymbol{MI}^3 - 2.5 \times \boldsymbol{MI}^2 + \frac{25}{6} \times \boldsymbol{MI}\right) \times \boldsymbol{R}^2 + \frac{45}{\boldsymbol{MI}} + 20.75\right) \times \frac{100}{97.75} \quad \text{(II.1)}$$

$$(expressed\ in\ \%)$$

By using equation (II.1) the Table *Scores* can be recalculated, as displayed in Figure II.3.

NOTE – If the range for R and MI is susceptible to be changed (e.g., someone wants to try a 1 to 5 range for both metrics) a new formula – to calculate the scores for the new combinations (e.g., [*R*=5; *MI*=5]) – is required.

In the current situation with fixed ranges for R and MI the scores in Figure II.2 could be considered directly.

		R			
		1	**2**	**3**	**4**
MI	**1**	70	76	86	100
	2	45	48	53	60
	3	35	32	27	20
	4	30	24	14	0

L.1023(20)_FII.3

Figure II.3 – 0% to 100% matrix for MI and R based on equation (II.1)

Appendix III

Additional circularity aspects and circularity indicators which may be relevant for certain ICT goods

(This appendix does not form an integral part of this Recommendation.)

Further circularity aspects and circularity indicators examples may be developed which are only valid for a certain type of ICT good. Tools which are mentioned in [b-EN 45554] could be such an example as outlined in Table III.1.

Table III.1 – Hints to defining the criteria for MI levels for potential circularity indicator Tools

Circularity aspect	Circularity indicator	Hints to defining the MI levels for the indicator of any ICT good	Scoring system
3Rue	3RUeIII.1: Tools	Tools required for repair operations per [b-EN 45554]	MI = 1 – Repair operations are feasible with no tools, basic tools, tools supplied with the product or spare part and/or product specific tools (as defined in [b-EN 45554]).
			MI = 2 – Repair operations are feasible with other commercially available tools (as defined in [b-EN 45554]).
			MI = 3 – Repair operations are feasible with proprietary tools (as defined in [b-EN 45554]).
			MI = 4 – Repair operations are not feasible with any existing tool (as defined in [b-EN 45554]).

Disassembly depth is another indicator which could be relevant, see Table III.2.

Table III.2 – Hints to defining the criteria for MI levels for potential circularity indicator Disassembly depth

Circularity aspect	Circularity indicator	Hints to defining the MI levels for the indicator of any ICT good	Scoring system
3Rue	3RUeIII.2: Disassembly depth	Number of steps necessary to reach priority parts [b-EN 45554]	MI = 1 – All the priority parts for repair operations are accessible after one or two disassembly steps
			MI = 2 – All the priority parts for repair operations are accessible after three or four disassembly steps
			MI = 3 – All the priority parts for repair operations are accessible after five or six disassembly steps
			MI = 4 – All the priority parts for repair operations are accessible after more than six disassembly steps

Appendix IV

Interpretation of circularity aspects' score

(This appendix does not form an integral part of this Recommendation.)

The estimation of relevance (R) is subjective and is based on assumptions made by the practitioner. However, the determination of the margin of improvement (MI) levels can be considered to be objective. Anyway, the final three individual scores between 0 and 100 for the circular aspects PD, 3RUe and 3RUm give indicative estimations of the products' circular performance. As such those circular aspects are not intended to be combined as it will distort the individual performance in one area compared to another area and hide the improvement areas. This Recommendation is intended to assess and improve the circularity of ICT goods at hand and the results are not intended to be used in comparative assessment of separate products.

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