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Foreword

This draft European Standard (EN) has been produced by ETSI Technical Committee Environmental Engineering (EE), and is now submitted for the combined Public Enquiry and Vote phase of the ETSI EN Approval Procedure (ENAP).

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
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Modal verbs terminology

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

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

Introduction

The present document defines Product Specific Requirements (PSR) for the Life Cycle Assessment (LCA) of smartphones to ensure that LCA studies conducted on smartphone models, including at the SKU level (e.g. different memory configurations and form factors such as foldables) are comparable, objective, and transparent.

Based on the LCA framework outlined in [1] and [i.1], as well as ideas and results presented in [i.2] and [i.3], the present document provides methodology guidance specific to smartphones, enhancing harmonization and communication of LCA results. It applies to all types of smartphones and sets requirements for conducting LCAs that allow valid comparisons between different device models.

The goals of the present document are to:

- Establish smartphone-specific LCA method and standard that builds upon and enhances existing general LCA standards by providing more specific and targeted guidelines for smartphones.
- Ensure consistent and comparable LCA studies across the industry.
- Improve the transparency and interpretation of smartphone LCA studies.
- Facilitate clear and standardized communication of LCA results at the SKU level for both manufacturers and distributors as part of their sustainability reporting, but not restricted to this application.

In addition, the present document should allow impact forecast and simulation already in the device design phase to help make conscious decisions in material and part/component selection for the reduction of the ecological footprint.

Background

The earth climate is affected by a human-caused climate change, which results in global warming. Global warming will have severe effects, even affecting possibly habitability in some parts, unless serious efforts are undertaken to limit the rise of the global temperatures.

The earth is in a radiation equilibrium given by the radiation it receives from the sun (149,6 million km average distance) and the radiation back into space, which leads to an equilibrium temperature. Unfortunately, this counter radiation happens predominantly in wavelength ranges where certain gases absorb, such as Carbon Dioxide or Methane (collectively Greenhouse Gases (GHG)), reducing the energy that is radiated back into space and thereby increasing the level of energy kept on the earth surface and atmosphere. The concentration of such gases has thus an immediate impact on that equilibration temperature. Mankind is using fossil carbon for energy generation and as a raw material for a multitude of applications. This activity causes the concentration of GHG to rise in the atmosphere which in turn fuels global warming.

To limit global warming and its associated negative consequences, the emissions of GHG should be limited. Therefore, many nations have come together to limit global warming to 1,5 °C in the Paris Climate Agreement. This requires a vigorous decarbonization of continents, nations and industries alike.

The manufacturing, transportation, use and disposal of smartphones are inevitably associated with GHG emissions. Seen globally the impact of Smartphone production and use is substantial. In 2023 alone, more than 1,3 billion smartphones were sold globally. This is only the number that is accumulated year on year into the connected base. Counting all smartphones in use, around 580 million tonnes of GHG are emitted annually which is ca. 1 % of all worldwide emissions. These should be reduced. The first step to the reduction of emissions is an inventory of what is currently emitted to define the basis from which emissions need to be reduced, and then a reliable measure is required to gauge the progress of emission reduction beyond effects of just different ways to calculate. This requires a standard for the calculation of emissions on a common basis that allows a fair comparison of emissions of the players in the industry and credible tracking of successes in reductions.

However, GHG emissions are only one of several impact categories considered in an LCA. A relevant category for Smartphones is also resource use. Resources are limited and conservation as well as recycling is paramount. Most elements of the periodic table are represented in smartphones. These elements need to be taken out of the soil unless taken from secondary (recycled sources). Mining of minerals and their subsequent processing in turn consumes land and causes the risk of pollution and natural habitat impediment or even destruction. Likewise, the resource use needs to be reduced, and primary sources replaced by secondary ones wherever that is possible. There is also a commercial and supply chain related side-effect to this. Some of the elements used in Smartphones are only available from a very few countries or with limited deposits which has an impact on supply risks and future price development. The present document will allow a comparable assessment of the resources used for any particular Smartphone design. By way of such comparison the progress of the industry in resource conservation will be made transparent.

Exemplified by two of the impact categories analogous considerations are also applicable and valid for the other impact categories.

Corporations in the ICT sector do not live in a societal vacuum. Their success depends on a friendly societal environment in which to operate. Modern societies increasingly demand corporate responsibility and a positive contribution to communities. Perception and acceptance of industry players is more and more influenced by these factors. Commitment to climate protection is an important, if not the most important element of it. A widely accepted standard for emission calculation associated with Smartphones is needed to serve as a fair, transparent and credible way to show to the public the industry contribution to climate protection.

Existing standards today are either not smartphone specific or allow a variance in methodology so that comparability is not possible. The present document closes this gap by creating Product Specific Requirements for Life Cycle Assessment (LCA) of smartphones.

Objectives of the present document

The present document allows performing LCA for Smartphones according to a common methodology. The results will allow an inventory of existing emissions for multi-vendor portfolios without the uncertainty of interpretation caused by variances in methodology application by different vendors or sources. Also, the results can directly be usable for financial statements, business and sustainability or any other reporting in relation to climate or environmental protection which may be legally mandatory in some jurisdictions. The present document will be readily acceptable to third parties auditing such reports.

The present document will also make emission reductions transparent achieved by players in the industry. These achievements will not disappear into differences in results just caused by different methodology application or calculations. If the latter were to happen no conclusion would be possible if a low emission value is due to real reduction or just a result of "optimized" calculation. Therefore, the present document will contribute to increased trust in the public that any reported emission reduction is real and not just apparent by different ways of calculation. Players achieving real emission reductions will be rewarded by making it transparent, as unambiguously as this is reasonably possible, and others encouraged to follow. Therein, the present document will already account for the coming Empowering the Consumer and Green Claims directives.

However, due to fundamentals of nature, no measurement and no calculation is completely free of uncertainties. Nevertheless, the ambition is to keep those as small as possible to allow valid comparisons between and/or predictions for different Smartphone models and portfolios to help making optimizations for emission reductions. Therefore, the present document also contains a semi-quantitative assessment of the uncertainty margin based on the expectable variance in input parameters.

Relationship to Existing LCA Standards

The present document is more specific than the "PCR" [1] (but reuses some its terminology for life cycle stages), the PCR guidance for electrical products [i.1] and the application of [1] to a mobile phone, [i.3]. The present PSR document is the first of its kind in the ICT industry.

1 Scope

The present document defines Product Specific Requirements for Life Cycle Assessment (LCA) of Smartphones so that it is possible to compare the LCA between different smartphone models on SKU level (e.g. considering different memory configurations). The present document provides a methodology for evaluating the environmental impact of smartphones objectively and transparently and is based upon the Life Cycle Assessment (LCA) framework standardized in ETSI ES 203 199 [1] and IEC 63366 [i.1]. The purpose of the present document is to:

- Provide smartphone-specific requirements, i.e. Product Specific Rules (PSR), in addition to those of ETSI ES 203 199 [1] and IEC 63366 [i.1] to ensure comparability of LCA studies of smartphones on SKU level.
- Harmonize the LCAs of smartphones.
- Increase the transparency and facilitate the interpretation of LCA studies of smartphones.
- Facilitate the communication of LCA studies of smartphones on SKU level.

The present document is valid for all types of smartphones. Moreover, the present document defines a set of requirements for which the LCA practitioners will comply. Comparisons of results from LCA studies of smartphones which belong to the same product family, including assessments which have been performed by different organizations, are within the scope of the present document.

2 References

2.1 Normative references

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

Referenced documents which are not found to be publicly available in the expected location might be found in the ETSI docbox.

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

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

[1] ETSI ES 203 199 (V1.4.1): "Environmental Engineering (EE); Methodology for environmental Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks and services".

[2] GSMA™ TS.09 v13.0: "Battery Life Measurement and Current Consumption Technique".

[3] ISO 14083:2023: "Greenhouse gases — Quantification and reporting of greenhouse gas emissions arising from transport chain operations".

[4] Global Logistics Emissions Council (GLEC) Framework v3.2.

2.2 Informative references

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

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

The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

[i.1] IEC 63366:2025: "Product category rules for life cycle assessment of electrical and electronic product and systems".

[i.2] ETSI TR 103 679 (V1.1.1): "Environmental Engineering (EE); Explore the challenges of developing product group-specific Product Environmental Footprint Category Rules (PEFCRs) for smartphones".

[i.3] ETSI TR 104 080 (V1.1.1): "Environmental Engineering (EE); Example of a Life Cycle Assessment (LCA) of a mobile phone".

[i.4] M. Billaud, C. Clemm, D. Sánchez, M. Proske, M. Jügel, L. Stobbe, N. F. Nissen, M. Schneider-Ramelow: "ICs as drivers of ICT carbon footprint: an approach to more accurate die size assessment".

[i.5] Eynard U., Ardente F., Gama Caldas M., Spiliotopoulos C. and Mathieux F.: "Ecoreport tool - Manual", Publications Office of the European Union, Luxembourg, 2024.

[i.6] Commission Recommendation C(2021)9332 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. Sections 4.4.8 and 4.4.9 in Annex I.

[i.7] Weltweite und europäische Kunststoffproduktion in den Jahren von 1950 bis 2024.

[i.8] Aktuelle Zahlen zur Kunststoffproduktion - Anteil fossiler Rohstoffe in Kunststoffproduktion rückläufig.

[i.9] Developer Environmental Footprint (EF).

[i.10] "Ecoreport tool - Manual", Publications Office of the European Union, 2024.

[i.11] ETSI TS 104 134 (V1.1.1): "Environmental Engineering (EE); Simplified Method for including Uncertainty and Sensitivity Aspects in Calculations of the Avoided Environmental Impact of Information and Communication Technology Solutions".

[i.12] GSMATerminals - Battery-Life-Measurement-Test-Files-Public.

[i.13] imec.netzero.

[i.14] Vanhouche, B., Cardinael, P., Boakes, L., Ragnarsson, L. Å., Rolin, C., Raskin, J. P., & Parvais, B. (2024, June): "Environmental Analysis of RF Substrates". In 2024 Electronics Goes Green 2024+(EGG) (pp. 1-8). IEEE™.

[i.15] Andrae, A. S., & Vaija, M. S. (2017): "Precision of a streamlined life cycle assessment approach used in eco-rating of mobile phones". Challenges, 8(2), 21.

[i.16] How Sustainable are Our OLED Lighting Panels? LCA Study Shows Benefits.

[i.17] A. Holo, C. Dubarry, J.-C. Lopes Barbosa, M. Dupont, S. Chabaud, F. Templier: "45-4: MicroLED Display Life Cycle Assessment".

[i.18] Ellingsen, L. A. W., Majeau-Bettez, G., Singh, B., Srivastava, A. K., Valøen, L. O., & Strømman, A. H.: "Life cycle assessment of a lithium-ion battery vehicle pack". Journal of Industrial Ecology, 18(1), pp. 113-124, 2014.

[i.19] Peters, J. F., Baumann, M., Zimmermann, B., Braun, J., & Weil, M.: "The environmental impact of Li-Ion batteries and the role of key parameters-A review". Renewable and Sustainable Energy Reviews, 67, pp. 491-506, 2017.

[i.20] Romare, M., & Dahllöf, L.: "The life cycle energy consumption and greenhouse gas emissions from lithium-ion batteries", 2017.

[i.21] Dai, Q., Kelly, J. C., Gaines, L., & Wang, M.: "Life Cycle Analysis of Lithium-Ion Batteries for Automotive Applications". Batteries, 5(2), p. 48, 2019.

[i.22] Sustainability Impact Metrics:"Idemat and Ecoinvent, and eco-costs midpoint tables".

[i.23] Tin Sustainable Production.

[i.24] A.S.G Andrae: "A Comprehensive LCA method Addressing Uncertainty, Sensitivity, Rebound and Cut-off assumptions", 2025. DOI: 10.13140/RG.2.2.16390.89929.

[i.25] Commission Regulation (EU) 2023/1670 of 16 June 2023 laying down ecodesign requirements for smartphones, mobile phones other than smartphones, cordless phones and slate tablets pursuant to Directive 2009/125/EC of the European Parliament and of the Council and amending Commission Regulation (EU) 2023/826.

[i.26] Salonitis, K., Jolly, M. R., Zeng, B., & Mehrabi, H.: "Improvements in energy consumption and environmental impact by novel single shot melting process for casting". Journal of Cleaner Production, 137, pp. 1532-1542, 2016.

[i.27] ETSI ES 204 085 (V1.1.1): "Environmental Engineering (EE); Guidance on simplified Life Cycle Assessments (LCA) of Information and Communication Technologies (ICT)".

[i.28] Commission Regulation (EU) 2019/1782 of 1 October 2019 laying down ecodesign requirements for external power supplies pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulation (EC) No 278/2009.

3 Definition of terms, symbols and abbreviations

3.1 Terms

3.1.1 Definition of covered product group: Smartphones

For the purposes of the present document, the terms given in Commission Recommendation C(2021)9332 [i.6] and the following apply:

A: allocation factor of burdens and credits between supplier and user of recycled materials

B: allocation factor of energy recovery processes: it applies both to burdens and credits

E^*_v: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of primary material assumed to be substituted by recyclable materials

E_D: specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery

E_{ER}: specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc.)

$E_{recycled}$: specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process

$E_{recyclingEoL}$: specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process

$E_{SE,heat}$ and $E_{SE,elec}$: specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively

Lower Heating Value (LHV): material in the product that is used for energy recovery

Q_{sin}: quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution

Q_{sout}: quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution

Q_p: quality of the primary material, i.e. quality of the primary material

R_1: proportion of material in the input to the production that has been recycled from a previous system

R_2: proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant

R_3: proportion of the material in the product that is used for energy recovery at EoL

smartphone: cordless handheld electronic device, which has the following characteristics [i.25]:

- It is designed for long-range voice communication over either a cellular telecommunications network or a satellite-based telecommunications network, requiring a SIM card, eSIM or similar means to identify the connected parties.
- It is designed for battery mode usage, while connection to mains via an external power supply and/or wireless power transmission is mainly for battery charging purposes.
- It is not designed to be worn on the wrist.
- It is characterized by wireless network connection, mobile use of internet services, an operating system optimized for handheld use and the ability to accept original and third-party software applications.
- It has an integrated touch screen display with a viewable diagonal size of 10,16 centimetres (or 4,0 inches) or more, but less than 17,78 centimetres (or 7,0 inches).
- Where the device has a foldable display or has more than one display, at least one of the displays falls into the size range in either opened or closed mode.

$X_{ER,heat}$ and $X_{ER,elec}$: efficiency of the energy recovery process for both heat and electricity

3.1.2 Out of scope

All devices that do not comply with clause 3.1 of the present document shall be considered to be out of scope. Additionally, mobile phones using satellite-based telecommunications network as its primary form of communication are out of scope.

3.2 Symbols

Void.

3.3 Abbreviations

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

5G	5th Generation
A2DP	Advanced Audio Distribution Profile
AAC	Advanced Audio Coding
ABS	Acrylonitrile Butadiene Styrene
ADP	Abiotic Depletion Potential
AP	Access Point
BOF	Basic Oxygen Furnace
BSI	Back-Side Illumination
CED	Cumulative Energy Demand
CFF	Circular Footprint Formulae
CO	Cobalt
COM	COMpleteness
CPU	Central Processing Unit
DASH	Dynamic Adaptive Streaming over HTTP
DQR	Data Quality Rating
DUT	Device Under Test
EDR	Enhanced DataRate

EF	Elementary File
EoL	End of Life
EoLT	End of Life Treatment
ErP	Energy related Products
eSIM	embedded Subscriber Identity Module
EU	European Union
E-UTRA	Evolved UMTS Terrestrial Radio Access
FPC	FingerPrint Cards
GaA	Gallium Arsenide
GaN	Gallium Nitride
GAN	Generic Access Network
GER	Geographical Representativeness
GFLOPS	Giga Floating Point Operations Per Second
GHG	GreenHouse Gas
GLEC	Global Logistic Emissions Council
GPRS	General Packet Radio Service
GPS	Global Positioning System
GPU	Graphics Processing Until
GSM	Global System for Mobile communications
GVW	GROOS Vehicle Weight
GWP	Global Warming Potential
GWP100	Global Warming Potential over a century
HDI	High Density Interconnector
HDPE	High Density PolyEthylene
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
HVAC	Heat Ventilation Air Conditioning
ICT	Information Communication Technology
IEA	International Energy Agency
IMEC	Interuniversity MicroElectronics Centre
IPA	IsoPropyl Alcohol
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCD	Liquid Crystal DIsplay
LDPE	Low Density PolyEthylene
LHV	Lower Heating Value
LLDPE	Linear Low Density PolyEthylene
LNM	Logic and Non Memory
LTE	Long Term Evolution
LTPS	Low Temperature Polycrystalline Silicon
MAG	Metal Active Gas
MCD	Material Content Declaration
MIG	Metal Inert Gas
MJ	MegaJoule
OLED	Organic Light Emitting Diode
PC	PolyCarbonate
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
PCR	Product Category Rules
PET	PolyEthyleneTerphtalate
PLMN	Public Land Mobile Network
PR	Precision
PSR	Product Specific Rules
RAM	Random Access Memory
RF	Radio Frequency
RR	Recycling Rate
SBR	Spectral Band Replication
SiC	Silicon Carbide
SIM	Subscriber Identity Module
SKU	Stock-Keeping Unit
SMT	Surface Mounting Technology
TB	TeraByte

TER	Technological Representativeness
TEU	Twenty foot Equivalent Unit
TFLOPS	Tera Floating point Operations Per Second
TIR	Time Representativeness
UE	User Equipment
USB	Universal Serial Bus
VoLTE	Voice over LTE
VoNR	Voice over New Radio
VoWiFi	Voice over Wi-Fi®
VPN	Virtual Private Network
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network
WTW	Well-To-Wheel

4 LCA requirements for Smartphones

4.1 Smartphone Specific Rules

4.1.1 Functional Unit Description

The functional unit serves as the baseline for the Lifecycle Assessment (LCA) of smartphones. It provides a standardized measure of the device's functionality, ensuring that environmental impacts are evaluated on a consistent and comparable basis across different devices. The functional unit shall define the expected usage scenario, encompassing the primary functions of a smartphone over its assumed lifetime.

This clause outlines the functional unit that shall be used when conducting LCA studies for smartphones under the present document. The defined functional unit captures typical smartphone usage and reflects both the product's functionality and its environmental impacts over its operational life.

For the purposes of the present document, the functional unit for a smartphone shall be defined as:

"Enable 3G/4G/5G access for 5,6 hours of daily use including call (0,16 hours), streaming content (1,2 hours), application software (1,2 hours), camera (0,1 hours), Bluetooth® interface (0,2 hours), GPS tracking (0,3 hours), browsing (1,34 hours) and idle(1,1 hours) over a period of 5 years."

The functional unit shall represent:

- Core Communication Functions: The ability to conduct voice calls for 0,16 hours daily over any mobile network (3G/4G/5G).
- Streaming content Usage: The ability to stream including video progressive steaming, dynamic adaptive streaming over HTTP(DASH), audio streaming for 1,2 hours daily.
- Application software: the ability to use common applications for 1,2 hours daily.
- Camera: the ability to use camera operation and video recording for 0,1 hours daily.
- Bluetooth interface: the ability to use Bluetooth headset for 0,2 hours daily.
- GPS tracking: The ability to utilize geo-navigation for 0,3 hours daily.
- Browsing: The ability to access and browse the internet for 1,34 hours daily.
- Idle Usage: The ability to standby time for 1,1 hours daily.
- Lifetime Expectancy: A functional service life of 5 years, representing the expected period of regular use.

Moreover, the defined functional unit shall be applied uniformly to all LCA studies conducted under the present document. Also, the functional unit shall be used to model energy consumption, material use, and environmental impacts over the smartphone's defined lifetime.

This functional unit reflects typical consumer usage patterns and aligns with the expected technological and functional performance of smartphones. The 5-year timeframe ensures that the LCA considers the impacts over a realistic period, accounting for both production and operational phases.

4.1.2 System Boundary

4.1.2.0 Introduction

This section cover System Boundaries for the PSR.

4.1.2.1 General

The system boundary establishes the scope of the Life Cycle Assessment (LCA) for smartphones, detailing the lifecycle stages, part/components, and processes included in the analysis.

The LCA shall include the following parts/components as part of the studied product system:

1) Smartphone: The core product, including all internal parts/components (e.g. display, battery, printed circuit boards, integrated circuits, antennas, and cameras).

2) Product Packaging: All materials used for packaging the smartphone, such as boxes, protective inserts, and labels.

3) Inbox Materials: All items included in the product package, which can include but is not limited to:

   a) Charger.

   b) USB cable.

   c) Headset.

   d) Instruction leaflets and warranty cards.

   e) Protective Cover.

   f) SIM Extraction Tool.

These elements shall be analysed for their contribution to the lifecycle environmental impacts.

The approach shall follow a cradle-to-grave perspective, encompassing all phases of the product lifecycle, from raw material acquisition to end-of-life treatment.

The following structure integrates generalized lifecycle categories for clarity while aligning with ETSI ES 203 199 [1] for subcategories and lifecycle stages.

4.1.2.1.0 Life cycle stages

4.1.2.1.1 Raw Material Acquisition

This stage as defined by ETSI ES 203 199 [1] encompasses the extraction and processing of all raw materials required for the production of the smartphone, its packaging, and inbox materials:

- A1 Raw Material Extraction: Includes the sourcing of metals (e.g. gold for connectors, lithium and cobalt for batteries, rare earth elements for displays) and non-metals (e.g. silicon for integrated circuits, polymers for covers). The impacts primarily relate to resource depletion and material acquisition processes.

- A2 Raw Material Processing: Covers the transformation of raw materials into intermediate materials or parts/components for further manufacturing.