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Environmental Engineering (EE); Methodology for environmental Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks and services

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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
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Foreword

This final draft ETSI Standard (ES) has been produced by ETSI Technical Committee Environmental Engineering (EE), and is now submitted for the ETSI Membership Approval Procedure.

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5. It will be published respectively by ITU and ETSI as Recommendation ITU-T L.1410 [i.28] and ETSI Standard ETSI ES 203 199 (the present document), which are technically-equivalent.

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 has been developed to complement ISO 14040 [1] and ISO 14044 [2] for the environmental assessment of the life cycle impact of ICT goods, networks and services.

The present document defines a set of requirements to reflect the quality that LCA practitioners should strive for. At this stage some of the requirements put forward here are considered as challenging due to Life Cycle Assessment (LCA) tool limitations, a lack of data, limitations in data granularity, etc. It is thus recognized that compliance to all requirements in the present document may not be possible at the time the present document is published. However, to foster results of LCAs becoming more transparent and, for the quality of data and LCA tools to improve over time, the present document is defining the requirements outlined in the following pages. The present document requires that deviation(s) from the requirements are clearly motivated and reported. For further details regarding compliance refer to clause 5.2.

The development of Information and Communication Technologies (ICTs) has led to concerns regarding its environmental impact. Taking into consideration the ongoing efforts within the United Nations Framework Convention on Climate Change [b-UNFCCC] to combat climate change, ITU-T and ETSI decided to enhance their previous work by jointly developing an internationally agreed methodology to help the ICT sector to assess the environmental impact of ICT goods, networks and services. The present document also gives guidance to the assessment of software.

Unlike many products and services sold in the world today, ICT distinguishes itself by its double-edged nature. On the one hand, ICTs have an environmental impact at each stage of its life cycle, e.g. from energy and natural resource consumption to e-waste. On the other hand, ICTs can enable vast efficiencies in lifestyle and in all sectors of the economy by the provision of digital solutions that can improve energy efficiency, inventory management and business efficiency by reducing travel and transportation, e.g. tele-working and video conferencing and by substituting physical products for digital information, e.g. e-commerce.

These different levels of impact are acknowledged in some academic literature as the three order effects of ICTs:

- First order effects (or the environmental load of ICTs): the impacts created by the physical existence of ICTs and the processes involved, e.g. energy consumption and GHG emissions, e-waste, use of hazardous substances and use of scarce, non-renewable resources.

- Second order effects (or the environmental load reduction achieved by ICTs): the impacts and opportunities created by the use and application of ICTs. This includes environmental load reduction effects which can be either actual or potential, such as travel substitution, transportation optimization, working environment changes, use of environmental control systems, use of e-business, e-government, etc.

NOTE: E.g. if an ICT service offers a reduced need for transport, the travel substitution replacing transportation by car is actual - the car does not run - whereas the reduced need for travel by public transport is potential - the plane, train or metro is still running if the timetable has not changed. However, the large scale deployment of video conferencing and tele-working (telecommuting) in the future will likely change lifestyles and impact on social structure and while it is expected to substantially reduce traffic volume, further research is required to assess what the full impact (including rebound effects) will be.

Higher order effects:

- include the impacts and opportunities created by the aggregated effects on societal structural changes by using ICTs;

- particularly include, for some ICT services such as tele-working or video conferencing, the time gained by an end user using an ICT service which then may cause additional impact e.g. a leisurely drive and economic activities, which are difficult to track. Such additional impacts are often defined as "rebound effects".

Most of the benefits of ICTs lie in the second order effects via increased efficiency, transparency, speed of transactions, rapid market-clearing, long-tail effects and so on. There are environmental impacts associated with the first order: environmental impact of ICT goods, networks and services such as resource consumption and carbon emissions during manufacturing and the disposal of hardware. Thus, the present document focuses on the first and second order effects.

Recommendation ITU-T L.1480 [i.25] provides further guidance on the second order effects and higher order effects as well as the impacts and opportunities created by the aggregated effects on societal structural changes by using ICTs.

In constructing a sustainable society from an environmental viewpoint, the negative aspects of ICTs should be minimized and the positive ones should be maximized, as summarized in Figure 1.

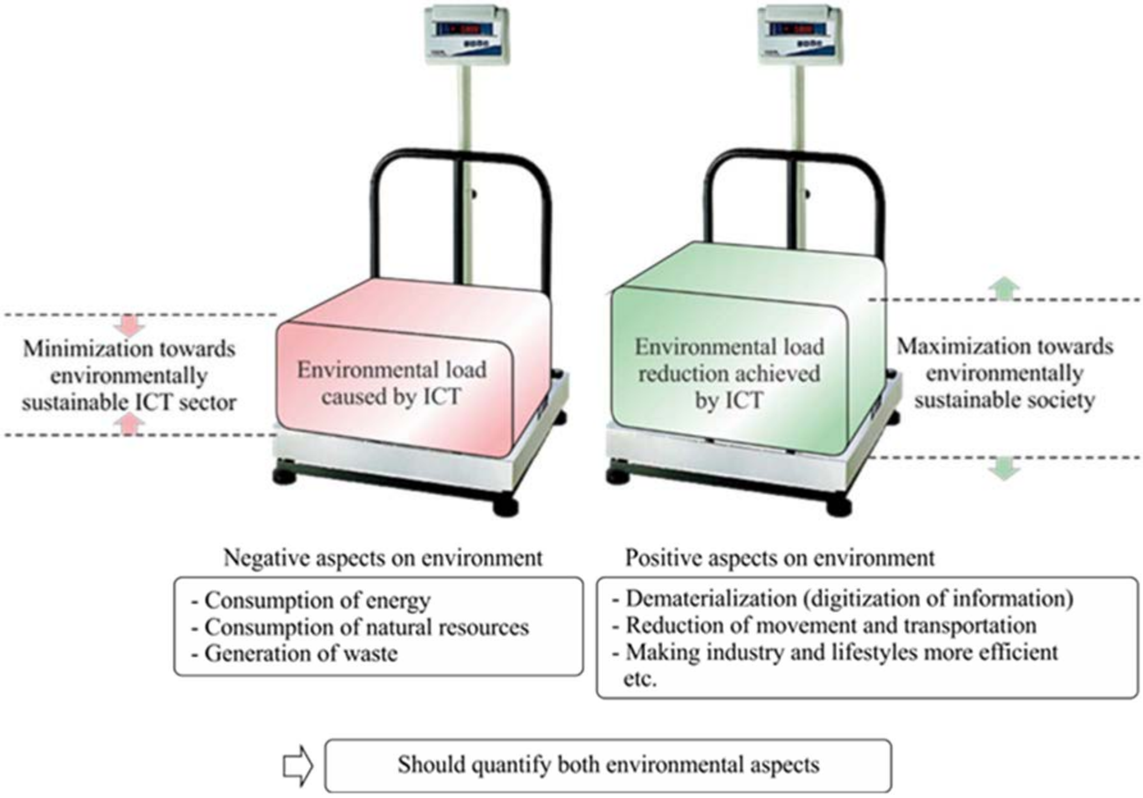

Figure 1: Schematic model for the environmental assessment of ICT goods, networks and services

The first order effect (or environmental load caused by ICT) can be quantified by performing a Life Cycle Assessment (LCA). The second order effect (or environmental load reduction achieved by ICT) can be quantified by the comparison of LCA results between the ICT goods, networks and services product system and the reference product system performing the same function.

To reflect the first two order effects, the present document describes environmental assessments through Life Cycle Assessment (LCA) which is a systematic analytical method and model by which the potential environmental effects related to ICT goods, Networks and Services can be estimated. The present document also gives guidance to the assessment of software. LCAs have a cradle-to-grave scope where the life cycle stages, i.e. *raw material acquisition, production, use* and *end-of-life* are included. Transports and energy supply are moreover included in each life-cycle stage.

ISO has standardized the LCA methodology. In the present document, ICT specific additions to the ISO 14040 [1] and ISO 14044 [2] standards will be described. As addition to the ISO 14040 [1] and ISO 14044 [2] standards, the European Commission has published a handbook that gives detailed guidance on all the steps required to conduct an LCA [i.16]. This handbook will also be referred to with special ICT considerations in mind.

The present document is divided into two parts:

- Part I (clauses 5 to 10) - ICT life cycle assessment: framework and guidance. This part deals with the LCA methodology applied to ICT goods, networks and services.
- Part II (clauses 11 to 14) - Comparative analysis between an ICT product system and a reference product system (baseline scenario): framework and guidance. This part deals with comparative analysis based on LCA results of the ICT goods, networks and services product system and the reference product system.

The structure of this LCA methodology specification for ICT goods, Networks and Services is shown in Figure 2. Figure 2 indicates where specific requirements and considerations apply for ICT goods, networks and services respectively and where the same requirements and considerations apply for all of those product systems.

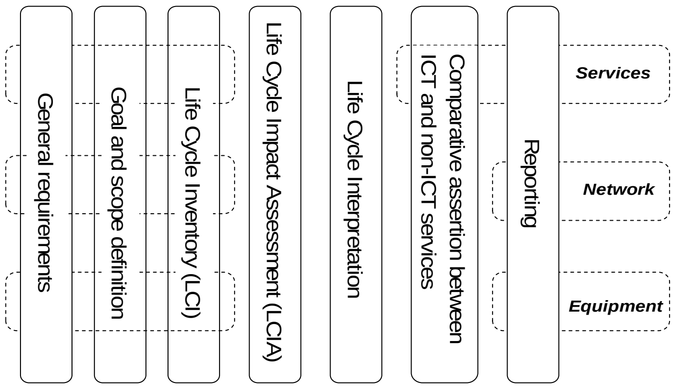

Figure 2: Structure of LCA methodology specification for ICT goods, Networks and Services

The structure of part I and part II is based on ISO 14040 [1] and ISO 14044 [2] in order to support the LCA practitioner and thus each part is structured in accordance with:

- General requirements: high level requirements of assessment.
- Goal and scope definition: requirements of the functional unit, system boundaries and data quality.
- Life Cycle Inventory (LCI): requirements for data collection, calculation and allocation.
- Life Cycle Impact Assessment (LCIA): requirements for impact assessment.
- Life cycle interpretation: requirements for the interpretation of results and calculation of second order effects.
- Reporting: requirements for reporting.

Both parts are then divided into applicable clauses and Part I is additionally structured into the three product system types, i.e. ICT goods, networks and services as appropriate.

The present document is intended for LCA practitioners wanting to assess ICT goods, networks and services impacts and it will help them to perform and report their LCAs of *ICT goods*, *Networks* and *Services* in a uniform and transparent manner. It is possible to use the present document to get guidance on what to consider in an LCA on three levels: ICT goods, Networks and Services.

The following uses of ICT LCA applications are the most frequently used ones, but others may be identified and used as well:

- Evaluation of product system environmental impact, such as climate change.
- Assessment of primary energy consumption.
- Identification of life cycle stages and activities with high significance.
- Comparisons of specific ICT goods, Networks, or Services under the conditions described in clause 5.3 (Comparisons of results).
- Comparative analysis between an ICT product system and reference product system.

1 Scope

The present document aims to provide a methodology for evaluating the environmental impact of ICTs objectively and transparently and is based upon the Life Cycle Assessment (LCA) methodology standardized in ISO 14040 [1] and ISO 14044 [2].

The present document can be read by anyone aiming for a better understanding of the specific conditions and requirements applicable to the LCA of ICT goods, networks and services. However, the present document is especially intended for LCA practitioners with a prior knowledge of LCA standards, i.e. ISO 14040 [1] and ISO 14044 [2].

The purpose of the present document is to:

- provide ICT-specific requirements, in addition to those of ISO 14040 [1] and ISO 14044 [2], to ensure a sufficient quality of LCA studies of ICT goods, networks and services; increase the quality of the LCA by adding ICT specific requirements to those of ISO 14040 [1] and ISO 14044 [2];
- harmonize the LCAs of ICT goods, Networks and Services;
- increase the credibility of LCAs of ICT goods, networks and services;
- increase the transparency and facilitate the interpretation of LCA studies of ICT goods, networks and services;
- facilitate the communication of LCA studies of ICT goods, networks and services; and
- provide a methodology for telecommunication operators and service providers to assess the environmental load of one or more Services carried by their ICT Networks.

While recognizing ISO 14040 [1] and ISO 14044 [2], including Annex A of ISO 14040 [1] "Application of LCA", as normative references, the present document will give generic and specific requirements for the LCA of ICT goods, networks and services. The present document is valid for all types of ICT goods including end-user goods and also for ICT networks and services. The present document also gives guidance to the assessment of software. LCA practitioners are encouraged to also consider other environmental aspects in accordance with ISO 14040 [1] and ISO 14044 [2].

The present document defines a set of requirements which reflect the quality that LCA practitioners should strive for. At this stage some of the requirements put forward here are considered as challenging due to LCA tool limitations, a lack of data, limitations in data granularity, etc. It is thus recognized that compliance to all requirements in the present document may not be possible at the time the present document is published. However, to foster results of LCAs becoming more transparent and, for the quality of data and LCA tools to improve over time, the present document defines the requirements outlined in the following pages. The present document requires that deviation(s) from the requirements are clearly motivated and reported. For further details regarding compliance refer to clause 5.2.

Comparisons of results from environmental assessments of ICT goods, networks and services, assessments which have been performed by different organizations are beyond the scope of the present document, as such comparisons would require that the assumptions and context of each study are exactly equivalent.

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 at https://docbox.etsi.org/Reference.

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] ISO 14040:2006: "Environmental management -- Life cycle assessment -- Principles and framework".

[2] ISO 14044:2006: "Environmental management -- Life cycle assessment -- Requirements and guidelines".

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 are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TS 102 706 (V1.3.1): "Environmental Engineering (EE); Measurement method for energy efficiency of wireless access network equipment".

[i.2] Void.

[i.3] European Commission - Joint Research Centre - Institute for Environment and Sustainability JRC48211: "International Reference Life Cycle Data System (ILCD) Handbook - Framework and Requirements for Life Cycle Impact Assessment Models and Indicators". First edition March 2010. EUR 24586 EN. Luxembourg. Publications Office of the European Union; 2010.

[i.4] ETSI ES 202 336-1: "Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks) Part 1: Generic Interface".

[i.5] Recommendation ITU-T L.1310 (09/2020): "Energy efficiency metrics and measurement methods for telecommunication equipment".

[i.6] Void.

[i.7] European Commission - Joint Research Centre EUR 25167: "Characterisation factors of the ILCD Recommended Life Cycle Impact Assessment methods" EN - 2012 (20/02/2013 updated).

[i.8] Green House Gas Protocol Corporate Standard, 2006.

[i.9] ISO 14046 (2013): "Environmental management -- Water footprint -- Principles, requirements and guidelines".

[i.10] IPCC (2013): "Climate Change 2013: The Physical Science Basis. Clause 8 Anthropogenic and Natural Radiative Forcing, Appendix 8. A: Lifetimes, Radiative Efficiencies and Metric Values", Table 8.A.1 p 731-738.

[i.11] Recommendation ITU-T L.1400 (03/2023): "Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies".

[i.12] ETSI TS 103 199: "Environmental Engineering [EE]; Life Cycle Assessment (LCA) of ICT equipment, networks and services; General methodology and common requirements".

[i.13] Recommendation ITU-T L.1023: Assessment method for circular scoring.

[i.14] André, H., Söderman, M. L., & Nordelöf, A. (2019). Resource and environmental impacts of using second-hand laptop computers: A case study of commercial reuse. Waste Management, 88, 268-279.

[i.15] Bracquené, E., Lindemann, J., & Duflou, J. (2022). Implementation of circularity indicators in a household product manufacturing company. Procedia CIRP, 105, 660-665.

[i.16] Document C(2021)9332 Commission Recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations C/2021/9332 final.

[i.17] Void.

[i.18] Prakash, S., Köhler, A., Liu, R., Stobbe, L., Proske, M., & Schischke, K. (2016, September). Paradigm shift in Green IT-extending the life-times of computers in the public authorities in Germany. In 2016 Electronics Goes Green 2016+(EGG) (pp. 1-7). IEEE.

[i.19] Proske, M., Clemm, C., & Richter, N. (2016). Life cycle assessment of the Fairphone 2. Fraunhofer IZM.

[i.20] Walzberg, J., Lonca, G., Hanes, R. J., Eberle, A. L., Carpenter, A., & Heath, G. A. (2021). Do we need a new sustainability assessment method for the circular economy? A critical literature review. Frontiers in Sustainability, 1, 620047.

[i.21] Zink, T., Maker, F., Geyer, R., Amirtharajah, R., & Akella, V. (2014). Comparative life cycle assessment of smartphone reuse: repurposing vs. refurbishment. The International Journal of Life Cycle Assessment, 19, 1099-1109.

[i.22] ETSI TR 104 080: "Environmental Engineering (EE); Example of a Life Cycle Assessment (LCA) of a mobile phone".

[i.23] TR 45550:2020: "Definitions related to material efficiency" (produced by CEN/CENELEC).

[i.24] ETSI EN 303 808: "Environmental Engineering (EE); Applicability of EN 45552 to EN 45559 methods for assessment of material efficiency aspects of ICT network infrastructure goods in the context of circular economy".

[i.25] Recommendation ITU-T L.1480: "Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impact greenhouse gas emissions of other sectors".

[i.26] Recommendation ITU-T L.1022: "Circular economy: Definitions and concepts for material efficiency for information and communication technology".

[i.27] Recommendation ITU-T L.1440: "Methodology for environmental impact assessment of information and communication technologies at city level".

[i.28] Recommendation ITU-T L.1410: "Methodology for environmental life cycle assessments of information and communication technology goods, networks and services".

[i.29] x-ADEME September 2022.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

active area: area of the display or touch panel which is useful for touch or viewing

activity data: quantitative measure of a level of activity that results in GHG emissions

NOTE: See Green House Gas Protocol Corporate Standard [i.8], clause 2.2.

black box module: device, system or object which can be viewed solely in terms of its input, output and transfer characteristics without any knowledge of its internal workings

NOTE: In this context the black box module may consist of several part categories such as integrated circuits, mechanics, cables, etc., e.g. a power module on a PCBA.

CO2 equivalent (CO2 e): universal unit of measurement to indicate the Global Warming Potential (GWP) of each of the seven greenhouse gases, expressed in terms of the GWP of one unit of carbon dioxide.

NOTE 1: It is used to evaluate releasing (or avoiding releasing) different greenhouse gases against a common basis

NOTE 2: See Green House Gas Protocol Corporate Standard [i.8], clause 2.2.

commercial lifetime: length of time that a good is owned for before a new one is bought to replace it (often used to estimate the lifetime for consumer products)

comparative assertion: See ISO 14040 [1], clause 3.6.

comparative analysis: analysis aiming to compare two different product systems based on the same functional unit

cradle-to-gate: partial life cycle of ICT goods or parts, from material acquisition through to when they leave the factory gate (e.g. immediately following the production)

NOTE 1: This definition has been amended from GHG Protocol Product Standard.

NOTE 2: E.g. ICT goods ready to be put on the market/sales with no need for further processing.

Customer-Premises Equipment (CPE): any terminal and associated ICT goods located at a subscriber's premises and connected with a carrier's telecommunication channel(s) at the NTPs CPE covers also home office goods

cut-off: amount of energy or material flow or the level of environmental significance associated with unit processes or product system excluded from the study

NOTE: Unit processes excluded from the studied product system in an LCA.

data gap: LCI flows excluded from a unit process within the studied product system

depreciation time: time during which a (new) revenue-generating asset reaches its residual economic value

NOTE: The depreciation time is sometimes referred to as the legal lifetime.

Economic Input-Output approach (EIO): method using tables, called Input-Output (IO) tables, that describe financial transactions between economic sectors in a national economy, to approximate environmental impacts

embodied emissions: life cycle(s) emissions from the following life cycle stages:

- raw material acquisition;
- production; and
- end-of-life treatment.

EXAMPLE: All life cycle stages other than the use stage.

NOTE: Each life cycle includes transportation as generic process as described in the present document.

embodied environmental impact: life cycle(s) environmental impact from the following life cycle stages:

- raw material acquisition;
- production; and
- end-of-life treatment.

EXAMPLE: All life cycle stages other than the use stage.

NOTE: Each life cycle includes transportation as generic process as described in the present document.

emission factor: factor allowing GHG emissions to be estimated from a unit of available activity data (e.g. tonnes of fuel consumed, kWh of electricity, tonnes of product produced) and absolute GHG emissions

NOTE 1: See Green House Gas Protocol Corporate Standard [i.8], clause 2.2.

NOTE 2: E.g. kgCO2e/kWh electricity, kgCO2e/(tonne × km).

end-user goods: any device that can connect to CPE or Networks

EXAMPLE: Laptop, mobile phone.

NOTE: See Annex O for examples.

environmental impact: impact including positive and negative aspects on the environment

environmental impact through the introduction of ICTs: difference between the environmental load reduction effect from the use of ICTs and the environmental load of ICTs

environmental load: environmental aspect which potentially causes interference with environmental conservation

environmental load intensity: numerical value of environmental load per unit

environmental load of ICTs: ICT environmental loads over its life cycle

NOTE: These include the environmental loads of ICT goods, networks and services in the processes of raw material acquisition, production, use and end of life treatment.

environmental load reduction effect from using ICTs: effect that noticeably reduces the environmental load of ICTs

NOTE: The effects of "improving energy efficiency", "improving the efficiency of and reducing the production and consumption of goods" and "reducing the movement of people and goods" are brought about by using ICTs.

extended operating lifetime: aggregated duration of the actual use periods of the first life cycle and possible consecutive life cycles

NOTE1: The user in different life cycles can be the same or different user.

NOTE2: Reuse and refurbishment, enable several use periods and consecutive life cycles.

NOTE3: ETSI EN 303 808 [i.24] definition is aligned with TR 45550:2020 [i.23]

first order effects: direct environmental effect associated with the physical existence of an ICT solution

NOTE 1: The raw materials acquisition, production, use and end-of-life treatment stages, and generic processes supporting those including the use of energy and transportation

NOTE 2: First order effects include environmental impacts, e.g. GHG and other emissions, e-waste, use of hazardous substances and use of scarce, non-renewable resources.

NOTE 3: First order effects are sometimes referred to as environmental footprints.

NOTE 4: This definition has been amended from Recommendation ITU-T L.1480 [i.25] by expanding from GHG emissions to all environmental impacts.

fresh water: water from river, lakes or subsoil water

functional unit: See ISO 14040 [1], clause 3.20.

generic operating system: commercially available software that handles the basic hardware operations such as memory allocation, handling of processes and disk access, as well as the user interface

GHG emission intensity: numerical value of Greenhouse Gas (GHG) emissions per unit

Global Warming Potential (GWP): ratio of the warming of the atmosphere caused by one green house gas to that caused by a similar mass of carbon dioxide

NOTE 1: GWP is calculated over a specific time frame generally 100 years

NOTE 2: See Green House Gas Protocol Corporate Standard [i.8], clause 2.2.

Green House Gases (GHG): for the purposes of this methodology, GHGs are the seven gases listed in the Kyoto Protocol:

- carbon dioxide (CO2);
- methane (CH4);
- nitrous oxide (N2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs);
- sulphur hexafluoride (SF6);
- nitrogen triflouride (NF3).

NOTE: See Green House Gas Protocol Corporate Standard [i.8], clause 2.2.

higher order effect: indirect effect (including but not limited to rebound effects) other than first and second order effects occurring through changes in consumption patterns, lifestyles and value systems

NOTE 1: See Recommendation ITU-T L.1480 [i.25]

NOTE 2: Rebound effects include effects occurring through financial gains, savings in time and space, and others.

NOTE 3: Higher order effects could be associated with both second and first order effects.

hybrid LCAs: method that combines the approach of process-sum and economic input-output LCAs

NOTE: Different models exist, prioritizing data from either process-sum or input-output data.

ICT goods: 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: ETSI TS 103 199 [i.12] instead used the word "equipment".

ICT manufacturer: organization which has the financial and organizational control of the design and production of ICT goods

ICT network: set of nodes and links that provide physical or over the air information and communication connections between two or more defined points

EXAMPLE: Wireless network, fixed network, Local Area Network (LAN), home network and server network, access networks, core networks, cloud computing networks.

ICT service (application): use of ICT goods and/or Networks to provide value to one or more users

EXAMPLE: Teleconferencing, teleworking, e-ticketing, e-learning, e-healthcare, smart transport and logistics, procurement systems, supply chain management systems, music/film distribution over Internet or voice over IP, machine-to-machine systems.

ICT specific data: data emerging from ICT specific applications and processes

NOTE: This data could be either primary or secondary.

ICT specific EoLT: any disassembly/dismantling/shredding/recycling process which needs special adaptation for handling of ICT goods

ICT specific infrastructure: basic structures needed for the operation of the goods, Network or Service

EXAMPLE: Antenna towers, cabling systems.

infrastructure: basic structures needed for the operation of the society

EXAMPLE: Transportation systems, buildings and power plants.

land use: human exploitation of land for agricultural, industrial, residential and recreational purposes

LCA practitioner: person(s) or organization(s) performing an LCA

life cycle: See ISO 14040 [1], clause 3.1.

life cycle stage: one of several consecutive and interlinked stages of a product system

lifetime: duration which may correspond to commercial lifetime, operating lifetime, extended operating lifetime or depreciation lifetime

maintenance: action carried out to retain a product in a condition where it is able to function as required

NOTE 1: See Recommendation ITU-T L.1022 [i.26].

NOTE 2: Examples of such actions include inspection, adjustments, cleaning, lubrication, testing, software update and replacement of a wear-out part. Such actions could be performed by users in accordance with instructions provided with the equipment (e.g. replacement or recharging of batteries); or the actions could be performed by service personnel in order to ensure that parts with a known time to failure are replaced in order to keep the product functioning.

mandatory activity: unit process which is significant to the result and therefore needs to be included

modelled data: assumption-driven estimates, such as estimates resulting from scenarios, which are forward looking or scaled up from smaller pilot studies

natural resource: material source, such as wood, water, or a mineral deposit, that occurs in a natural state

Network Termination Points (NTP): points established in a building or complex to separate CPE from telephone company goods

node: point in a Network topology at which lines intersect or branch

operating lifetime: duration of the actual use period (consisting of both active and non-active periods) for the first user

NOTE: Storage time is not included in operating lifetime.

operator: organization operating Networks and ICT goods and Services

optional activity: unit process which can be left out of the LCA because of low significance, low precision, general lack of data or other practical reasons

organizational data: data that describe central characteristics of organizations, their internal structures and processes as well as their behaviour as corporate actors in different social and economic contexts

other EoLT: any disassembly/dismantling/shredding/recycling process which does not need special adaptation for handling of ICT goods but could be used for any kind of good

part: constituent of ICT goods and Support goods

EXAMPLE: Cable.

part category: classification of a part e.g. by its type

EXAMPLE: Fibre cable.

potential environmental load reduction effect: potential environmental load reduction which is expected due to the progress of ICTs throughout society, but which is not expected to take place immediately

primary data: See ISO 14046 [i.9], clause 3.6.1.

NOTE 1: In practice, primary data may be emission factors and/or activity data.

NOTE 2: Primary data includes site-specific data, i.e. data from one specific unit process within a site; and site-average data, i.e. representative averages of site-specific data collected from organizations within the product system which operate equivalent processes.

primary energy: the energy content of natural resources which can be used for energy production

primary raw material: material which origins from natural resources

process category: classification of a process type

EXAMPLE: Landfill, Air, Ship and Train.

processed materials: raw materials which have been physically and/or chemically changed by humans

process-sum approach: method using facility-level data describing processes in terms of the inputs of materials and energy, outputs of products and waste and emissions

product system: See ISO 14040 [1], clause 3.28.

public data: data which is available to the public without access being restricted by requirements on membership, none-disclosure agreements, or similar

ratio of recycled raw material content: amount of recycled raw material in relation to the amount of primary raw material used as input to production

raw material: See ISO 14040 [1], clause 3.15.

raw material extraction: production of extracted raw materials used in raw material processing

raw material processing: production of processed raw materials used in Part production

raw material recycling: production of raw materials from recycled products

recommended activity: unit process potentially significant to the result and which should be included in the LCA

recycling rate of disposed raw material: rate with which disposed goods ends up in a recycling process is part of the scope of the LCA

reference product system: (basically non-ICT but can also be ICT) system which is replaced by ICT

EXAMPLE: Traditional Service which is replaced by an ICT Service.

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: See Recommendation ITU-T L.1023 [i.13], clause 3.2.10.

NOTE 2: New and/or used parts can be used during refurbishment.

repair: process of returning a faulty product to a condition where it can fulfil its intended use

NOTE: See TR 45550:2020 [i.23].

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

NOTE 1: Reuse after second or subsequent usage is also considered as reuse, but normal, regular or sporadic use is not considered as reuse (TR 45550:2020 [i.23] and ETSI EN 303 808 [i.24]).

NOTE 2: ICT goods usage by a new user or in a new context is considered to be reuse.

NOTE 3: Definition amended from ETSI EN 303 808 [i.24] with additional Note 2.

second order effect: indirect impact created by the use and application of ICTs which includes changes of environmental load due to the use of ICTs that could be positive or negative

NOTE 1: See Recommendation ITU-T L.1480 [i.25]

NOTE 2: Second order effects can be either actual or potential.

secondary data: See ISO 14046 [i.9], clause 3.6.2.

NOTE: Such sources can include databases (a list of LCA databases (publicly available and licence based) provided by the EU, published literature, national inventories and other generic sources.

secondary raw material: material which origins from recycled primary raw materials

service provider: organization operating a service (could be the same organization as the operator organization)

storage time: length of time for which the goods are stored, including both the before and after its use stage

support activity: activities supporting unit processes associated with the function of the goods, Network or Service

NOTE: Examples of support activities are activities directly associated with the product system such as marketing, development and sales and also more general activities of the organization such as data support, communication and financial support.

support goods: device, system or object needed to realize the function of support the use of ICT goods

EXAMPLE: Goods for power supply and temperature regulation.

NOTE: See ETSI ES 202 336-1 [i.4] for explanation which defines support goods for networks as infrastructure goods.

the 100/0 method: allocation method that allocates the primary raw material acquisition processes fully to the studied product system

NOTE: No recycling is assumed to occur at End-of-Life.

the 0/100 method: allocation method that allocates 0 % of the primary Raw Material Acquisition processes to the studied product system

NOTE: 100 % recycled Raw Material is assumed as input to the studied life cycle.

the 50/50 method: allocation method that allocates the credits equally to the life cycle using and the one supplying recycled material

NOTE: In reuse/refurbishment scenarios, the LCA practitioner needs to clearly declare how the allocation of raw materials has been handled in the assessment.

traffic: total volume of cells, blocks, frames, packets, calls, messages, or other units of data carried over a circuit or Network, or processed through a switch, router or other system

unit process: smallest element considered in the life cycle inventory analysis for which input and output data are quantified

NOTE: See also ISO 14040 [1] and ISO 14044 [2].

EXAMPLE: Part unit process such as IC Encapsulation and Display module assembly.

waste: See ISO 14040 [1], clause 3.35.

3.2 Symbols

Void.

3.3 Abbreviations

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

3G	Third generation telecom networks
4G	Fourth generation telecom networks
ABS	Acrylonitrile Butadiene Styrene
AC/DC	Alternating Current Direct Current
ADSL	Asymmetric Digital Subscriber Line
AM	Acquisition Method
BAT	Best Available Technology
BGA	Ball Grid Array
BOD	Biochemical Oxygen Demand
BOM	Bill of Materials
BS	Base Station
BSC	Base Station Control site
CAS	Chemical Abstracts Service
CATV	Cable Access Television
CC	Climate Change
CD	Compact Disc
CDMA	Code Division Multiple Access
CED	Cumulative Energy Demand
CFC	Chloro Fluoro Carbons
CO	Carbon Monoxide
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
CPE	Customer Premises Equipment
DALY	Disability Adjusted Life Years
DR	Data Representativeness
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
DVD	Digital Versatile Disc
EA	Eutrophication Aquatic
EHW	Environmentally Hazardous Waste
EI	Environmental Impact
EIICT	Environmental Impact of ICT
EIO	Economic Input-Output
eNB	evolved Node B
EOL	End Of Life
EoLT	End of Life Treatment
EPC	Evolved Packet Core
ET	Eutrophication Terrestrial
ETFW	Ecotoxicity Freshwater
E-UTRAN	Evolved Universal Mobile Telecommunications System Terrestrial Radio Access Network

FAN	Fixed Access Node
FWT	Fixed Wireless Terminal
GB	GigaByte
GC	Geographical Correlation
GGSN	Gateway GPRS Support Node
GHG	Green House Gas
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GWP	Global Warming Potential
GWY	Gateway
HD	High Density
HFC	Hydro Fluoro Carbons
HLR	Home Location Record
HTC	Human Toxicity Cancer effects
HTNC	Human Toxicity Non-Cancer effects
HW	Hardware
IC	Integrated Circuit
ICT	Information and Communication Technology
ILCD	International Reference Life Cycle Data System
IP	Internet Protocol
IPCC	Intergovernmental Panel on Climate Change
IPTV	Internet Protocol Television
IRE	Ionizing Radiation Ecosystems
IRH	Ionizing Radiation Human health
LAN	Local Area Network
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LD	Low Density
LED	Light Emitting Devices
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
LR	Location Register
LTE	Long Term Evolution
LU	Land Use
MC	Methodological Consistency
MGW	Media Gateway
MJ	Megajoule
MMC	Multimedia Messaging Centre
MME	Mobility Management Entity
MS	Mobile Station
MSC	Mobile Switching Center
NMHC	Non Methane Hydrocarbons
NMVOC	Non-methane Volatile Organic Compounds
NOX	Nitrogen Oxides
OD	Ozone Depletion
ODP	Ozone Depletion Potential Indicator
OLED	Organic Light Emitting Diodes
OLT	Optical Line Terminal
OM	Operational Maintenance
ONU	Optical Network Unit
OTN	Optical Transport Network
PA	Polyamide
PAH	Polycyclic Aromatic Hydrocarbon
PBA	Printed Board Assembly
PBX	Private Branch Exchange
PC	Personal Computer
PCB	Printed Circuit Boards
PCBA	Printed Circuit Board Assembly
PDH	Plesiochronous Digital Hierarchy

PDP	Plasma Display Panel
PE	PolyEthylene
PEF	Product Environmental Footprint
PET	Polyethylene Terephthalate
P-GW	Packet Data Network Gateway
Pkt sw	Packet Switch
PMMA	Polymethyl-Methacrylate
POF	Photochemical Ozone Formation
PP	Polyproylene
PS	Polystyrene
PTFE	PolyTetraFluoroEthylene
PUR	Polyurethane
PVC	PolyVinyl Chloride
RAN	Radio Access Networks
RBS	Radio Base Station
RDMR	Resource Depletion Mineral Resources
RDW	Resource Depletion Water
RI/PM	Respiratory Inorganics/Particulate Matter
RIE	Rule Inclusion Exclusion
RMA	Raw Material Acquisition
RNC	Radio Network Controller
ROADM	Reconfigurable Optical Add/Drop Multiplexer
RSS	Remote Subscriber Switch
SAC	Sn/Ag/Cu alloys
SAN	Styrene Acrylonitrile
SDH	Synchronous Digital Hierarchy
Secur. GW	Secure Gateway
SGSN	Serving GPRS Support Node
S-GW	Serving Gateway
SI	Supplier Independence
SMS	Short Messaging Service
SOHO	Small Offices Home Offices
SPLT	Splitter
STB	Set Top Box
STM	Synchronous Transport Module
SW	Software
TC	Technological Correlation
TOE	Total Oil Equivalent
TV	Television
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UN	United Nations
UPS	Uninterruptable Power Supply
USGS	United States Geological Survey
UV-B	Ultraviolet B
VDSL	Very-high-bit-rate Digital Subscriber Line
VLR	Visitor Location Register
VOC	Volatile Organic Compounds
VoIP	Voice over Internet Protocol
WAN	Wide Area Network
W-CDMA	Wideband Code Division Multiple Access
WDM	Wavelength Division Multiplexer
WE	Water Eutrophication indicator
WEEE	Waste Electrical and Electronic Equipment
WLAN	Wireless Local Area Network

4 Void

Part I: ICT life cycle assessment - framework and guidance

5 General description

5.1 General description of an LCA

An environmental Life Cycle Assessment (LCA) is a systematic analytical method by which the potential environmental effects related to ICT goods, networks and services can be estimated. LCAs have a cradle-to-grave scope where all the life cycle stages (raw material acquisition, production, use and end-of-life treatment) are included. Moreover, transport and energy supplies are included at each stage of the life cycle assessment.

LCA became internationally standardized by the International Organization for Standardization (ISO) with the publication of the ISO 14040 [1] series of life cycle assessment standards representing an important step to consolidate procedures and methods of LCAs.

As an addition to ISO 14040 [1] and ISO 14044 [2], the European Commission has published a handbook [i.16] that gives detailed guidance on all the steps required to conduct an LCA.

ICT goods, networks and services are associated with the environmental load emerging from different processes over the life cycle. The environmental impact caused by this environmental load is sometimes referred to as first order effects.

By definition, LCA considers the full life cycle, i.e. no life cycle stages should be excluded a priori. However, if a life cycle stage is found to have a limited impact on the results and conclusions of an LCA, the corresponding life cycle stage or items in the life cycle stage may be excluded in accordance with applicable rules for cut-off.

The present document shall also apply to studies not covering the full life cycle. In this case, see clause A.1.2 in ISO 14040 [1].

ICT goods, networks and services have the potential to reduce the environmental load and impact by reducing the amount of energy consumption and materials used in society. This potential of reducing the environmental impact is referred to as second order effects and is covered by Part II (clauses 11 to 14).

Often the impact from second order effects outweighs the first order effects, leading to a net positive environmental impact when systems of ICT goods, networks and services are applied.

The ISO LCA standards define four phases of an LCA study:

- Goal and scope definition.
- Life Cycle Inventory (LCI).
- Life Cycle Impact Assessment (LCIA).
- Life cycle interpretation.

To report the results of an LCA study, ISO also defines a critical review and reporting as additional steps in addition to these phases.

LCA is by nature an iterative technique, where each phase or step is dependent on the results or methodologies used in another (previous or subsequent) phase or step. For example, defining the studied product system is a step that directly impacts on the subsequent steps of boundary setting, data collection and allocation. When performing an LCA of ICT goods, networks and services, the eight checklist items specified in clause 6.2.3.5.2 should be considered in the system boundary setting to identify activities associated with the ICT goods, networks and services life cycle for which data will be collected. Other items may also exist.

Figure 3 shows the framework of Part I which is based on Figure 1 of ISO 14040 [1].

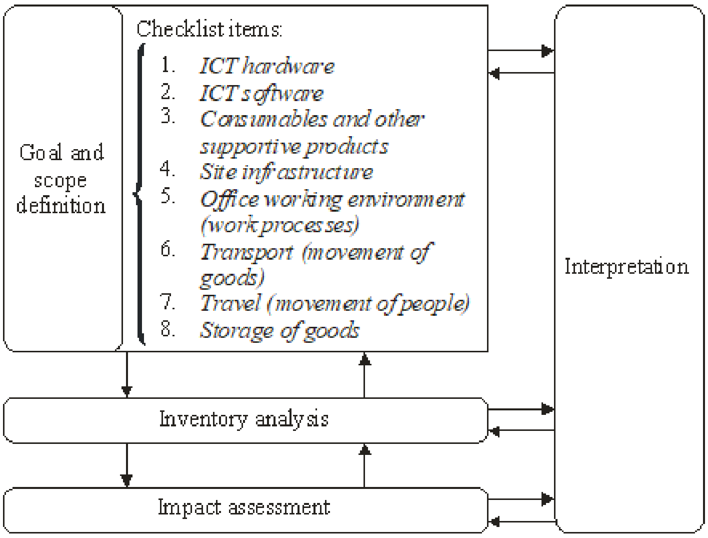

Figure 3: Framework of Part I of the present document

5.2 Compliance to the present document

The present document contains requirements (denoted as mandatory or by the use of the word shall), recommendations (denoted by the use of the word should) and options (denoted as optional or by the use of the word may).

Requirements are summarized in Annex W.

In addition the present document contains numerous recommendations which also need consideration.

Full compliance towards the present document can be claimed if all mandatory requirements are fulfilled.

LCAs can also partially comply to the present document by complying to the majority of mandatory shall requirements; however, they are unable to fulfil all of them due to data gaps, a lack of transparency in databases and so forth.

In both cases the fundamental LCA principles of relevance, completeness, consistency, accuracy and transparency shall guide the LCA practitioner.

As stated in the scope, clause 1 it is acknowledged that full compliance to the present document may not be possible at this stage, especially at the Network and Service level, where some data may be based on already published LCAs of ICT goods, which, especially initially, may not be in accordance with the present document.

The compliance statement contained in the present document should disclose and explain any deviations from the requirements and the use of non-compliant data.

5.3 Comparisons of results

It is important to realize that comparisons of results (absolute and relative values) between LCAs are beyond the scope of the present document, as such comparisons would require that the assumptions and context of each LCA are exactly equivalent.

LCA can be performed and presented by different individuals/organizations or by the same individual/organization. However, comparisons of LCA results obtained by the same individual/organization who/which uses:

1) the present document;

2) the same LCA tool; and

3) the same LCI databases for all comparables are supported by the present document. A third-party review is also needed if the comparison result is to be externally communicated.

In case of comparative assessment between ICT goods LCAs, the operating lifetime shall be set to equal. Differences in lifetime could only be accepted if they reflect differences in actual characteristics.

5.4 Relationship between methodologies of LCAs for ICT goods, networks and services

Figure 4 shows the product systems targeted by the impact assessment methodologies of ICT goods, ICT networks and ICT services. In this context, ICT networks and ICT services can be seen as logical structures, which are physically made up by ICT goods, including hardware and software, but also rely for instance on building premises, civil works to create cable ways, air conditioning, power generators and power storage such as UPS.

ICT services
ICT networks
ICT goods

Figure 4: Relationship between ICT goods, networks and services

As ICT networks are composed of ICT goods and as ICT services utilize ICT networks, the methodology for ICT goods is the basis for the methodologies for ICT networks and ICT services. In other words, the methodology for ICT networks is based on the methodology for ICT goods and the methodology for ICT services accommodates both methodologies for ICT goods and networks. Consequently, the environmental impact assessment of ICT networks reflects the environmental impact of ICT goods employed in the ICT networks and the environmental impact assessment of ICT services reflects the environmental impact assessments of ICT goods and ICT networks employed in the ICT services.

ICT networks and ICT services are not physical entities but logical concepts which are built upon ICT goods. For this reason, it could be difficult to define their assessment boundaries in detail. Consequently, it is important that their boundaries do not overlap to avoid any double counting effect when an ICT service is assessed with both ICT goods and networks.

Due to the use of ICT goods, networks and services in projects, organizations, cities and countries, the present document may form a basis for the environmental impact assessment methodologies for those assessment purposes (Recommendation ITU-T L.1400 [i.11]).

6 Methodological framework

6.1 General requirements

6.1.1 Life cycle stages

When performing an ICT related LCA, the requirements of the present document shall apply as well as those of ISO 14040 [1] and ISO 14044 [2]. I.e. all three standards have to be taken into account.

The following four high-level life cycle stages shall apply to ICT goods, Networks and Services and shall be assessed as applicable in LCAs which are based on the present document in accordance with the goal and scope:

- Goods Raw material acquisition which is composed of:
  - Raw material extraction.
  - Raw material processing.
- Production which is composed of:
  - ICT goods production (including refurbishment)

- Support goods production. Use which is composed of:
  - ICT goods Use.
  - Support goods Use.
  - Operator support Activities.
  - Service Provider support Activities.
- Goods End of Life Treatment (EoLT) which is composed of:
  - Preparation for extended operating lifetime
  - ICT specific EoLT.
  - Other EoLT.

NOTE 1: Production waste is allocated to the production stage see clause 6.3.3.2.

If all these life cycle stages have not been assessed, this should be stated when reporting.

For guidance on software refer to clause 6.1.3.

Impacts from transports and energy supplies shall be included in all life cycle stages. Deviation(s) from this requirement shall be clearly motivated and reported.

NOTE 2: The assessment of the raw material acquisition stage is generally based on secondary data from databases. At the time of publication, to collect appropriate data related to raw materials transport and to separate data related to raw material acquisition stage and production stage is considered challenging due to LCA tool limitations, lack of data, limitations in data granularity and the nature of ICT supply chains.

It is important that all transports within and between life cycle stages are included in the assessment, for instance transports of goods between production and use stages shall be taken into account. The data collected shall be structured in such a way that the GHG emissions and energy consumption/environmental impact arising from the transport processes could be reported transparently as far as possible.

It is optional to include the construction of plants in which ICT or Support goods are manufactured.

If construction of factory is included in the assessment, impact per product is to be calculated by following allocation rules in clause 6.3.3 and cut-off rules in clause 6.2.4 when applicable.

Table 2 in clause 6.2.3.1 defines the detailed life cycle stages which further defines the system boundary and which are to be considered when assessing the life cycle impact of ICT goods, networks and services. In particular, it is important to cover all processes which are marked as mandatory in that table.

The system boundaries outline the life cycle activities that are of relevance to define the life cycle of the ICT goods, Networks and Services to be assessed. Within these system boundaries, the cut-off rules according to clause 6.2.4 shall apply. This means that activities that are found negligible may be cut-off although they are within the system boundary.

The study report should transparently show and justify whenever processes marked with Mandatory are not taken into account.

Throughout the life cycle some processes will reoccur several times, e.g. unit processes associated with the life cycle impact of electricity use, transports and travel. These processes are referred to as generic processes and are further described in Annex D.

Also Annex N gives additional information on the different stages and on the interfaces between the processes.

6.1.2 ICT goods with multiple life cycles

ICT goods may experience different forms of extended lifetime for example by means of reuse or refurbishment. Products that are reused or refurbished will enter a new life cycle (as part of extended operating lifetime). At the end of product's use stage, a decision about product's future is done - whether it goes to reuse or refurbishing, or to waste processing. An assessment boundary shall be established at the point where the current life cycle ends and a new life cycle starts (second use). The environmental impact associated with the product that does not proceed to the next life is considered in waste management (EoLT) of the first (or current) life and environmental impact associated with the refurbishment production process (making it fit for second use) is considered in production stage of the next life.

6.1.3 The goods, networks and services Product System

6.1.3.0 Introduction

The ICT goods, networks and services product system to be assessed shall be clearly described as well as relevant functions and characteristics.

6.1.3.1 ICT goods

For the ICT good under study, applicable types of parts, as well as the amounts of these, shall be defined.

In-depth information about the product composition is required before setting the system boundary of the product. Often, Bill Of Material (BOM) data (where parts information including mass and material composition is listed) is necessary to understand the full product composition. Table E.1 provides generic information about the composition of ICT goods. A process tree showing the interconnectivity among parts and various items in each life cycle of ICT goods can be developed using the product composition information. By arranging parts in descending order of mass and by calculating the cumulative mass of each part, a basis is given for a cut-off of insignificant parts from the product system. Note however that other cut-off criteria shall apply as well.

6.1.3.2 ICT networks

An ICT network is an ICT based infrastructure which offers the possibility to transfer voice and/or data between different access points, usually referred to as nodes and also further on to the end users (e.g. represented by a mobile phone or a PC).

ICT networks are often grouped into fixed and wireless networks. Each ICT network consists of:

a) customer premises (e.g. terminal, terminating goods and protectors);

b) access network goods (e.g. telephone poles, conduits, changers, local switches and base stations); and

c) core networks (e.g. routers and transmitters).

Figure 5 gives an example of the physical layer of a fixed network.

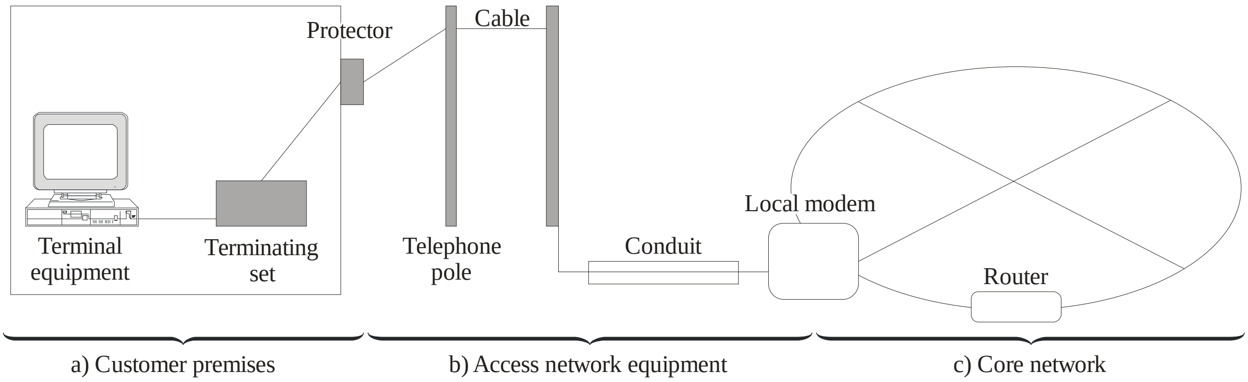

Figure 5: Fixed telecommunication network - simplified physical view

Ultimately the total network may be studied, taking into account both fixed and wireless networks and the connection between them. However, a study may also focus on just a part of the network. In the goal and scope phase it shall be outlined which network building blocks are covered.

For the ICT network under study, applicable types of nodes and infrastructure, as well as amounts of these, shall be defined.

Annex J details the most frequently adopted ICT networks in use today. However, the present document is not restricted to these networks but shall also apply when assessing any existing or future networks.

Examples of how the functional unit, system boundaries and the data to be gathered may be defined are given in ETSI TR 104 080 [i.22].

6.1.3.3 ICT services

For the ICT service under study, applicable types of ICT network elements and infrastructure, as well as the amounts of these, shall be defined.

6.1.4 Handling of software

6.1.4.1 General

Software shall be considered as well as hardware.

Any ICT good, network or service consists of both hardware and software which both impacts, e.g. the production and use stages. Moreover, software may also be an assessment target in itself. For the production stage software development impacts on the number of people involved in the development work and thus impacts on the amount of buildings and travel associated with the development of the ICT good or Network, in the same way as hardware development. For the use stage the software impacts, e.g. maintenance and energy use. In general it is not relevant to distinguish between software and hardware impact for the use stage but rather to focus on the impact from the ICT goods or Network or Service as such.

For specific software applications, such as music distribution applications, the software is to be seen as an ICT service and shall be assessed according to the requirements outlined for services. In these cases the hardware needed to operate the software shall be considered as well. This development is either within B1.3 or B1.1.11 (see Figure 9) depending on where the software is developed.

Due to the uncertainties of allocation it is optional to consider the embedded impact from use of generic operating systems and other widely spread software (e.g. simulation tools) when assessing the software impact, also the life cycle impact of this software may be considered negligible for the users of the operating systems.

However, for the developer of this software the impact of the usage of this software shall be taken into account.

6.1.4.2 Assessment of software

Many software products are used in ICT goods, Networks and Services. The software categories include, but are not limited to, operating systems, middleware (information system management, databases, etc.), application software (software for electronic applications, etc.) and software customized for specific users, according to the structure shown in Figure 6.

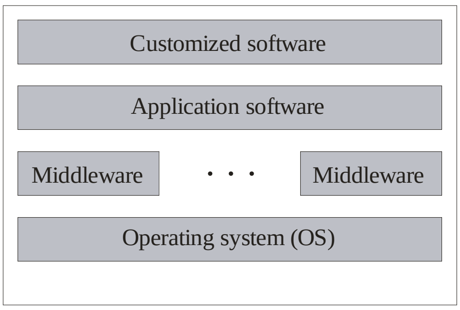

Figure 6: Software structure of an ICT system (example)

A user, e.g. an operator, often designs or purchases customized software and also purchases other shared software. Table 1 goes further than Figure 6 and provides the corresponding allocation principles.

Table 1: Classification and allocation principles for ICT software

Type	Classification	Category	Allocation embedded of environmental impact
1	Customized software developed specifically for or by the user	Customized software	1
2	Shared software developed for general purposes	Application software (e.g. system software for electronic application)	1/L (see note)
3		Middleware (e.g. information system management, database and others)	1/M (see note)
4		Operating system	1/N (see note)
NOTE:	L = sales volume of Application software (e.g. system software for electronic application) M = sales volume of Middleware N = sales volume of Operating system.		

It is not necessary to report the sales volumes L, M and N.

As stated in clause 6.1.4.1, generic operating systems should not be included in assessments performed by its user as the uncertainty of allocation is high.

For details on assessment of software, refer to Annex A.

6.1.5 Operating lifetime

Operating lifetime is critical for the interpretation of the results of LCAs and shall therefore always be reported when presenting LCA results. Operating lifetime estimates and assumptions shall also be clearly described in the reporting.

Operating lifetime can only be defined for goods. In general the lifetime of an ICT network cannot be defined as a network lifetime with one start date and one end date, instead the network is continuously built out, upgraded etc. and the associated operating lifetimes are therefore the lifetimes of the individual nodes. The same is valid for ICT services. However, in some cases temporary networks could be established for a limited amount of time. For such networks an operating lifetime is applicable.

Operating lifetime should be based on available information on actual goods use (e.g. statistics for similar goods, networks and services or information on commercial lifetime) and should model a real operating lifetime as closely as possible. If information on actual use of goods, networks and services cannot be found, economical statistics may be used to estimate operating lifetime, e.g. depreciation time. However, such estimates are considered as less accurate and should be avoided.

NOTE: If the LCA is used to estimate historic environmental impact, actual use time may be available and can then be used. In most cases an actual operating lifetime is not available and estimates are needed.

Storage time is not included in operating lifetime.

When available, results for a known extended operating lifetime, taking into account also any reuse should be reported together with any corresponding information about the first use. Extended operating lifetime is estimated according to the same principles as the (first) operating lifetime.

6.2 Goal and scope definition

6.2.1 Goal and scope of the study

In accordance with ISO 14040 [1], the goal of an LCA states:

- the intended application;
- the reasons for carrying out the study;

- the intended audience, i.e. those to whom the results of the study are intended to be communicated;
- whether the results are intended to be used in comparative assertions intended to be disclosed to the public.

During the LCA scoping phase the building blocks of the ICT goods, Networks or Services shall be identified including software.

NOTE: These building blocks are preferably identified from functional block diagrams provided, e.g. by system engineers/architects.

Schematically three main levels of targeted product systems exist:

- Goods (ICT goods and Support goods).
- Network (ICT Network).
- Services (ICT Service).

In addition software may be assessed according to clause 6.1.3.

All these product systems use ICT goods which follow the life cycle stages introduced in clause 6.1.1 and further described in this clause.

Goods refer to the different physical products, with associated software, constituting the Network. ICT and Support goods consist of, e.g. Electronic Parts, Mechanical Parts, Cooling Parts and Cables.

Printed Circuit Board Assemblies (PCBA) and shelves are examples of included Parts. The PCBAs consist of printed circuit boards, integrated circuits and other parts.

In summary, any ICT goods, including end-user ICT goods, which can be part of a Network delivering voice and/or data lies within the scope of the present document. A hierarchical view is suitable for describing Networks. At the top level, different types of ICT goods can be identified, e.g. Network nodes, End-user goods and Services such as video conferencing.

6.2.2 Functional unit

6.2.2.1 General

It is required to define a functional unit for the LCA. The functional unit shall be chosen in accordance with the goal and scope of the LCA. An ICT goods, Network or Service has a number of possible functions and the one(s) selected for an LCA depend(s) on the goal and scope of the specific LCA. e.g. a mobile phone/device may have several functions: phone calls, text messaging, emailing, use the internet, camera, music player, etc.

The functional unit defines the performance characteristics delivered by the ICT goods, networks and services being studied. The functional unit shall have a function and a quantifiable unit measuring the performance of that function.

The functional unit requires inclusion of the relevant quantifiable properties and the technical/functional performance of the system. This means that the operating lifetime of all included ICT goods shall be specified and also the number of users/subscribers supported by the Network and the traffic profile shall be included where applicable.

The primary purpose of a functional unit is to provide a *reference* to which the inputs and outputs are related or normalized (in a mathematical sense). Such a reference is necessary to ensure comparability of LCA results. Comparability of LCA results is particularly critical when different systems are being assessed, to ensure that such comparisons are made on a common basis. Equivalency between two systems shall be ensured by selection of a relevant function and functional unit.

NOTE 1: Comparisons are only possible if assumptions and other conditions are equivalent.

NOTE 2: The identification of the common basis could be challenging for comparisons of ICT Services and reference product systems. It is important to determine the reference flow in each product system, in order to fulfil the intended function, i.e. the amount of products needed to fulfil the function.

NOTE 3: Depending on the scope of the LCA assessment and the function(s) of the ICT good selected, the relevant intensity feature and performance parameter might vary; therefore, the LCA practitioner needs to consider these aspects when defining the functional unit.

The functional unit shall be clearly defined and measurable.

Based on the functional unit, the reference flow (amount of ICT goods, ICT network or ICT service needed to fulfil the function) is determined. The reference flow shall reflect the chosen functional unit.

Example (storage server):

The function of storage servers is to provide formatted capacity. The functional unit is "A storage subsystem providing one terabyte of formatted capacity to be suited for the needs of the purchasing customer for one year".

The reference flow is $\frac{Life\ Cycle\ Inventory}{Capacity\ (TB) \times Lifetime(year)}$

Example (laptop):

The function experienced by a user of an (offline) laptop is the ability to handle documents, use multimedia, etc. The corresponding functional unit could then be usage of laptop applications, ten hours per week during an operating lifetime (e.g. 4 years). The corresponding reference flow is defined as one laptop sales package.

Comparing LCAs and tracking performance changes over time require that the assessments are based on the same function and functional unit. Therefore, selecting the right function(s) of the studied product is crucial to track emission reductions over time.

Quantitative and qualitative aspects needed to define the function should be considered when defining the functional unit, e.g. data transmitting speed for a certain quality level, the number of users/subscribers supported and the traffic profile.

A well-defined functional unit thus considers the following aspects:

- the magnitude of the function or service;
- the duration or operating lifetime of that function or service;
- the expected level of quality.

Specific attention on selection of the functional unit for goods is needed if the goal of the result from the LCA study is to communicate the results to the public in order to enable a correct interpretation of the results.

NOTE 4: Comparisons are only possible if assumptions and other conditions are equivalent.

The explanation of the common basis could be challenging for comparisons of ICT Services and reference product systems. It is important to determine the reference flow in each product system, in order to fulfil the intended function, i.e. the amount of products needed to fulfil the function.

6.2.2.2 ICT goods

The functional unit shall be chosen in the context of goal and scope of the LCA and shall be further clarified by system boundary and cut-off rules. *ICT goods* LCA results may be further used as basis for *Networks* and *Services* LCA.

To comply with the present document, the following functional unit shall be applied where applicable:

- annual ICT goods use (per one year of ICT good use); or
- total ICT good use per lifetime of ICT good.

For relevant LCA results realistic use scenarios shall be captured. Additionally, other more specific functional units may be applied as well based on the scope and purpose of the LCA.

For ICT goods, additional more specific functional units may also be considered when the result is presented, e.g. the time during which one uses a phone and the number of e-mails sent. The reference flow could be one sales package of an ICT good (e.g. one server, one PC or one phone), including all inbox materials package may vary from one package to another package or from company to company, the content considered should be described in the assessment together with the results.

Specifically, for ICT network infrastructure goods intensity features are often suitable for the functional unit, e.g. product system providing a certain capacity per year, with the typical reference flow being "life cycle inventory/(capacity of product×lifetime of product).

Example (mobile phone):

The function of overall usage of a mobile phone is studied from cradle to grave. The mobile phone provides several sub-functions, e.g. phone calls, text messages, e-mails, use of Internet, camera and music player, but in this case the aggregated use of the phone is the focus. The function is thus the provision of smart phone capabilities. The functional unit is then "the use of a model X smartphone during an operating lifetime of three years". The reference flow is one sales package of the model X smartphone.

Example (software):

The function experienced by a user of a word processor program is to deliver word processing of documents electronically. The corresponding functional unit could then be the number of pages processed per time unit (e.g. one hour) during the operating lifetime (e.g. three years). Further, the reference flow is defined as one unit of word processing software (distributed e.g. in a CD with packaging).

6.2.2.3 ICT networks

ICT networks can be seen as a system composed of different types of ICT goods. For the purpose of the present document the following functional unit shall be applied where applicable for ICT networks used during at least one year:

- annual network use.

For relevant LCA results realistic use scenarios shall be captured.

Additionally, other more specific functional units may be applied as well based on the scope and purpose of the LCA, for instance: Annual Network use per amount of users, or per transmitted data, or coverage area (if applicable).

The annual network use should be defined with respect to a traffic scenario to make it possible to define the reference flow, i.e. the number of different node types needed to perform the intended function.

If using more specific functional units it is recommended to base them on data which is easily understood by the users, e.g. the functional unit of the circuit switching type and the packet switching type should be expressed in terms of communication time and amount of information, respectively.

To achieve consistency between LCAs for ICT, it is recommended to always use the basic functional unit and then to add others as needed.

It shall be noted that comparison between different systems shall reflect the information flow as well. Furthermore, ISO 14040 [1] and ISO 14044 [2] standards state that comparison between results from different studies is not allowed unless the studies are based on the same assumptions. The conclusion is that great care shall be taken before using such studies for any kind of comparison to other systems.

Example (ICT network):

A mobile telecommunication system has a large number of different functions working on different system levels. From an end-user customer point of view the basic function of a mobile communication system is to be able to communicate. The basic functionality of a mobile communication system is thus the possibility to communicate with speech and data "anywhere, anytime".

The functional unit is "one year of operation of a mobile communication system". To be able to make comparisons between different systems and to make the functional unit unambiguous, it shall be noted that the mobile communication system shall be defined further, with a number of factors such as the number of subscribers and the coverage area. A traffic model shall also be defined. It is possible also to relate the results of one system to the number of subscribers it supports. The functional unit may then be expressed as "one year of operation of a mobile communication system per subscriber".

The reference flow is the number of goods needed to perform the requested function.

6.2.2.4 ICT services

For the purpose of the present document, the following functional unit shall be applied where applicable:

- annual Service use.

For relevant LCA results realistic use scenarios shall be captured.

Additionally, other more specific functional units may be applied as well based on the scope and purpose of the LCA.

Corresponding realistic use scenarios shall be defined. The *annual Service* use shall be defined with respect to the usage scenario to make it possible to define the reference flow, i.e. a series of ICT goods involved with an ICT service to perform the functional unit. Generally these amounts are based on an allocation of network capacity between the service under study and other services.

6.2.3 System boundaries

6.2.3.1 General

NOTE 1: Clause 4.2.3.3 of ISO 14044 [2] also applies.

The system boundaries define the unit processes across the life cycle of the studied ICT goods, networks and services that are to be assessed in terms of data collection and calculation of environmental load.

The life cycle stages and the unit processes that shall apply to the analysed product system are those required for providing its function as defined by its functional unit. The selection of the system boundary shall be consistent with the goal of the study. Consequently, the system boundaries here define the life cycle stages and the unit processes that shall be taken into account in an LCA of an ICT product system.

Figure 7 shows the system boundary of an LCA of *ICT goods*, *Networks* and *Services*. The boxes A to D denote the life cycle stages of the ICT product system. The boxes for G1 to G7 in Figure 7 denote generic processes that reoccur several times during these life cycle stages. These processes are further defined in Annex D.

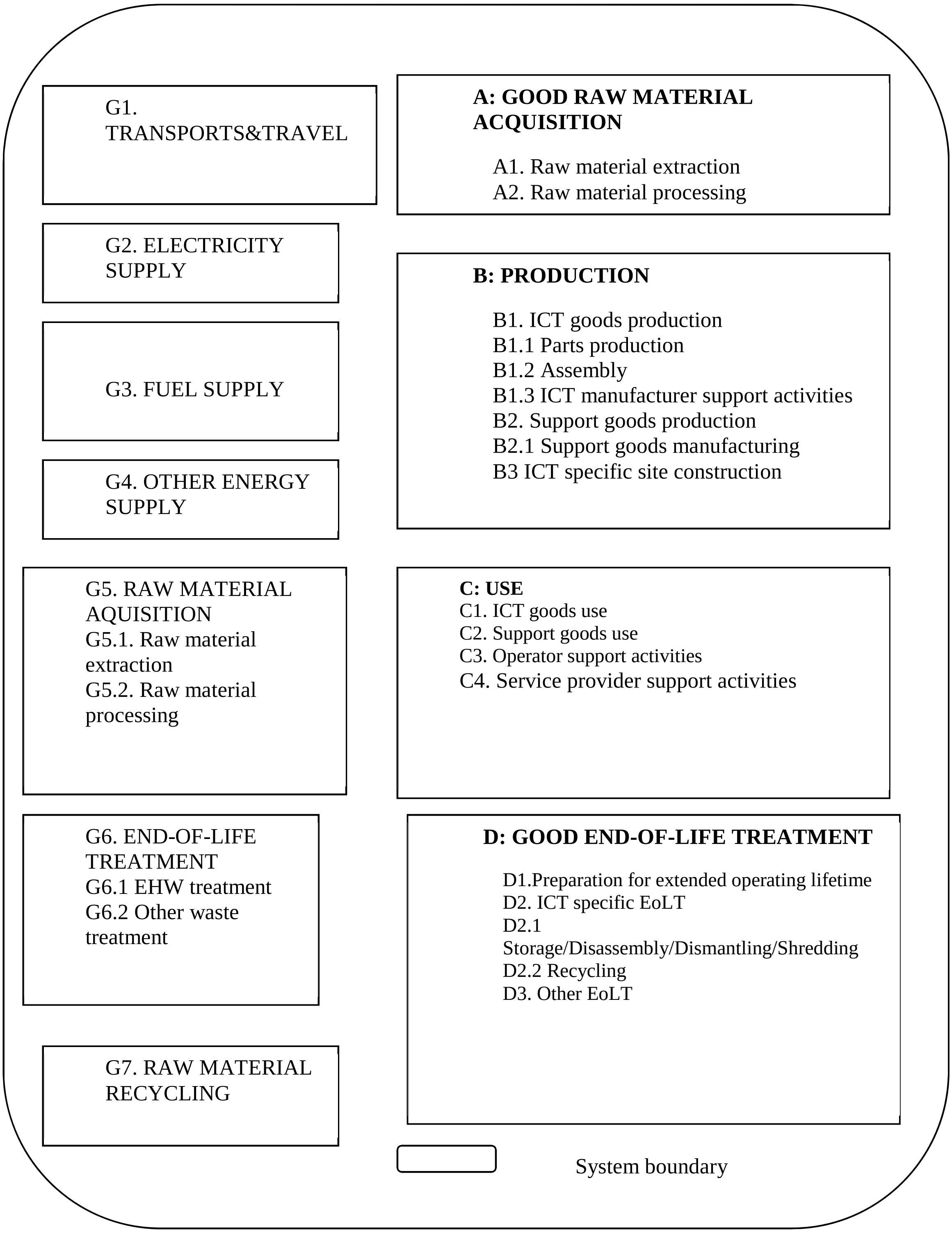

Figure 7: The system boundary of the product system for LCA of ICT goods, Networks or Services

Table 2 further details the life cycle stages to be included in LCAs of *ICT goods, Networks and Services*. The different life cycle stages are further described in clauses 6.2.3.3.2 to 6.2.3.3.5. Mandatory life cycle stages or unit processes shall not be cut-off before considered for inclusion by using alternate data. However, on a more detailed level, not all life cycle processes shall apply to all product systems, e.g. even if Parts production (B1.1, Figure 9) is mandatory not all Parts given in Annex E are applicable to all studied product systems.

Table 2: Classification of life cycle stages/unit processes

Tag	Life cycle stage/Process		Unit process	Class		
				ICT goods	Network	Service
A	Good Raw Material Acquisition					
A1		Raw material extraction		Mandatory	Mandatory	Mandatory
A2		Raw material processing		Mandatory	Mandatory	Mandatory
B	Production					
B1		ICT goods production				
B1.1			Parts production (for further details refer to Annex E)	Mandatory	Mandatory	Mandatory
B1.2			Assembly (see note 2)	Mandatory	Mandatory	Mandatory
B1.3			ICT manufacturer support activities	Recommended	Recommended	Recommended
B2		Support goods production				
B2.1			Support goods manufacturing	Mandatory if Support goods is included in the studied product system	Mandatory	Mandatory
B3	ICT specific Site construction					
B3.1			Construction of ICT specific Site (see notes 1 and 3)	Mandatory if Site construction is included in the studied product system. Recommended if Support goods is included in the studied product system	Recommended	Recommended
C	Use					
C1		ICT goods use		Mandatory	Mandatory	Mandatory
C2		Support goods use		Mandatory if Support goods is included in the studied product system	Mandatory	Mandatory
C3		Operator support activities (see note 3)		Optional	Recommended	Recommended
C4		Service provider support activities (see note 3)		Not applicable	Optional	Recommended

Tag	Life cycle stage/Process		Unit process	Class		
D	Goods End of Life Treatment					
D1		Preparation of ICT goods for extended operating lifetime		Mandatory	Recommended	Recommended
D2		ICT specific EoLT				
D2.1			Storage/Disassembly/Dismantling/ Shredding	Mandatory	Mandatory	Mandatory
D2.2			*Recycling*	*Mandatory*	*Mandatory*	*Mandatory*
D3		*Other EoLT*		*Mandatory*	*Mandatory*	*Mandatory*
NOTE 1: Include both construction of site for Support goods and ICT goods. NOTE 2: Includes soldering of PCBAs. NOTE 3: Not applicable for End-user goods. NOTE 4 - Support activities include installation and de-installation of ICT end-user goods (e.g. IoT devices, Set-Top Boxes, End-user terminals, etc.). Depending on the business model, these activities may be qualified as "Operator Support activities" or "Service provider Support activities". Example: Considering the case of a smart metering service deployed by a service provider within households/organizations, the installation and de-installation activities of smart meters within households and organizations would be considered as service provider support activities.						

In Table 2 "Mandatory" means that the life cycle stage, if applicable to the studied product system, shall always be taken into account in an LCA for ICT.

A more detailed overview (Figure N.1), showing the detailed content and connection between all life cycle stages, is shown in Annex N. Guidance on how to interpret Table 2 for different stakeholders is given in clause 6.2.5.2.

All stages in the life cycle are associated with various kinds of organizational activities, in the present document referred to as support activities. The term support activities include the activities directly associated with the deliverables of the organization, e.g. development, marketing and sales. Additionally, it also covers all other activities needed for the organization to function, e.g. researchers, human resources staff, educational staff, etc. allocated to the reference flow. All these different categories involve the use of buildings and travelling. For the ICT manufacturer, Operator and Service providers the support activities are indicated explicitly in Table 2 (B1.3, C.3 and C.4) and specified in clauses 6.2.3.3.3 to 4. For all other activities of Table 2 support activities are seen as an integrated part of the activity. It is recommended to include impact from support activities wherever possible. See Annex C.

NOTE 2: It could be argued that support activities representing processes under the financial or operational control of the organization undertaking the LCA should be mandatory to include whereas others are seen as optional. In the present document all support activities are handled in the same way as that approach would give better figures for companies with higher degree of outsourcing.

6.2.3.2 The use of unit processes

Each life cycle stage (A to D) is further refined into activities, referred to as unit processes, which represent the basic physical flows (materials and energy) of the life cycle.

A unit process typically represents a production facility but can also model an office or even a vehicle. Annexes B, G and N give more details on modelling of unit processes and applicable inputs and outputs.

6.2.3.3 ICT goods

6.2.3.3.1 General

The system boundary of the ICT goods should encompass all life cycle stages specified in clause 6.1.1 and in Table 2.

In order to set the system boundary of ICT goods the life cycle stages listed in clause 6.1.1 shall be detailed. Further guidance is given in Table 2, Annex D, Annex E, Annex F and Annex N. As stated in clause 6.1.3, the environmental impact from both hardware and software shall be considered, if applicable.

For the ICT good under study, applicable types of parts, as well as amounts of these, shall be defined.

In-depth information about the product composition is required before setting the system boundary of the product as described in clause 6.1.2.1.

6.2.3.3.2 Goods Raw materials acquisition

Goods Raw Material Acquisition (A) **starts** with the extraction (A1) of natural resources (e.g. iron ore, crude oil, etc.) and **ends** with the transport of *Raw Materials* from Raw materials processing (A2) to Part Production facilities. A2 deals with the processing of extracted *Raw Materials* (e.g. iron ore pellets) into processed *Raw Materials* (e.g. steel sheet, copper wire, etc.). *Goods Raw Material Acquisition* is the life cycle stage for ICT goods as defined in Figure 8.

As *Raw Materials* are used as additives in every life cycle stage, *Raw Material acquisition* can additionally be regarded as a generic process (G5).

Table H.1 provides a mandatory set of *Raw Materials* (both ICT specific and generic) which shall be included in the LCA of ICT goods.

As shown in Figure 8, Raw Material Extraction and Raw Material Processing are within the system boundary of Raw Materials Acquisition.

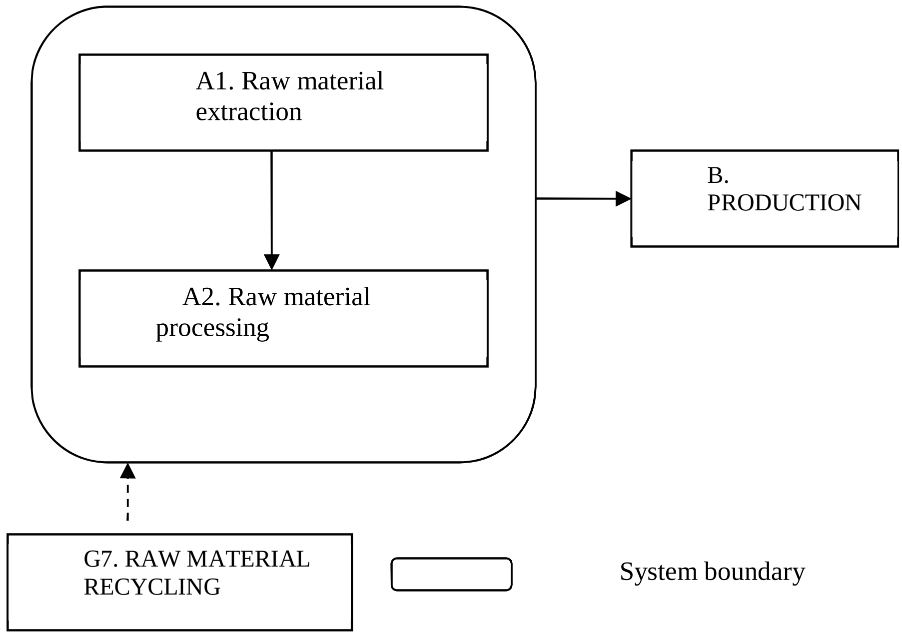

Figure 8: The system boundary of goods Raw material acquisition in LCA of ICT goods

6.2.3.3.3 Production

The Production (B) **starts** with the Parts Production and **ends** with the transport of ICT goods and Support goods to Use (C). The system boundary for Production, shown in Figure 9, includes ICT goods Production and Support goods Production.

NOTE 1: Detailed flow chart figures are provided in each unique LCA project.

It is optional to include the construction of plants in which the ICT goods are assembled.

In case *Support goods* is part of the studied product system, *Support goods Production (B2)* is mandatory.

It is optional to include the construction of plants in which the *Support goods* are assembled.

As a starting point B2 and B3 are optional for *ICT goods* LCAs as the variance in solution may vary significantly both for B2.1 and B3.1 between markets and operators.

NOTE 2: However, for LCAs referring to specific conditions it is encouraged to include also B2 and B3 in the studied ICT product system as Support goods can have a significant impact on the use stage for an ICT solution.

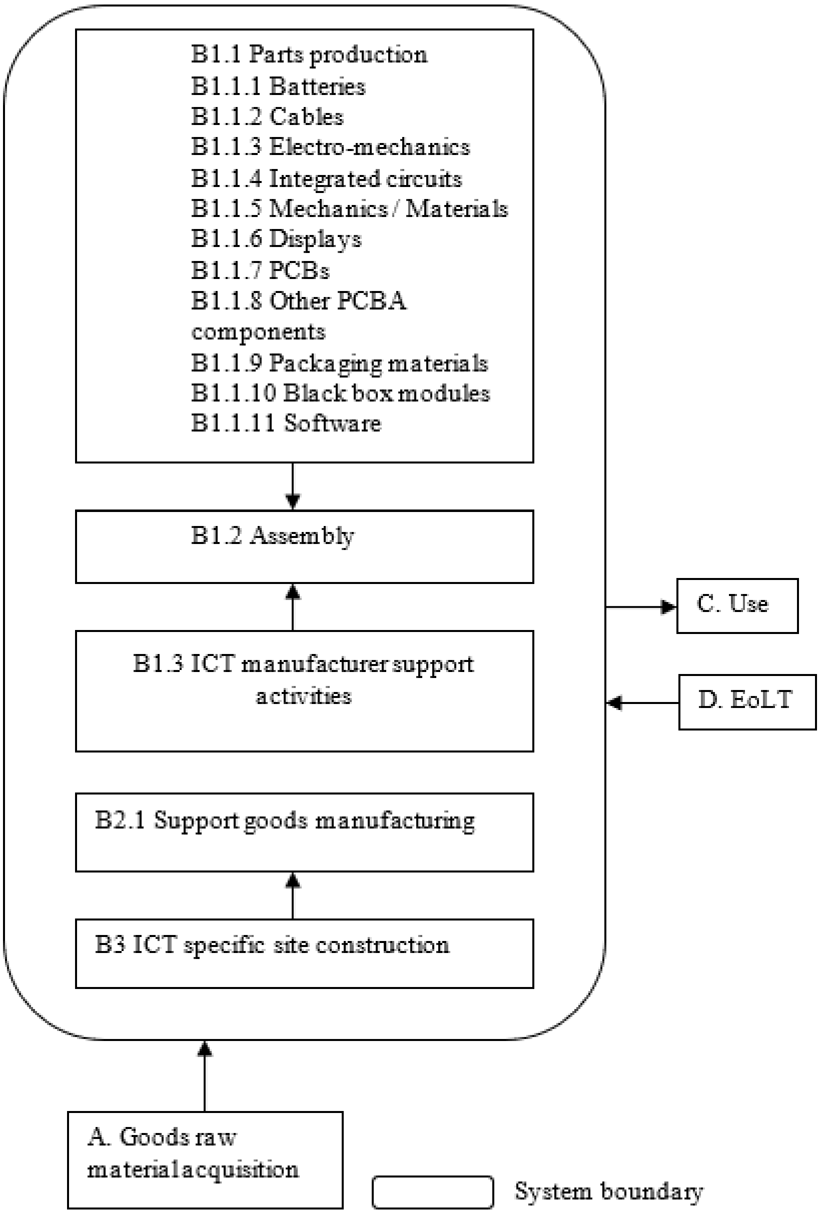

Figure 9: The system boundary of Production in LCA of ICT goods

The ICT goods Production (B1) consists of **Parts Production** (B1.1) and **Assembly** (B1.2) and ICT manufacturer support Activities (B1.3).

For refurbished ICT goods, "B1 ICT goods production" and "B2 Support goods production" includes the environmental impact associated with the refurbishment production process (making the ICT goods fit for next use). Refurbishment process may use new, reused, or refurbished parts and/or support goods. The respective environmental impact of these parts needs to be considered and included in B1 as relevant. The refurbishment process often consists of inspection, cleaning, repair & replacement of worn/out parts, quality testing etc. The environmental impact due to these activities shall be included when they occur in the respective unit process.

Annex E lists a mandatory set of **Parts** to be included where applicable to the studied ICT product system, when performing an LCA of ICT goods, as well as mandatory Part unit processes which shall be included for each Part.

As an example, if batteries are part of the studied *ICT goods* product system they shall be included in within the system boundary and for every battery the Battery Cell manufacturing and Battery module manufacturing shall be included. Except for **Parts** listed in Annex E, other **Parts** may be as important and should be considered as well.

Note that **Parts** can be complex modules themselves consisting of several other **Part** types as building blocks.

The **Assembly (B1.2)** shall include as minimum PCBA Module Assembly, Final Assembly, Warehousing and Packaging.

For B1.2 it is optional to include Testing and Repair.

NOTE 3: Production yields may have an influence on the final results.

If included, for ICT manufacturer support activities (B1.3) see general guidance on support activities Annex C.

Support goods (B2.1) which shall be included if applicable to the studied product system include at least air conditioners, cables and power supply systems.

As stated in Table 2 Construction of ICT specific Site (B3) is mandatory if the ICT specific site is included in the studied product system. Depending on the specific case at hand, a site can be pre-produced or constructed on place. Site building blocks needed for B3.1, which at least shall be included if applicable to the studied product system, are antenna towers, fences and shelters.

Support activities for ICT manufacturer (B1.3) are specifically indicated in Figure 9. Regarding other support activities for Support goods production and Parts Production, see clause 6.2.3.1.

6.2.3.3.4 Use

The Use stage starts with the Installation of ICT goods and Support goods and ends with the de-installation just before the transport to EoLT. As shown in Figure 10, the use stage includes ICT goods Use (C1), Support goods Use (C2), Operator support activities (C3) and Service provider support activities (C4).

(C1) and (C2) include energy supply during the operating lifetime of the ICT goods.

Operator support activities (C3) which should at least be included are installation and de-installation of ICT goods and operation and maintenance of the ICT goods and Support goods, including associated transports and travel. The maintenance includes replacing, e.g. PCBAs. The Raw Material Acquisition and Production for the additional PCBAs and other goods used during the operating lifetime of the ICT goods are mandatory. The additional Raw Material Acquisition and Production impacts from spare parts and Support goods are reported in Raw Material Acquisition and Production and EoLT results. The spare parts management is typically shared between ICT goods manufacturer and Operator and should be considered if applicable to the studied system.

Service provider support activities (C4) see general guidance on support activities Annex C.

NOTE: An example of a Service provider support activity is the development of an "app" for smart phones.

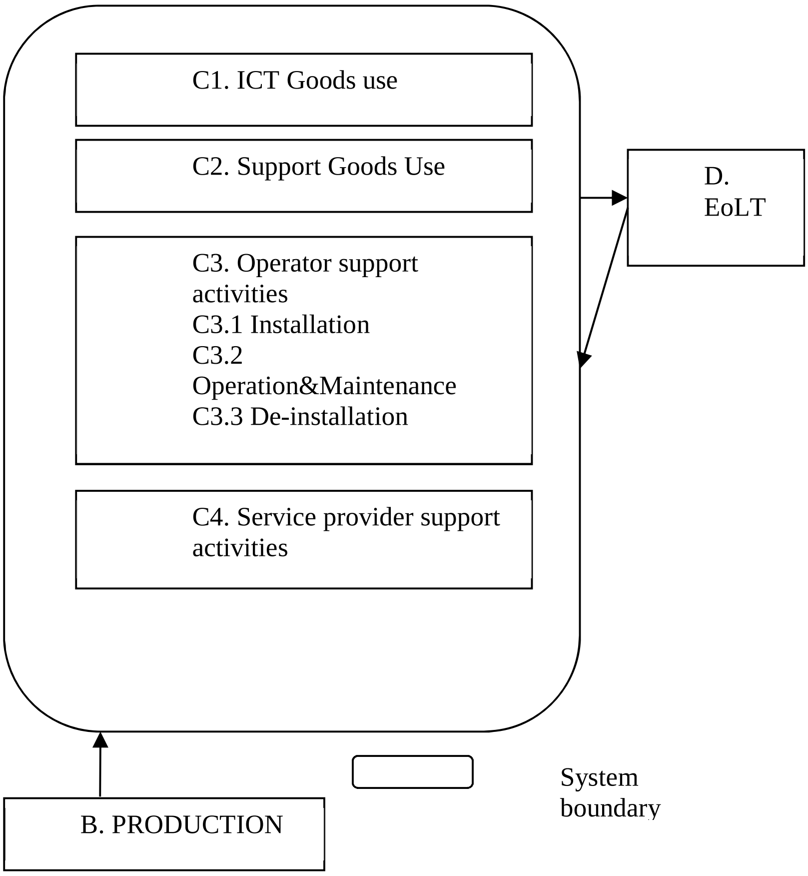

Figure 10: The system boundary of Use in LCA of ICT goods

6.2.3.3.5 End-of-life treatment (EoLT)

EoLT **starts** with the transport of de-installed *ICT goods* and/or s*upport goods* to storage, factory or recycling center, and **ends** either after *preparation of ICT goods for extended operating lifetime (D1)* when the product starts its second life cycle or when ICT goods and support goods go through End-of-life treatment ("D2 ICT specific EoLT" or "D3 Other EoLT").

NOTE 1: The first destination for the de-installed ICT goods depends on the goal and scope of the specific LCA study (studied ICT product system).

As shown in Figure 11, *Preparation of ICT goods for extended operating lifetime (D1), ICT-specific EoLT (D2) and Other EoLT (D3) are within the mandatory system boundary* for EoLT depending on the appropriate route for the specified ICT good at hand.

Extended operating lifetime can be achieved by such as refurbishment or reuse. It should be noted that although repair serves the purpose of extending the operating lifetime of ICT goods, repair activities do not belong to EoLT stage.

ICT-specific EoLT is applicable to the *ICT goods* itself and also applies to ICT based s*upport goods*.

Other EoLT mainly deals with non-ICT based s*upport goods*.

After the EoLT starts *Raw Material Recycling (G7)* and/or *Production (B)* in case of ICT goods intended for refurbishment, depending on the decision made during the *Prepare for extended operating lifetime (D1).*

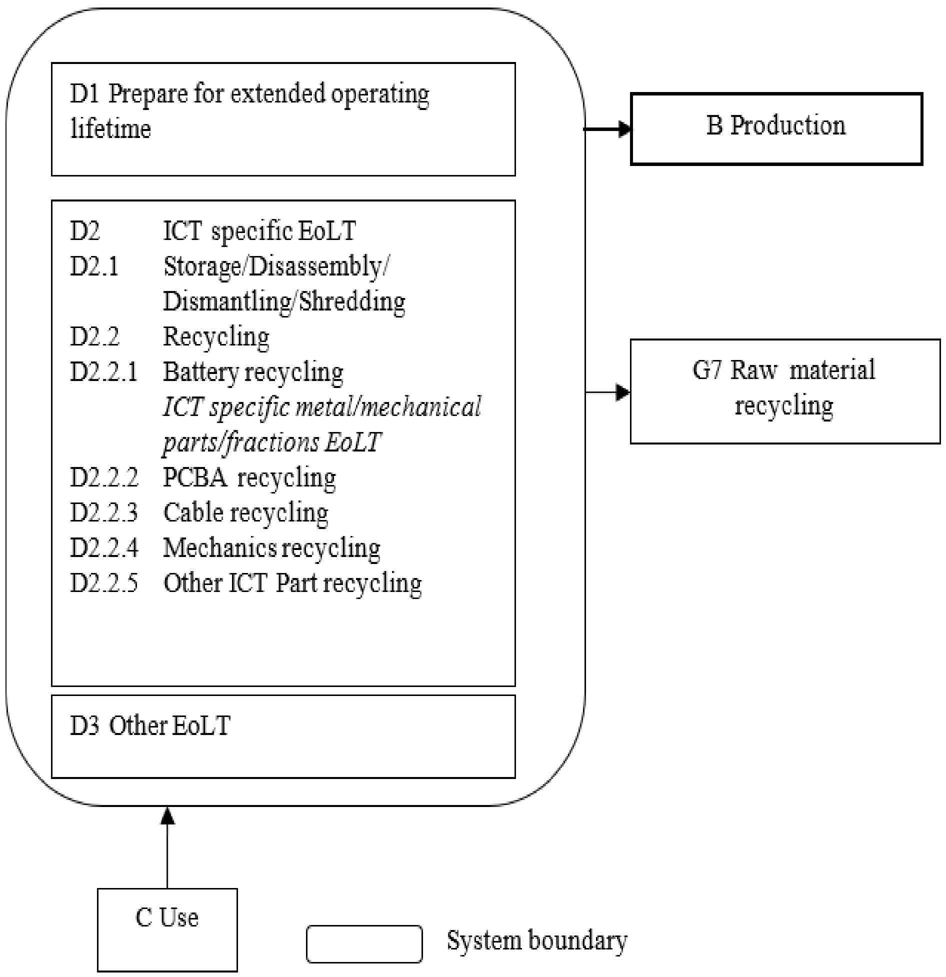

Figure 11: The system boundary of goods EoLT in LCA of ICT goods

The ICT-specific EoLT (D2) in an LCA of ICT goods includes transport from use to storage, factory, refurbishment or recycling center (D2.1), and recycling processes D2.2.1-5 for batteries, PCBAs, cables, mechanics and other ICT parts.

The output from these recycling processes is not raw materials but rather products which the Raw material recycling (G7) can use (e.g. lead anode from D2.2.1, copper wire from D2.2.3, aluminium frame from D2.2.4, plastic constituent of cartridge from D2.2.5).

It has to be judged from case to case which treatments (PCBA, recycling, etc.) shall apply to ICT goods and support goods, respectively.

Annex F lists a mandatory set of EoLT processes to be included where applicable when performing an LCA of ICT goods which includes the EoLT stage.

6.2.3.3.6 ICT goods and processes for extended operating lifetime

Figure 12 illustrates the LCA stages of an ICT product, supporting multiple life cycles. There "D1 preparation of ICT goods for extended operating lifetime" includes the decision point where product is checked if it should proceed to refurbishment or reuse, or to waste treatment. Correspondingly, "B Production" includes "B1 ICT goods production", where the processing for extended operating lifetime (e.g. refurbishment process) takes place.

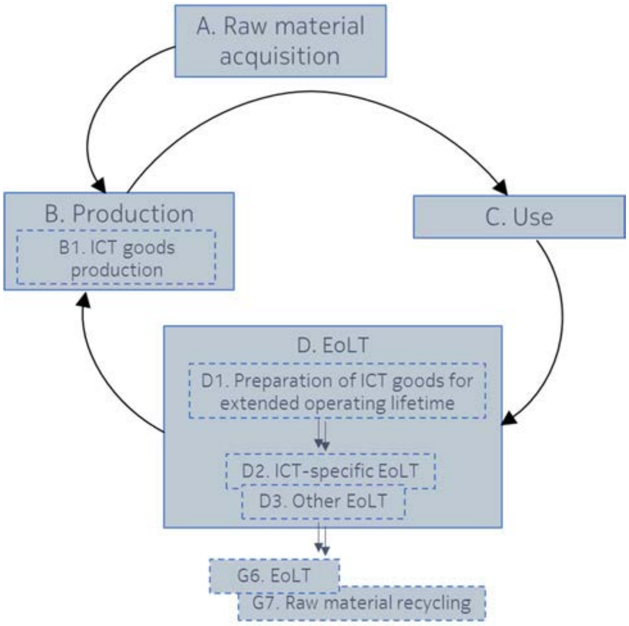

Figure 12: Life cycle stage details for refurbished ICT goods

6.2.3.4 ICT Networks

The aggregated impact of an ICT network equals the sum of the impact from the different goods constituting the ICT network. When aggregating results, data should be based on equivalent assumptions or use scenarios.

As the ICT network operation depends on several types of software, including the software program needed to run the primary subscription service, as outlined in applicable standards (e.g. 3GPP for LTE), the impact from the development of such software should be included in the assessment.

For each type of ICT good constituting the ICT Network, the rules defined for ICT goods in the present document shall apply.

Though it is acknowledged that LCA results for ICT goods that comply with the present document may not be available for all ICT goods, such data takes precedence over other data.

The Network shall be defined in terms of ICT goods, Support goods and ICT infrastructure (e.g. cables duct). For each included product types number of units shall be defined as well as corresponding lifetime. For each type of ICT goods the rules defined for ICT goods in the present document applies for the assessment. For the reporting the same reporting rules applies but it is also allowed to aggregate the results to network level.

Annex P shows typical ICT goods of which the Network consists.

As stated before, each of these goods is associated with Support goods for powering and cooling, as well as the ICT specific Site infrastructure.

For assessment of Networks, operator activities shall be included.

Services provider activities and data centres are to be seen as recommended activities.

6.2.3.5 ICT Services

6.2.3.5.1 General

The operation of an ICT Network could be described as the operation of several ICT services working in parallel, among which there is the primary subscription service which allows transfer of voice and data, but also different applications. Thus, to calculate the impact of an ICT service, it is generally necessary to assess the ICT network, as outlined in the previous clause and if necessary (i.e. in a multi-service situation) allocate an appropriate amount of this impact to the ICT service under study. For details on allocations refer to clause 6.3.3.9.

The system boundary requirements defined for ICT networks shall apply also to ICT services but with some additions, listed below.

In addition to the use of ICT goods and networks, an ICT service may also have additional impacts associated with application software development, use of consumables, infrastructure for sales and logistics, associated travel and transport (in addition to those already included for the ICT goods and networks) which shall also be included when applicable. Often these activities are part of the overall service provider activities.

The impact of the data centres where the service is operated shall be assessed. The associated activities of the service provider should also be considered. Service provider support activities consist of, e.g. offices and business travel, like operator support activities and may also include the activities listed above.

Important data that defines the hardware associated with the service is the number of servers, storage and network goods units, their energy consumption and the data centre overhead energy consumption for cooling and power systems (including back-up power).

The data centre shall be studied and assessed in the same way as other ICT goods and support goods.

The usage of the ICT services provided by the ICT network shall be established based on the actual use scenario of the ICT services.

If the actual scenario is unavailable an estimated use scenario can be used which e.g. cover the energy consumption, any waste disposal or emissions due to the services during the period which the services are provided.

It is optional to include the production/realization of the data centre infrastructure, e.g. the construction of the data centre building and cooling and power infrastructure.

NOTE: If the ICT Service offers the possibility to replace an already existing Service reference product system (i.e. an e-health solution replacing hospital visits), a comparative study that includes the reduced impact from this change has to be carried out to get a more complete understanding of impact of the Service. For further details refer to Part II.

6.2.3.5.2 Eight items to consider

The following eight checklist items should be considered in the system boundary setting of ICT Services, including their associated goods and Networks, to identify activities associated with their life cycle and usage.

These checklist items may then also be used to structure data and reporting but other structures are also possible.

NOTE 1: It is important to avoid that double-accounting takes place between the eight checklist items.

1) ICT hardware

This checklist item refers to the life cycle impact of ICT goods and Networks, for instance PCs, printers, base stations or core nodes. The use of materials and the energy consumption should be considered at each life cycle stage. See clauses 6.2.3.3 and 6.2.3.4 for details.

2) ICT software

This checklist item refers to the life cycle impact (including design, development and use) of ICT software (e.g. individual software, packages, middleware and operating systems). Examples of software impact are the use of electricity and paper by the designers. See clause 6.2.3.5.1 for details.

NOTE 2: In practice it may be hard to assess use of SW and HW separately.

3) Consumables and other supportive products

This checklist item refers to life cycle impact of consumables and other supportive products needed for the utilization of the ICT product system. The supportive products include for instance, information printouts, information media (e.g. CDs and DVDs) and printer cartridges.

4) Site infrastructure

This checklist item refers to life cycle impact of facilities providing ICT-related services for the assessed ICT (ICT sites) and associated goods, e.g. cooling and power supply. Depending on the scope of the assessment, buildings could also be considered. Examples of sites are base station sites and data centres.

5) Transport (movement of goods)

This checklist item refers to the impact from transportation of all the goods within the ICT product system boundary except ones included in 1) 'ICT hardware' or 'ICT software'. Examples of such goods are courier of documents and delivery of newspaper. This includes use of fuels as well as fuel supply chains of trucks, trains, planes, etc.

NOTE 3: Except for fuel supply chain, only use stage need to be considered for transport.

6) Travel (movement of people)

This checklist item refers to the impact from travel, not related to ICT hardware and software. This checklist item includes commuting, professional travel and travel by customers depending on scope and purpose of the study. It includes the use of fuels as well as fuel supply chains of cars, trains, buses, etc.

7) Storage of goods

This checklist item refers to the storage of products not related in ICT hardware and software such as ICT goods, document archives, etc., in an applicable storage place. This implies in particular that the energy consumption for cooling and lighting should be considered.

8) Working environment

This checklist item refers to the use of working environments by the personnel of an organization for business purposes, not related to ICT hardware and software. This checklist item mainly deals with the use of buildings but tentatively the building life cycle could also be considered. The associated impact includes the energy consumption from cooling or heating systems, lighting, PCs, etc. This checklist item includes all utilization of the working environment applicable to all the other checklist items.

NOTE 4: The office could sometime be located in a factory or a home. Production areas of factories belong to checklist item 1.

Annex K defines a method which shall be considered for assessing the environmental impact of the working environment.

The intention of the eight checklist items above is to ensure that all relevant impacts are considered for all life cycle stages when defining the impact from a product system viewpoint. These are typical items to be often considered, but other items may be considered as well depending on study.

EXAMPLE: The assessment of a telepresence service may include ICT hardware (telepresence audio sets, networks and servers), ICT software (telepresence software), site infrastructure (facility for servers), travel (business trip for setting telepresence system and having meetings) and working environment (cooling and lightning of the meeting room) may be needed to consider.

Table 3 illustrates the relationships between the checklist items and the life cycle stages.

Table 3: Mapping of checklist items on life cycle stages

Life cycle stage/Category	Raw material acquisition	Production	Use	EoLT
ICT hardware				
ICT software				
Consumables and other supportive products				
Site infrastructure				
Transport (movement of goods)				
Travel (movement of people)				
Storage of goods				
Working environment				

The purpose of Table 3 is to check whether all relevant items for data collection are included, it may not be part of the overall assessment reporting.

Energy consumption, material inputs and environmental releases shall be assessed in accordance with the system boundary. The checklist items above should be considered to structure energy and material inputs and environmental releases.

In terms of assessment, the checklist items may be considered separately or together depending on the purpose and scope of the study. Also whether this table is for internal purpose or for public disclosure depends on studies.

6.2.4 Cut-off rules

NOTE 1: Clause 4.2.3.3.3 of ISO 14044 [2] also applies.

Cut-off in an LCA is defined as the process for the exclusion of input and output flows associated with unit processes from the product system. Several cut-off criteria exist and are further outlined below. By invoking cut-off, the assessment can be simplified by excluding processes that will not significantly change the overall conclusions of the study, as long as the intended application is met.

Cut-offs shall be avoided as far as possible. An alternative to cut-off is often to model unavailable data based on known data. However, if cut-offs are performed, careful considerations are required.

ISO 14044 [2], clause 4.2.3.3 gives general guidance, especially with regard to mass, energy and environmental significance and cumulative considerations. ISO 14044 [2], clause 4.2.3.3 recommendations shall be used as closely as possible.

All cut-off criteria stated by ISO 14040 [1] and ISO 14044 [2] are to be considered before cut-off of a certain process - and the process shall be included if significant to at least one criterion. The cut-off criteria include mass, energy and environmental significance. Regarding the environmental significance criteria, a qualitative approach can be accepted, as the estimate of the total impact is often not possible at an early stage. Cut-off is only acceptable if allowed by all the above-mentioned criteria.

NOTE 2: Environmental significance refers to contribution of for instance GHG emissions.

Irrespective of the cut-off method applied, the accumulated effects need careful consideration, to prevent the sum of cut-offs exceeding the targeted share of the total impact which is acceptable for cut-off.

As a basis for cut-off either modelled, secondary or primary data can be used.

The cut-off is strongly connected to clause 6.2.3 about System boundaries, as system boundary setting can be seen as a qualitative cut-off. Cut-off of processes or input/output data within the system boundaries requires careful consideration and should be avoided.

An alternative to cut off is often to model unavailable data based on known data. LCA modelling of an ICT good, network or service involves Mandatory, Recommended and Optional life cycle stages, unit processes and activities. Obviously 100 % of the environmental impacts of any studied product system are never known a priori. However, the life cycle stages, unit processes and activities of Table 2 together constitute a significant share for typical product systems in ICT LCAs. The intention of the present document is to include all mandatory activities of Table 2. If these activities are not included such cut-offs shall be clearly motivated.

As the total values of environmental impacts can be difficult to calculate, another alternative cut-off method would be to create a reference value based on important activities and to use this reference value to cut-off processes having a negligible contribution compared to that value. Such an approach is especially appropriate when a limited number of processes or phases of a single aspect of the life cycle, contribute by a disproportionate amount to the overall impact. To establish the reference value, secondary data is considered sufficient.

Any cut-off made shall be clearly described and documented. Activities, processes and flows that have been cut-off should be included in the sensitivity analysis.

For practical examples on cut-off refer to ETSI TR 104 080 [i.22].

6.2.5 Data quality requirements

6.2.5.1 General

In general, data used should reduce bias and uncertainty as far as practicable by using the best quality data achievable. Also data that is more specific with respect to time, geography and technology takes precedence over data which is less specific. Consequently, primary data is generally preferred to secondary data.

NOTE 1: In some cases secondary data may have lower uncertainty than primary data available.

In addition, highly accurate, precise, relevant and up-to-date data is preferred. For all data categories the data quality requirements from ISO 14040 [1] and ISO 14044 [2], clause 4.2.3.6 shall apply.

A qualitative description of the data quality and any efforts taken to improve it shall be disclosed while considering the following data quality indicators:

- Methodological appropriateness and consistency.
- Completeness (total LCA level).
- Uncertainty.
- Data representativeness.
- Data age (timeliness).
- Acquisition method.
- Supplier independence.
- Geographical correlation.
- Technological correlation.
- Cut-off rules (rules of inclusion/exclusion).

NOTE 2: As an example the level of supplier independence could range from "verified data from independent source" to "unverified information from enterprise interested in the LCA".

It should be noted that LCA databases might not contain all the necessary data quality attributes or descriptions. In such case, it is the LCA practitioner's responsibility to inquire and obtain the appropriate data quality indicators.

For further information on the data quality indicators please refer to Annex R.

In the LCA context, data refer to activity data, emission factors and, in some cases, direct emissions.

In selecting emission factors for use in calculating GHG emissions under this methodology the following guidance shall be followed.

Emission factors used should be the most up to date from publicly available sources. Where emission factors are sourced from non public sources, or are not the most up to date ones, a justification for their use shall be provided. See also Recommendation ITU-T L.1440 [i.27], clause 7.7.

In addition distribution and transport losses from electricity generation should be included.

NOTE 3: While LCA results that comply with the present document take precedence over the other data it may at the same time lead to situations where in the reuse of previous studies the most up to date emission factors are not used.

The specific GWP values used shall be those taken from the latest UN IPCC reports. For further guidance see Table V.1. See also clause 6.3.1.2.3 regarding energy mixes.

6.2.5.2 Specific requirements on data and data sources

In general data age and technological correlation are especially important in LCAs for ICT goods, Networks and Services due to the fast technology evolution and the growth in network traffic. E.g. for data traffic, up-to-date data shall always be used, e.g. for allocation between Services, as data traffic grows considerably year by year. Older data therefore tend to give overestimated results for energy use and related emissions per amount of data. The availability of most recent data may vary from one organization to another.

For support activities (e.g. ICT manufacturer support activities and operator support activities) primary data shall be used for all individual processes under the financial or operational control of the organization undertaking the LCA and data shall be representative of the processes for which they are collected.

When available, data compliant with the present document takes precedence before other secondary data sources.

The data used in the assessment shall be representative and relevant. The LCA practitioner shall transparently describe how these requirements are fulfilled.

The following requirements (Table 4) on data quality shall apply for the different life cycle stages and unit processes.

In general ICT specific data are required for ICT specific processes. However, the complexity of the supply chain is acknowledged and a representative approach for data are considered as enough for most LCA purposes, i.e. the LCA practitioner needs not collect data from all suppliers but can focus on a number of representative suppliers whose data are extrapolated to represent all similar products.

Moreover, it is acknowledged that LCA practitioners from different parts of the value chain have various possibilities to get hold of primary data. One way to handle this situation is the reuse of published data. (e.g. the operator can refer to previous LCAs of ICT goods but have to ensure that the LCA in question is in compliance with the present document). Likewise, an operator can use previous LCAs for Networks but has to ensure that these LCA are in compliance with the present document. Data have to be collected (or modelled) at least one step up in the value chain. For further guidance see ETSI TR 104 080 [i.22].

NOTE: This data could be either primary or secondary.

Table 4: Applicable data types per life cycle stage/unit processes

Tag	Life cycle stage	Unit process	Type of data		
			Goods	Network	Service
A	Goods Raw Material Acquisition				
A1	Raw material extraction		Secondary data	Secondary data	Secondary data
A2	Raw material processing		Secondary data	Secondary data	Secondary data
B	Production				
B1	ICT goods production				
B1.1		Parts production (for further details refer to Annex E)	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
B1.2		Assembly	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
B1.3		ICT manufacturer support activities	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
B2	Support goods production				
B2.1		Support goods manufacturing	Primary data or ICT Specific Secondary data: Amounts, etc. Secondary data: processes	Primary data or ICT Specific Secondary data: Amounts, etc. Secondary data: processes	Primary data or ICT Specific Secondary data: Amounts, etc. Secondary data: processes
B3	ICT specific site construction				
B3.1		ICT specific site construction	Primary data or ICT Specific Secondary data: Amounts, etc. Secondary data: processes	Primary data or ICT Specific Secondary data: Amounts, etc. Secondary data: processes	Primary data or ICT Specific Secondary data: Amounts, etc. Secondary data: processes
C	Use				
C1	ICT goods use		Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
C2	Support goods use		Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data

Tag	Life cycle stage	Unit process	Type of data		
C3	Operator support activities		Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
C4	Service provider support activities		Not applicable	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
D	Goods End of Life Treatment				
D1	Preparation for extended operating lifetime		Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
D2	ICT specific EoLT		Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
D2.1		Storage/Disassembly/Dismantling/Shredding	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
D2.2		Recycling	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data	Primary data or ICT Specific Secondary data
D3	Other EoLT		Secondary data	Secondary data	Secondary data
NOTE 1: For end of life treatment, the term ICT-specific should be interpreted as processes applicable to relevant end of life treatment procedures which may also be used for other electronic goods. NOTE 2: For the unit processes for which secondary data is recommended, primary data may be used if available. NOTE 3: In case the impact of ICT specific data and other data do not differ substantially other data sources may be acceptable.					

6.3 Life Cycle Inventory (LCI)

6.3.1 Data collection

6.3.1.1 General

For data collection, requirements according to ISO 14040 [1], clause 5.3.2 and ISO 14044 [2], clause 4.3.2 shall apply.

Data shall be collected for all mandatory processes outlined in Table 2. Further, data shall be collected, for each unit process that is included within the system boundary, in accordance with Annex B for unit processes listed within Annexes D to F. The collected data, whether measured, calculated or estimated, are utilized to quantify the inputs and outputs of a unit process.

The major headings under which data may be classified are listed in ISO 14044 [2], clause 4.3.2.3.

For specific unit process data, measurements at the operated processes are the preferred option (examples are energy consumption, area for multilayer printed circuit boards, good die area for Integrated Circuits (ICs), mass of materials, etc.). In practice other data sources are helpful (e.g. for cross-checks) or even necessary (e.g. in the case of missing data). This includes but is not limited to, process engineering models, process and product specifications and testing reports, legal limits, data of similar processes and Best Available Technology (BAT) reference documents.

Before the collection of data can be made, each life cycle stage needs to be refined into items, also referred to as unit processes, which represent the basic physical flows (materials and energy) of the life cycle. For details on applicable unit processes for ICT goods, networks and services, refer to clause 6.2.3.

A unit process typically represents a production facility but can also model an office or even a vehicle. Annex B and Annex G as well as Annex N give more details on modelling of unit processes and applicable inputs and outputs.

In general, data collected should be as accurate as possible in relation to the purpose of the study, the amount of work needed, etc. In particular, primary data based on measurements are considered as more accurate than secondary data.

Practically, when working with certain LCA tool and LCI database, e.g. Transports and Travel (G1) and energy supplies (G2-G4) could be included in larger data sets, whereas other LCA tools/LCI databases provide transports/energy supply separately. The LCA practitioner should report for which processes transports/energy supplies have been added separately and for which they are "hidden".

The data collection process should be reviewed during the inventory reporting process. It is recognized that there are various potential sources for errors that are inherent to studies that encompass a large number of sites and volumes of separate data.

The LCA approaches used to date include process sum and economic input/output tables. Both approaches have advantages and disadvantages. In the case of ICT goods, networks and services, a process sum approach is generally the preferred option for evaluating the environmental load. However, situations exist where the process sum may not be the best approach. This could be the case when the scale and complexity of the material inputs and the dynamic nature of the supply chains, where assessments based only on process sum could narrow the system boundary (due to a lack of available data or the time and resources required to capture it) to such an extent that the results will not fully capture the environmental load. In this case, a hybrid approach may be applied where both process sum and Economic Input Output (EIO) are used for the assessment so as to overcome these barriers. In these cases, the approach used should be fully documented and all assumptions made fully disclosed.

When data have been collected from public sources, the source shall be referenced. For data that may be significant for the conclusions of the study, details about the relevant data collection process, the time when data has been collected and further information about data quality indicators shall be referenced. If such data do not meet the data quality requirements, this shall be stated. In these cases the approach used should be fully documented and all assumptions made fully disclosed.

6.3.1.2 ICT goods

6.3.1.2.0 Introduction

Data shall be collected at least for the processes marked with mandatory in Table 2, unless these are found negligible in accordance with the cut-off rules.

The use stage of ICT goods can show variations depending on operational conditions and therefore needs special consideration when modelling.

For LCAs of ICT goods, data from representative suppliers, rather than collection of data from all suppliers in the complex and dynamic supply chain is considered sufficient.

6.3.1.2.1 Use stage energy consumption of ICT goods

From a data quality perspective, the best way to determine the energy consumption of ICT goods during the use stage is, whenever possible, to measure a large number of ICT goods operating in a live network/ products in real live operating environments over a long period of time (e.g. a year to capture all aspects of variations in traffic, temperatures, different use behaviour, climate, etc.). This is facilitated if network goods are equipped with remotely accessible energy meters. Many network goods are installed in sites with energy meters.

If obtaining data from such measurements is not technically or economically feasible/available, the second best alternative would be to estimate energy consumption based on available standards for laboratory measurements of energy consumption. E.g. for Radio Base Stations, ETSI TS 102 706 [i.1] and Recommendation ITU-T L.1310 [i.5] apply, for estimation of the energy consumption based on available data measured in a laboratory context. This method will however only give a snapshot of real energy consumption and is considered as less accurate.

The third alternative would be to use estimated or measured energy consumption for a certain traffic profile and user behaviour. In this case, it should be noted that, for many products (especially end-user goods), periods of idling and power off may be significant and are important to consider when modelling the traffic profile/model the usage profile and shall be included if applicable.

The Network energy consumption is calculated as the sum of all ICT goods and Support goods energy consumption values obtained as described above.

6.3.1.2.2 ICT goods data for other life cycle stages

For life cycle stages other than the use stage (use stage is discussed in clause 6.3.1.2.1), the best quality data should be used for each stage, meaning primary data. The used input data needs to be documented and justified by the LCA practitioner, as described in the present document.

Simplified life cycle assessment includes methods such as life cycle stage ratio profiling and input output analysis. If embodied emissions versus use stage emissions ratio is known, that gives an approximation in the absence of more detailed information. It could also mean component characterization or hardware parameterization applicable to the assessed case. The method adopted for different data sets should be documented.

It should be noted that simplified assessment methods are not suitable for all purposes. It is LCA practitioner's responsibility to ensure that the used methods can be applied for the intended purpose.

6.3.1.2.3 Consideration of Energy mixes

When calculating the potential environmental impact the LCA practitioner is encouraged to use the most accurate data for the energy mix that is applicable to the ICT goods under assessment. Particularly the use stage shall use the applicable electricity mix to calculate the potential environmental impact from the use stage more exactly.

When known, market-based data (emissions from electricity that a company have purposefully chosen, e.g. derived from contractual instruments) is recommended for most accurate results. Location-based data (average grid emission factor data for the given locality or region) can be used when market-based data are not available. Global average data are not preferred as it provides the least accurate results.

NOTE: The electricity mix ought to closely reflect the intended use place for the goods. For further guidance see Annex Q.

For other life cycle stages, representative energy mixes are preferred in accordance with the goal and scope of the assessment.

It is observed that different emission factors for electricity may or may not consider the energy supply and distribution. As complete emission factors as possible should be used and the comprehensiveness of those should be transparently reported.

See clause 6.2.5.1 for further guidance on emission factors.

Also, Annex D and ETSI TR 104 080 [i.22] give guidance on how to consider energy mix related matters.

6.3.1.2.4 Handling of LCI results for electricity and energy

During the assessment and when reporting energy consumption, the following inputs should be considered:

- electricity (with use stage separated from the other stages);
- other forms of delivered energies (for example district heating and cooling);
- fuels (typically indicates the fuels are combusted on-site or in a vehicle connected to the site).

When reporting both total primary energy and electricity, it is important to note that these two cannot be summarized because electricity is contributing to the total primary energy.

NOTE: Primary energy usage, assessed with methods such as Cumulative Energy Demand (CED), is to be reported as LCI result appropriately according to Table L.9.

Annex G contains important Life Cycle Inventory (LCI) elementary flows (emissions and resources) and fuels that shall be considered be taken into account in LCA studies for ICT.

6.3.1.3 ICT networks

As ICT networks consist of ICT goods, the principles in clause 6.3.1.2 shall also apply for data collection of ICT networks.

Particularly the network energy consumption is calculated as the sum of all ICT goods and support goods energy consumption values obtained as described above.

Often network LCAs are very challenging and may need to rely on previous LCA results for the different ICT goods. If so data from studies that are compliant with this Recommendation takes precedence if available. The data used in the assessment shall be representative and relevant, in alignment with data quality requirements described in clause 6.2.5. The LCA practitioner shall transparently describe how these requirements are fulfilled.

6.3.1.4 ICT services

Often Service LCAs are very challenging and may need to rely on previous LCA results for the different ICT goods. If so data from studies that are compliant with the present document takes precedence if available. Use time, goods type, data traffic and network access type give important statistical data that needs to be collected in order to quantify the use of ICT systems.

6.3.2 Data calculation

6.3.2.1 General

The general requirements for data calculations in ISO 14040 [1] and ISO 14044 [2] shall be applied.

NOTE 1: ISO 14044 [2], clause 4.3.3 applies as well.

Several operational steps are needed for data calculation. These are described in ISO 14044 [2], clauses 4.3.3.2 to 4.3.3.4 and 4.3.4 and ILCD Handbook [i.16], clause 7.10. All calculation procedures shall be explicitly documented and the assumptions made shall be clearly stated and explained. The same calculation procedures shall be consistently applied throughout the study. Practically, when working with certain LCA tools and LCI databases, calculation procedures could be included in larger data sets, whereas other LCA tools/LCI databases provide each procedure separately.

NOTE 2: It may be possible to derive the calculation procedures from the LCI databases, e.g. for Raw Materials.

A check on data validity shall be conducted during the process of data collection to confirm that the data quality requirements for the intended application have been fulfilled.

Validation involves establishing, e.g. mass balances.

6.3.2.2 ICT goods

ICT goods consist of hardware and software. For both hardware and software, design, development, production, procurement and operation and maintenance activities are of interest and should be considered in accordance with clause 6.2.3.

In terms of life cycle stages, most of these activities can be seen as support activities as detailed in clause 6.2.3, and the associated environmental impact emerges from the use of buildings, office goods and consumables, from travel and transport, and from the generation of waste. All of these should be assessed as fully as possible, but it is not necessary to make a distinction between them, i.e. the total energy consumption of the office of the designers should be allocated between the designers, but it is not necessary to make a distinction between energy for heating and energy for office goods associated with each designer.

For applicable allocation rules, refer to clause 6.3.3.

Similar conditions shall also apply for software being procured from a supplier and integrated into the product.

For example, when assessing the environmental impact coming from the use stage of a Base Station (BS), the assessment may take into account power-saving opportunities resulting from low or empty load periods during which the BS may turn off part or all of its transmission/reception; in this case, the spatio-temporal distribution of traffic load may be based on actual or modelled data.

6.3.2.3 ICT networks

It is necessary to consider the functional unit of an ICT network when performing data calculation. The following data calculation method should be performed in order to take into account the functional unit of the assessed ICT network.

First, the functional unit is established in accordance with clause 6.2.2 and then the corresponding environmental load is estimated. Since each ICT network is continuously evolving, the life cycle of an ICT network cannot be generalized with terms such as "from cradle to grave". Instead, each ICT good, which is part of the considered ICT network, is regarded as a product system and is assessed separately.

The total environmental load of each ICT good should be divided by the operating lifetime of each ICT good in order to calculate the annual environmental load of each considered ICT good. If the actual operating lifetime is not available, a statistically, economically or legally defined lifetime may be used instead. See clause 6.1.4 for details.

In the next step, the annual environmental loads of the ICT goods belonging to the considered ICT network are added in order to calculate the total annual ICT network environmental load.

For instance, for a theoretical mobile access network composed by 1 000 identical base stations and 10 identical radio network controllers, the annual environmental load of this mobile access network is calculated as 1 000 times the individual annual environmental load of one base station plus 10 times the individual annual environmental load of the radio network controller.

For the following described kinds of ICT networks, the environmental load of the use stage should be calculated as follows:

- For the assessment of fixed access networks, a constant value is generally applicable for the use stage energy-related environmental load (e.g. per subscriber), as the goods are connected to the access network whether or not the subscriber is using it. However, when power-saving features are used, a fixed value may not be applicable.
- For the mobile access network the assessment needs to consider the temporal variation in both traffic load and different power save modes. Additionally, different BSs experience different overall loads, which also needs to be considered in the impact assessment. For further details refer to clause 6.3.2.2.

6.3.2.4 ICT services

Data calculation for services is to a large extent related to the allocation of an appropriate amount of network data to the targeted service. For further details refer to clause 6.3.3.

6.3.3 Allocation procedure/Allocation of data

6.3.3.1 General

NOTE: ISO 14044 [2], clauses 4.3.3 and 4.3.4 apply as well.

During the boundary setting phase, LCA practitioners may identify processes that have inputs and/or outputs that are shared between different product systems. In these situations, data collected on emissions needs to be shared between the studied ICT goods, networks and services product system and the other products systems. This apportioning is referred to as allocation and is often considered one of the most challenging issues in LCAs. This clause provides requirements and guidance to help LCA practitioners to choose the most appropriate method to address this allocation issue.

The same allocation method shall be used for all environmental loads for all products from a common process.

The study shall identify the processes shared with other product systems and deal with them according to the stepwise procedure presented below:

- Step 1: Wherever possible, allocation should be avoided by dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes, or expanding the product system to include the additional functions related to the co-products.
- Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned based on the underlying physical relationships between them (e.g. mass).
- Step 3: If step 2 is not feasible, the inputs should be allocated between the products and functions reflecting other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of each product (e.g. market value of the scrap material or recycled material in relation to the market value of primary material).

If alternative allocation processes are applied the different options should be tested in the sensitivity analysis.

More specific guidance is given in the following clauses.

6.3.3.2 Allocation rules for generic processes

Data for generic processes (G1 to G7) shall be allocated as a whole (i.e. for the full lifecycle for the generic process) to the associated life cycle stage of the product system.

However all Raw Material Acquisition (G5) shall be allocated to the life cycle stage Raw Material Acquisition (A).

6.3.3.3 Allocation rules for allocation of support activities between projects/product systems

Data for relevant part of the organization/operation shall be allocated to the relevant part of the product system life cycle. If no detailed information on organization/operation is available the allocation shall be based on organizational/economic data.

NOTE: Previous studies indicate that results may be sensitive to different allocation methods.

6.3.3.4 Allocation rules for facility data

Facility data for production facilities shall preferably be allocated to product systems based on relevant physical data (i.e. area for printed circuit boards, good die area for ICs, mass for other components according to Table E.1). If information regarding physical parameters is insufficient economical allocation may be used.

NOTE: Other relevant physical data are indicated in Annex E.

For software design the "facility" is usually an office. In that case the allocation rules in clause 6.3.3.3 shall apply.

6.3.3.5 Allocation rules for transports

Transports should be allocated based on chargeable mass or volume whichever limits the transport capacity. Empty return trips need also to be considered if applicable.

6.3.3.6 Allocation rules for recycling

The impacts of Raw Material Recycling (G7) should be allocated between life cycles, in practice between Raw Material Acquisition (A1-A2) and EoLT (D), according to the following principles:

- All elementary flows and consequently all environmental impacts of Landfill shall be fully allocated to the life cycle that puts the material on a landfill, or other types of residual waste storage.

- The material resource depletion impact and related elementary flow shall be fully allocated to the life cycle that depletes the material resource (e.g. put the material on landfill). Consequently, if the assessed ICT product system is wasting materials it shall carry this burden fully and could not share it with other product systems.

NOTE 1: See ETSI TR 104 080 [i.22] for example of fulfilment.

- The 100/0 allocation method should be used for calculating primary Raw Material Acquisition impact.

- The 50/50 allocation method should be applied when possible to allocate both the use of recycled input material in the raw material acquisition stage and the recycling of materials in the EoLT stage. USGS yearly mineral report can be used to estimate the ratio of recycled material content for input material if primary data are not accessible.

NOTE 2: US geological survey USGS available (http://www.usgs.gov/).

If available input LCI data does not distinguish between primary Raw Material Acquisition and Raw Material Recycling, the 100/0 method can be used as a fall-back alternative (see examples in Annex M).

6.3.3.7 ICT goods

Allocation principles stated in clause 6.3.3.1 shall apply to allocations for ICT.

6.3.3.8 ICT networks

Allocation principles stated in clause 6.3.3.1 shall apply to allocations for ICT networks.

To calculate the total impact of a network, a top-down approach is recommended, i.e. it is in most cases more practicable to assess the overall energy consumption of a network than to assess the energy consumption per service and add it up to a total value.

Support activities and, when applicable, Support goods which is shared between several nodes or all Network goods need not be allocated to the different ICT goods but can be presented without being distributed.

End-user goods (e.g. PCs, smart phones) which are accessing more than one ICT Network (e.g. 3G, WLAN) shall be allocated to these ICT Networks based on use time. The assumptions regarding use time for access to different ICT Networks and off line work shall be described and motivated.

NOTE: Preferably usage studies can be used as a source but if such studies are not available estimates need to be done.

Impact from shared Network resources (e.g. transmission goods, core nodes and data centres) shall be allocated to an access Network based on data traffic. The assumptions regarding data traffic shall be described and motivated.

6.3.3.9 ICT services

The allocation procedure for ICT services should comply with the allocation procedure used for the ICT networks and goods supporting these ICT services.

If an ICT goods is shared among several ICT services, the environmental load should be allocated according to the estimated usage of these various ICT services, as illustrated in Figure 13.

ICT services	Service A
ICT networks	
ICT goods	

Figure 13: Allocation procedure for ICT services

The environmental load of an ICT service should then be calculated as follows:

- First, the ICT networks, which are allowing the service to be operated and the additional ICT goods, which are not part of networks and which are used by the service, should be identified. Then, the environmental load of each ICT network supporting the service and each additional ICT good using the service, should be assessed. After that, the impact from each ICT goods used should be allocated to the service based on either estimated or measured use time or amount of data traffic. The impact from each ICT network supporting the service should be allocated to the service based on access use time or data traffic.

- More specifically, in alignment with clause 6.3.3.8, the following allocation principle of ICT Network data to an ICT Service shall be used:

  - Data for End-users goods:

    - To be allocated based on active use time of the ICT Service.

NOTE: In certain cases the above rule provides unreasonable results and other allocation bases may then be more appropriate.

  - Data for CPE:

    - To be allocated based on active use time of the Service or data traffic or data rate/allocated bandwidth.

  - Data for access networks, control and core nodes and operator activities:

    - To be allocated based on active use time of the service unless there is a substantial dependency between data traffic and energy consumption. Thus, access/active use time is preferred for circuit-switched networks and data traffic is preferred for packet-switched networks. Data traffic is also preferred for e.g. mobile access networks as mobile access networks show a large dependency between data traffic and energy consumption and need a traffic model that takes data traffic into account. However, also in this case the load independent part of the energy consumption can be allocated based on active use time.

  - Data for transport goods:

    - To be allocated based on data traffic.

  - Data for data centres and Service provider activities:

    - The data centre(s) where the ICT Service is operated as well as the service provider activities shall be allocated based on number of subscriptions and service users or amount of data/transactions.

It should be noted that the assessment of the impact of ICT services can be a complex exercise, which may require collecting large volumes of data just as a prerequisite when assessing a single service. The LCA practitioner needs to be careful because this may introduce problems regarding the availability of data.

NOTE: Average figures for energy use and related emissions per amount of data reflect average traffic. Thus, for low and high data traffic scenarios, average figures may give unrealistic results and results that do not reflect the actual impact of the service data traffic.

The following example shows the estimation of CO_2 emissions of PCs included in customer premises when the environmental load item is CO2 emissions:

[Annual environmental load per PC [kg-CO_2/(unit・year)] × [Number of units used (unit)] × [Operational hours of the ICT service (hours/service)] × [Frequency of use of the ICT service (times/year)]/[Total operation time of the PC (hours/year)]

7 Life Cycle Impact Assessment (LCIA)

7.1 Introduction to LCIA

For LCIA the requirements according to ISO 14044 [2], clause 4.4 and ISO 14044 [2], clauses 6.7 and 8 shall apply.

The Life Cycle Impact Assessment (LCIA) aims to describe and indicate the impact of the environmental loads quantified in the inventory analysis. LCIA is a stepwise aggregation of the information given by the Life Cycle Inventory (LCI) results.

The LCIA aims to evaluate the significance of potential environmental impacts using the LCI results. In general, this process involves associating inventory data with specific environmental impact categories and category indicators, thereby attempting to understand these impacts.

7.2 Impact categories

In general, one single impact category cannot solely evaluate the environmental impact of a product. Instead, multiple impact categories are needed.

See ISO 14044 [2], clause 4.4.2.2.1.

Of various impact categories, an important impact category to the ICT goods, networks and services is climate change (global warming), which results to a large extent from energy consumption.

In the LCA it shall be ensured that the inventory elementary flows (see Annex G are correctly linked with appropriate LCIA characterization factors).

The link to end-point categories (e.g. infectious diseases and plant damage) is optional.

The mid-point category Climate Change is mandatory.

For climate change, the most recent global warming characterization factors from the Intergovernmental Panel on Climate Change [i.10], Annex V, for each GHG shall be used and the timeframe should be 100 years.

For other impact categories there is no methodological consensus in the LCA community, thus the LCA practitioner shall decide which impact categories to consider and how to calculate them, based on the studied ICT product system and purpose of the LCA study. In general, a broad approach in terms of environmental impacts is recommended to give a broad understanding of the environmental impact of the studied ICT product system.

All impact categories and category indicators included shall be disclosed (Table L.10) and justified.

Table 5 shows examples of impact categories.

Table 5: Examples of environmental impact categories and indicators

Midpoint impact categories	Midpoint category indicator	End-point impact Categories	End-point category indicator	Recommended level (Midpoint - End-point)	Reference
Climate change (CC) (mandatory)	Mass CO_2 equivalent (Infrared forcing as GWP100-year)	Infectious diseases, Land loss	DALY, Extinction of species, Resource cost	I - Interim	IPCC [b-IPCC (2013)]
Ozone depletion (OD)	Mass CFC-11 equivalent (see note 3) (UV-B radiation as Ozone Depletion Potential)	Plant damage, Skin cancer	Net primary production, DALY	I - Interim	ILCD [b-EUR 24586 EN] [i.3]
Human toxicity (HTC), cancer effects	Comparative Toxic Unit for humans (CTUh) (Concentration at human uptake level)	Cancer	DALY	II/III - II/interim	[b-EUR 24586 EN] [i.3]
Human toxicity (HTNC), non-cancer effects	Comparative toxic unit for humans (CTUh) (Concentration at human uptake level)	Memory loss	DALY	II/III - Interim	[b-EUR 24586 EN] [i.3]
Respiratory inorganics/Particulate matter (RI/PM)	Mass PM2.5 equivalent (see note 4)	Bronchitis, Asthma attacks	DALY	II/III - II (see note 5)	[b-EUR 24586 EN] [i.3]
Ionizing radiation (IRH), human health	Mass U235 equivalent	Cancer	DALY	II - Interim	[b-EUR 24586 EN] [i.3]
Ionizing radiation (IRE), ecosystems	Comparative toxic unit for ecosystems (CTUe)×volume× time			Interim - No methods recommended	
Ionizing radiation (IRE), ecosystems	Comparative toxic unit for ecosystems (CTUe)×volume× time			Interim - No methods recommended	
Eutrophication (EA), aquatic	Freshwater: Mass P-equivalents Marine water: Mass N-equivalents	Fish population	Resource cost	II - Interim	[b-EUR 24586 EN] [i.3]
Eutrophication (ET), terrestrial	Mole N-equivalents	Herbivore population	Resource cost, Extinction of species	II - No methods recommended	[b-EUR 24586 EN] [i.3]
Photochemical ozone formation (POF)	Mass C2H4-equivalents (Tropospheric O3 concentration increase)	Asthma, Plant damage	DALY, Net primary production	II - II	[b-EUR 24586 EN] [i.3]
Acidification (A)	Mole H^+-equivalent	Plant damage	Net primary production	II - Interim	[b-EUR 24586 EN] [i.3]

Midpoint impact categories	Midpoint category indicator	End-point impact Categories	End-point category indicator	Recommended level (Midpoint - End-point)	Reference
Ecotoxicity (ETFW), freshwater (see Note 6)	Comparative toxic unit for ecosystems (CTUe)×volume× time (Concentration at aquatic ecosystem species uptake level)	Aquatic ecosystem population	Extinction of species	II/III - No methods recommended	[b-EUR 24586 EN] [i.3]
Land Use (LU)	Mass deficit of soil organic matter	Land loss	Extinction of species, resource cost	III - Interim	[b-EUR 24586 EN] [i.3]
Resource Depletion Water (RDW)	Water amount as water use related to local scarcity of water	User cost	Resource cost	III - No methods recommended	[b-EUR 24586 EN] [i.3]
Resource depletion (RDMR), mineral, fossil, (see Note 7)	Minerals as mass Sb-equivalent and fossil fuels as MJ (Resource amount as scarcity)	User cost	Resource cost	II - Interim	[b-EUR 24586 EN] [i.3]

NOTE 1: The midpoint impact categories are suggested by the ILCD [b-EUR 24586 EN] [i.3] and PEF [i.16]. For other impact categories beyond 'Climate change', the scientists are still debating on the suitable methodology and the Category indicators referred in this table may change in the future. Especially Land use methodology is still very open. Refer to ILCD and other documents for up-to-date methodology to use for each impact category.

NOTE 2: At the time of publication of this Recommendation, the recommended levels are taken from the most recent ILCD guideline [b-EUR 25167 EN] [i.7]. Refer to ILCD guideline for the most up-to-date information and the explanation of the different recommended levels.

NOTE 3: CFC-11 = Trichlorofluoromethane, also called freon-11 or R-11, is a chlorofluorocarbon.

NOTE 4: PM2,5 = Particulate matter with a diameter of 2,5 μm or less.

NOTE 5: These recommended levels are taken from ILCD guideline [b-EUR 25167 EN] [i.7], clause 3.3. The same guideline has different recommended levels for respiratory inorganics/Particulate matter in clause 1.1 [b-EUR 25167 EN] [i.7], where the levels are I - I/II.

NOTE 6: There are currently no recommended methods for ecotoxicity, marine water and terrestrial.

NOTE 7: There are currently no recommended methods for resource depletion, renewables.

8 Life cycle interpretation

8.1 General

NOTE: ISO 14044 [2], clause 4.5 also applies.

Interpretation is the phase of LCA in which the findings from the Life Cycle Inventory (LCI) analysis and the Life Cycle Impact Assessment (LCIA) are considered together. In the life cycle interpretation, the results of the LCA are evaluated in order to answer questions raised in the goal definition (clause 6.2). The steps of the interpretation shall ensure the robustness of the conclusions from the LCA.

During the iterative steps of the LCA the interpretation phase serves to improve the LCI model.

In the end the interpretation relates to the intended applications of the LCI/LCA study and is used to draw conclusions, identify limitations and produce recommendations.

The life cycle interpretation shall include an analysis of the results and the consistency, a completeness check and a sensitivity check of the significant issues and methodological choices as to understand the uncertainty of the results.

The challenge of the completeness check is to overcome the paradox of evaluating the degree of completeness of the product system when not knowing 100 % of its environmental impacts.

If two or more ICT goods, Networks or Services LCA results do not differ significantly, there is a risk of erroneous interpretations. I.e. there is a risk of inappropriately claiming equality/superiority of one or several compared alternatives, based on poor data quality that results in underestimations/overestimations of differences. This risk could lead to bad general conclusions and recommendations.

NOTE: The significance is determined for instance by magnitude in difference, modelling assumptions and LCA tool calculation algorithm.

8.2 Uncertainty analysis

The uncertainty of the results of an LCA study shall be assessed in accordance with ISO 14044 [2] to the extent needed to understand the study results. Also the sources of uncertainty and methodological choices made shall be assessed and disclosed. Annex S gives more information regarding uncertainty categories and important uncertainty sources for the different life cycle stages of ICT goods, networks and services. Annex T gives more information regarding opportunities and limitations in the use of LCA for ICT goods, networks and services.

8.3 Sensitivity analysis

The results of the LCI or LCIA phases shall be interpreted according to the goal and scope of the study. The interpretation shall include a sensitivity check of the significant inputs, outputs and methodological choices and defined use scenarios, in order to understand the uncertainty of the results. Especially when modelled data are used, different scenarios should be assessed to establish a range of potential outcomes to limit the uncertainty. For requirements on sensitivity analysis refers to ISO 14044 [2], clauses 4.3.3.4 and 4.5.3.3.

9 Reporting

9.1 General

Reporting is essential to ensure accountability and effective engagement with stakeholders. The purpose of this clause is to summarize the various reporting requirements and to identify additional reporting considerations that together provide a credible reporting framework and enable users of reported data to make informed decisions.

The reporting of ICT product systems shall fulfil the reporting rules as defined by ISO 14040 [1] and ISO 14044 [2]. In the case of reporting, a public GHG inventory report, the key accounting principles (relevance, accuracy, completeness, consistency and transparency) shall be met.

For LCA results to be credible, a level of transparency in the reporting of how the data has been collected, to an extent that does not conflict with confidentiality considerations, is recommended.

In addition to the reporting obligations outlined by ISO 14040 [1] and ISO 14044 [2], the requirements of the prsent document shall include the following information:

- contact information;
- studied goods, networks and services product system name and description;
- type of inventory (i.e. final product cradle-to-grave or intermediate product cradle-to-gate inventory);
- goals of the study.

The reporting of results shall include:

- total GHG emissions reported as amount of CO2e per functional unit for ICT good, network and service that have been assessed;
- percentage for each life cycle stage contributing to the total results;
- electricity (with use stage separated from the other stages);
- primary energy;

NOTE: Primary energy and electricity cannot be summarized because electricity is contributing to the total primary energy.

- fuels;
- value and sources of emission factors, clearly indicating their use, for CO2 and CO2e and Global Warming Potential (GWP) metric used, for generic processes G1 to G4 described in Annex D. For further details see Annex L;
- other data, justifications and explanations as stated throughout the present document.

The emission factors used shall be stated. The source used and the year they represent shall be stated.

In the case of emission factors for grid electricity also the location (specific, country, global average) shall be stated.

Where emission factors are sourced from non public sources, or are not the most up to date ones, a justification for their use shall be provided.

Generally, in addition to the rules outlined in this clause, what is stated in Annex L shall be followed for reporting of studies claiming compliance with the present document.

The present document shall contain a compliance statement saying either that the LCA fully complies with the present document (in case of *full compliance*) or that the LCA partially complies with the present document with the exceptions transparently listed and justified (*partial compliance*). See clause 5.2 for details.

The extent in which *Support activities* and other optional/recommended activities are excluded for different parts of the life cycle shall be clearly described and for recommendations also motivated in the study report.

The intention of having common ways of reporting is to increase transparency and provide the reader with a proper basis for interpretation of results.

Optionally other data, graphs, statements, etc. may be added to the present document based on the scope and purpose of the LCA.

For each product system (including *ICT goods*, *Network and Service*) the following aspects, being of special importance to ICT applications, shall be transparently motivated and described in accordance with the principles defined in this clause:

- Operating lifetime: All lifetime assumptions shall be stated and motivated.
- Cut-off: Any cut-off made shall be clearly stated and motivated.
- Allocations: Basis for allocations made shall be described, especially for recycling, use of recycled materials, distribution of facility data and support activities. Data sources: Data sources (i.e. primary/secondary) shall be clearly stated and deviations towards Table 2 shall be motivated.
- System boundaries: In case of cradle-to-gate system boundaries, the LCA practitioner shall clearly state what definition of 'gate' has been used in the assessment. Default definition is given in clause 3.1 in the present document, but it is also acknowledged that other definitions are possible depending on the scope and goal of the assessment.
- For each product system (including ICT goods, Network and Service) an additional diagram shall be presented whenever optional activities in Table 2 have been included. I.e. one diagram is presented with the mandatory activities/processes and one with both the mandatory and the optional activities included for transparent reporting.

9.2 ICT goods

9.2.1 Total results

For each impact category studied, diagrams corresponding to Figure 14a and Figure 14b shall be reported for the corresponding category indicator result.

Due to the importance of operating lifetime to results, information regarding this shall always be present in the diagram, together with some other basic modelling statements including total result for the indicator, LCA study year operating lifetime, etc. as shown below. Figure 14a shows an example of the results corresponding to the Mandatory section of Table 2 whereas Figure 14b shows an example of the results for the Mandatory/Recommended/Optional section of Table 2.

NOTE 1: Other diagram styles are allowed as long the content equals that of Figure 14a and Figure 14b.

NOTE 2: It is recognized that due to LCA tools/LCI databases limitations it may be difficult to have a full split between life cycle stages (A-D).

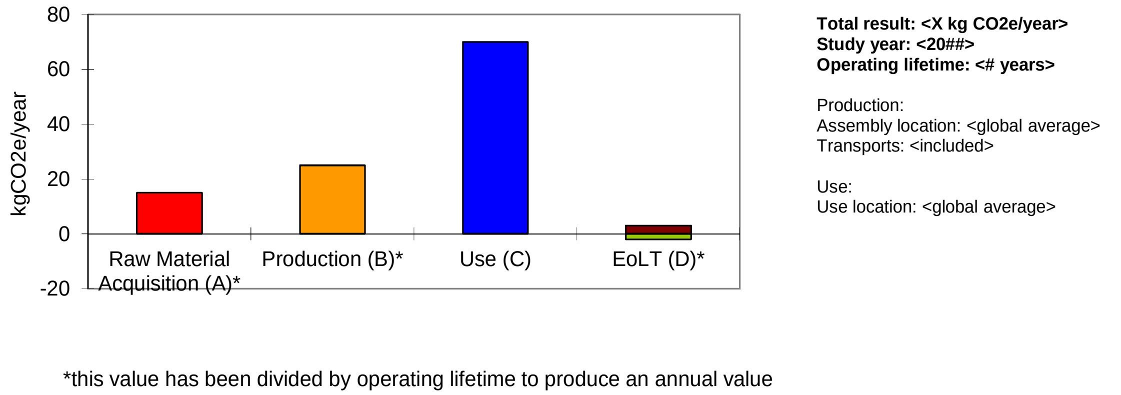

Figure 14a: Environmental impact category indicator result diagram example for Mandatory processes/activities (diagram for Global Warming Potential (GWP100) (CO2e))

Figure 14a shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation in the scope and clause 5.3.

Figure 14b shall be presented whenever optional activities/processes from Table 2 have been included in the studied product system.

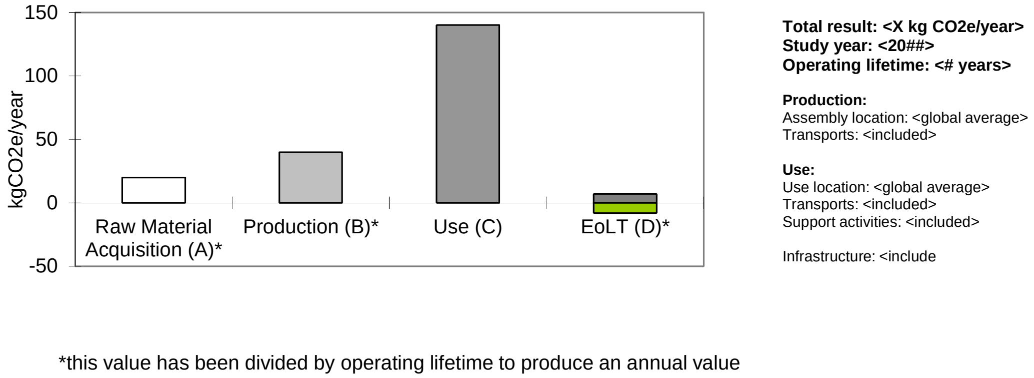

Figure 14b: Environmental impact category indicator result diagram example for Mandatory/Recommended/Optional processes/activities (diagram for Global Warming Potential (GWP100) (CO2e))

For transports, the total result including all transports throughout the life cycle Annex L (Table L.4) shall be stated in the immediate proximity of the diagram (Figure 14a and Figure 14b). If used data sets do not report transports separately any missing transport shall be listed and motivated.

Optionally, a diagram showing transport and other sub-unit processes within each life cycle stage should also be reported (Figure 15). Such transparency is encouraged.

Figure 15 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation in the scope and clause 5.3.

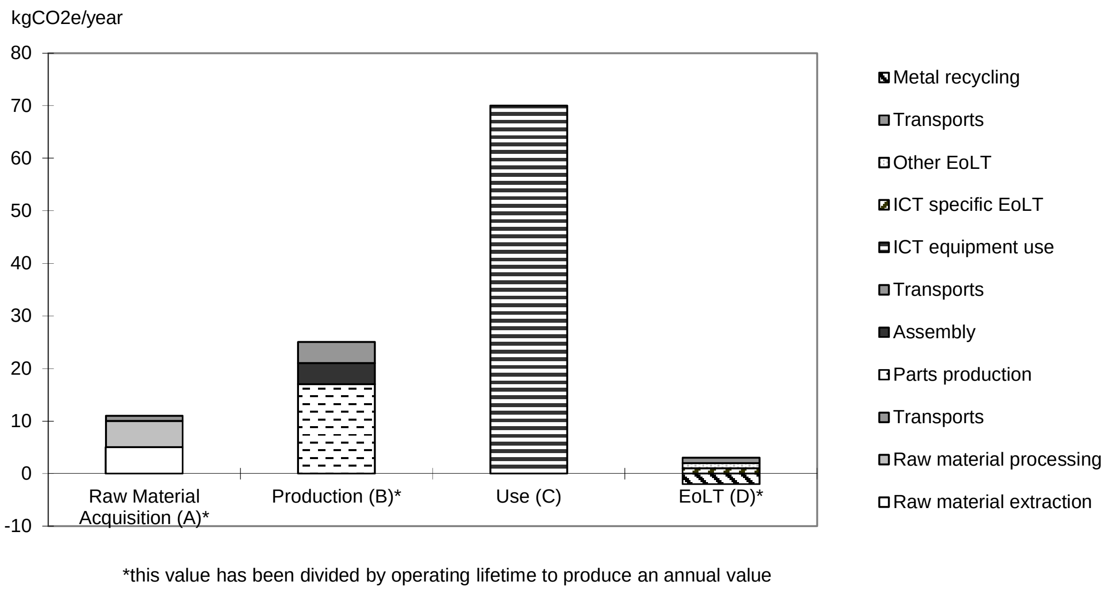

Figure 15: Environmental impact category indicator result: distribution between sub-unit processes within each life cycle stage

A diagram summarizing distribution of selected environmental impact category indicators between life cycle stages shall be prepared together with absolute figures as shown in Table L.10. The diagram may be presented according to Figure 16.

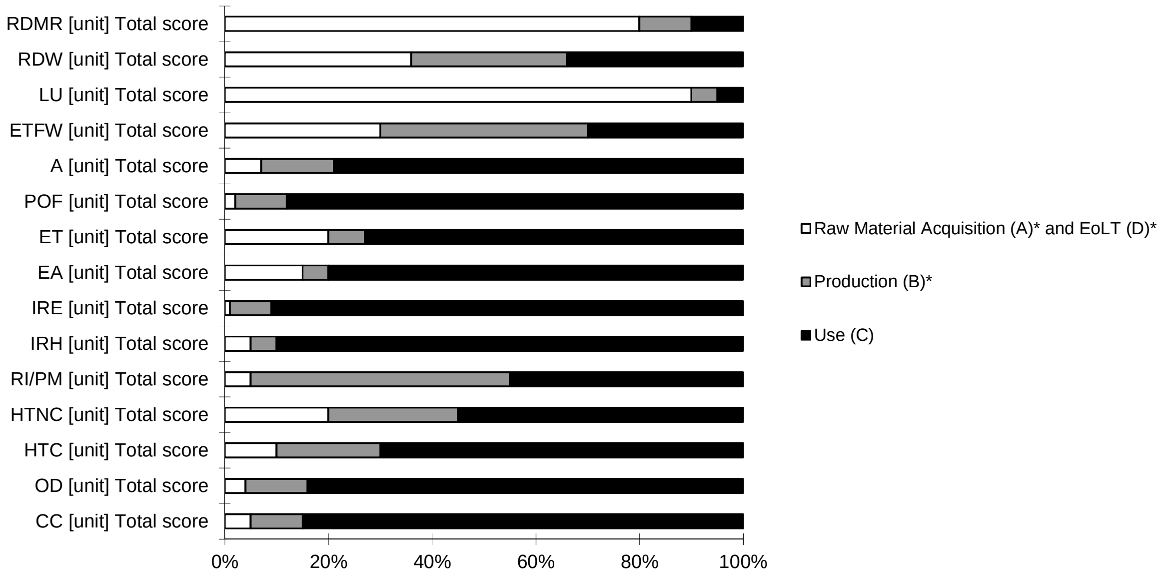

Figure 16: Environmental impact category indicators overview for ICT goods

Figure 16 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation in the scope and clause 5.3.

9.2.2 System boundaries

9.2.2.1 Life cycle stages, unit processes and generic processes

Any deviation to Table 2 and clause 6.2.3 with respect to mandatory life cycle stages/unit processes shall be clearly stated and motivated.

Also handling of optional stages/activities shall be clearly reported as well as electricity mix applied and handling of support activities and transports.

For appropriate reporting format refer to Table L.2.

Especially for transports it is acknowledged that there is a lack of transparent secondary data for many unit processes.

Additionally, inclusion of generic processes for the different life cycle stages shall be clearly stated and reported. This may be shown in a flow diagram.

Deviations for Generic processes shall be reported according to Table L.3.

For reporting of transports and travel refer to Table L.4.

State if data are missing or is included in, e.g. support activity data are included but could not be reported separately.

9.2.2.2 Raw material acquisition

The use of raw materials shall be transparently reported as outlined below. The most important metals from recycling point of view shall always be stated.

Other materials can be shown as well but such reporting is optional.

For appropriate reporting format refer to Table L.5.

NOTE: At the time of publication, some of the requirements in Table L.5 are considered as challenging due to LCA tool limitations, lack of data, limitations in data granularity, etc. It is thus recognized that compliance to these requirements may not be possible at the time the present document is published.

Deviation(s) from the requirements shall be clearly motivated and reported.

9.2.2.3 Production

Compliance to Table E.1 shall be reported according to below and any deviation shall be described and motivated.

For appropriate reporting format refer to Table L.6.

9.2.2.4 Use

9.2.2.4.1 ICT goods use

The basis and rationale for the energy consumption values for the ICT goods use stage shall be reported together with the annual value of the energy consumption. For appropriate reporting format refer to Table L.7.

The model of distribution over time of different usage modes including power off and idle and the rationale for those shall be transparently reported.

For appropriate reporting format refer to Table L.7.

9.2.2.4.2 Support goods use

The basis and rationale for the energy consumption values for the Support goods use shall be transparently described and motivated. For appropriate reporting format refer to Table L.7.

9.2.2.5 EoLT

If EoLT is included any deviations towards Annex D shall be transparently reported and motivated. For appropriate reporting format refer to Table L.8.

9.2.3 LCI results

For LCI the following items shall be reported transparently: total use of primary energy and electricity.

NOTE: The Cumulative Energy Demand method is appropriate to express Primary Energy Usage.

It is further recommended to report land use and water use when applicable to the selected impact categories.

Additionally, results for elementary flows according to Table G.1 could be transparently reported on an optional basis. If such reporting is not made it is mandatory to describe unexpected results, lack of data and other findings associated with the elementary flows.

For appropriate reporting format refer to Table L.9.

9.3 ICT Network

9.3.1 Example reporting

Figure 17 illustrates how network-level LCA reporting can be built up by the goods level LCA data, using a typical wireless network as an example. The same principle applies for other types of networks, e.g. broadband, traditional fixed voice, IP-voice, LAN and IPTV networks.

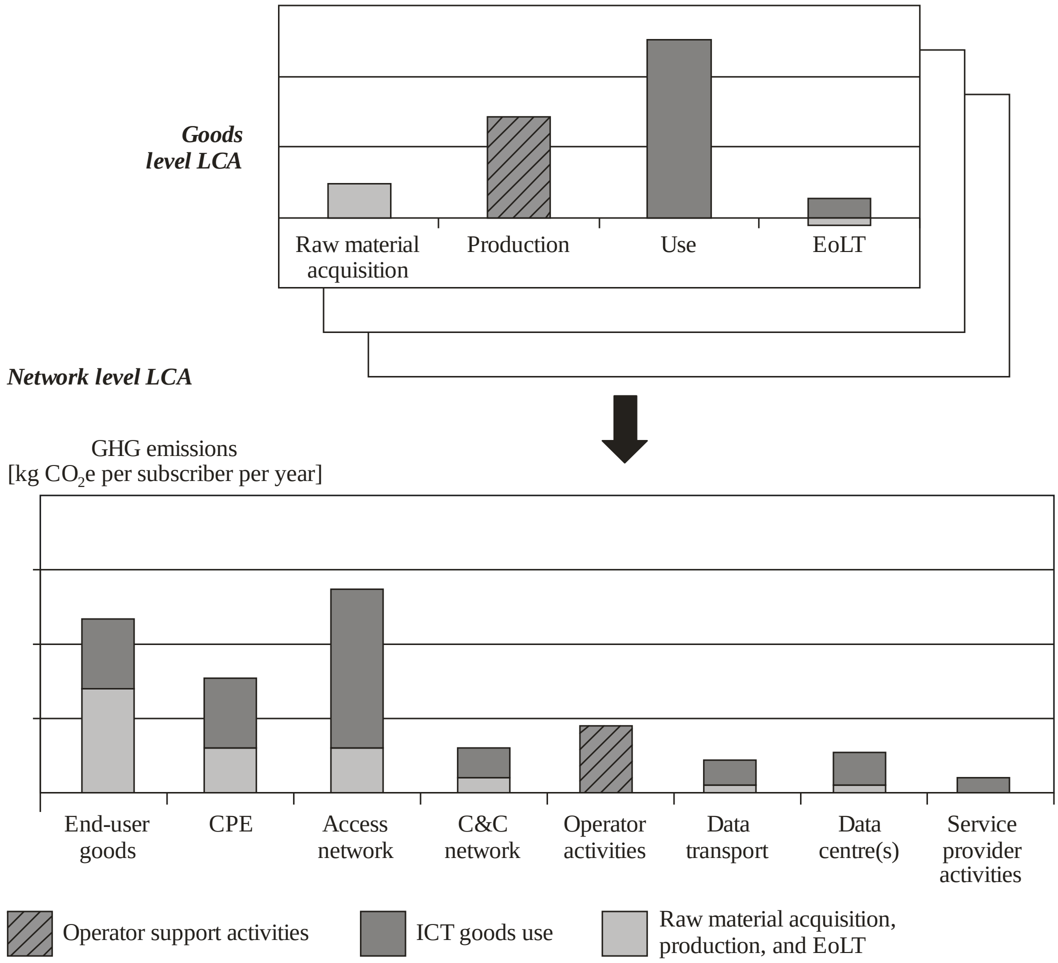

Figure 17: Example of a reporting structure for a Network LCA

Additionally, the proposed network structure can also be used to report important high-level parameters such as quantities and energy consumption of included goods (see Table 6).

Table 6: Example of reporting structure

	Studied network (Example of wireless network)	Quantity	Energy consumption
End-user goods	Mobile phone (UE)		
Home goods	Fixed Wireless Terminal (FWT)		
Access network	RBS sites, control & core network sites		
Service provider(s)	Wireless network operator business and O&M activities		
Data transport/transmission	Allocation of shared data transport/transmission		
Data centres/data rooms	Allocation of shared data centres/data rooms		

9.3.2 Total results

For each environmental impact category studied, a diagram should be prepared splitting the impact of different parts of the network. Figure 18 and Figure 19 show examples of Network LCA reporting.

Operating lifetime is important also for Networks, but is associated with the lifetime of the different nodes, which shall be reported. It shall be reported following the format of Table L.11 which also describes the studied Network.

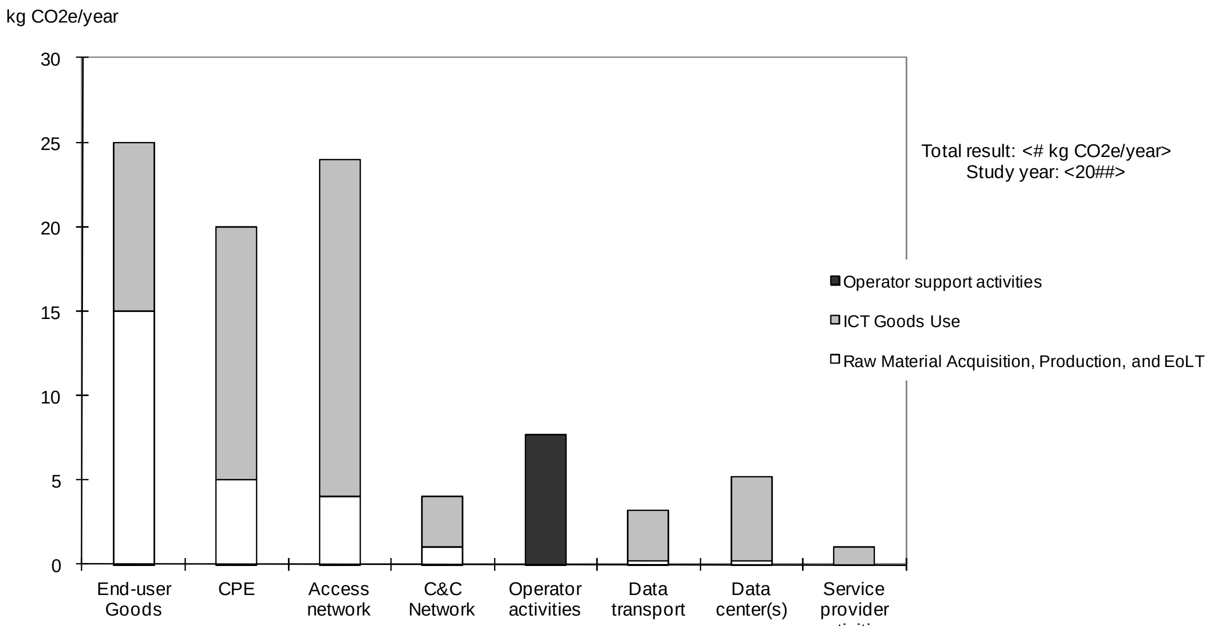

Figure 18: Environmental impact category indicator result diagram example for Network (diagram for Global Warming Potential (GWP100) (CO2e))

Figure 18 shows an example of Network LCA with a wide scope and it is not applicable to all studied product systems.

Figure 18 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation the scope of the present document.

Optionally, a diagram showing the distribution of impacts between sub-activities within each life cycle stage could also be reported in the same way as for ICT goods (see clause 9.2.1).

Additionally a diagram summarizing distribution of environmental impact category indicators between life cycle stages shall be prepared together with absolute figures as shown in Table L.10. The diagram may be presented according to Figure 19.

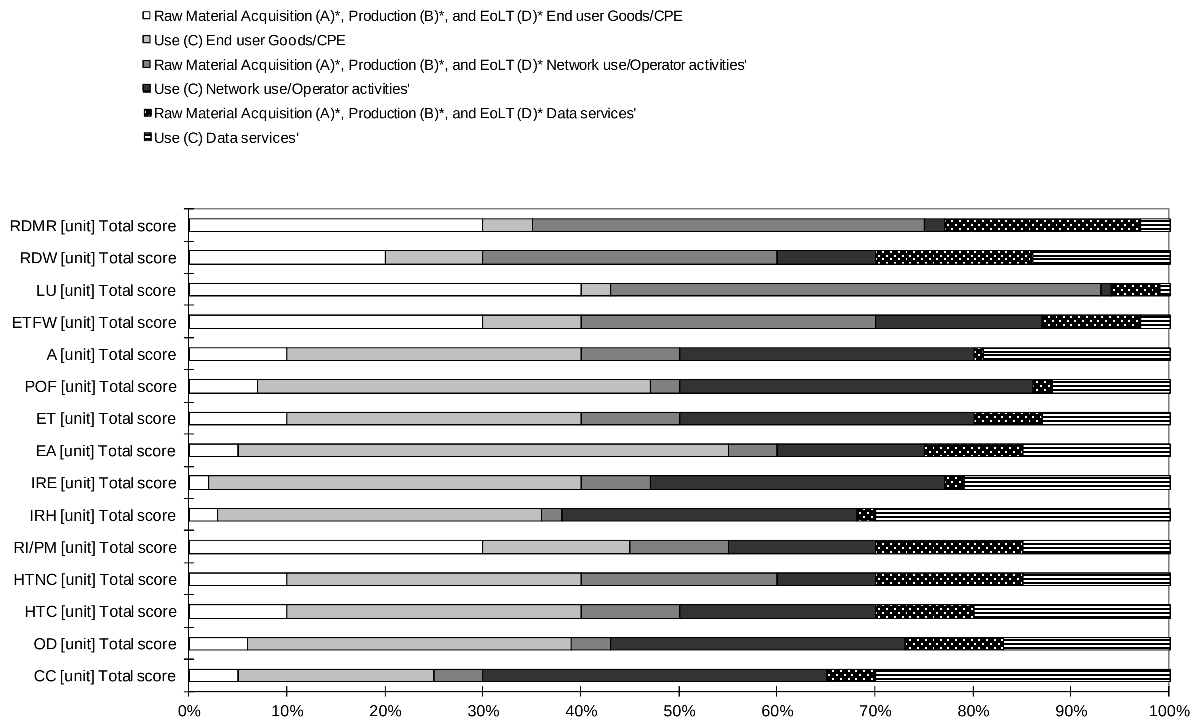

Figure 19: Environmental impact category indicators overview for Networks

Figure 19 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation in the scope of the present document.

Details of network energy consumption shall be reported with a split of different elements of the network. An example of table for Reporting is provided in Table L.12.

9.4 ICT services

9.4.1 Example reporting

Reporting at the service level may be structured based on the various network parts used by the ICT service, in the same way as networks are reported. Each bar should then show the relation between the dedicated impact of the ICT service under study and the impact associated with all other ICT services (see Figure 20), in order to illustrate the relative contribution of each activity to the total amount of environmental load.

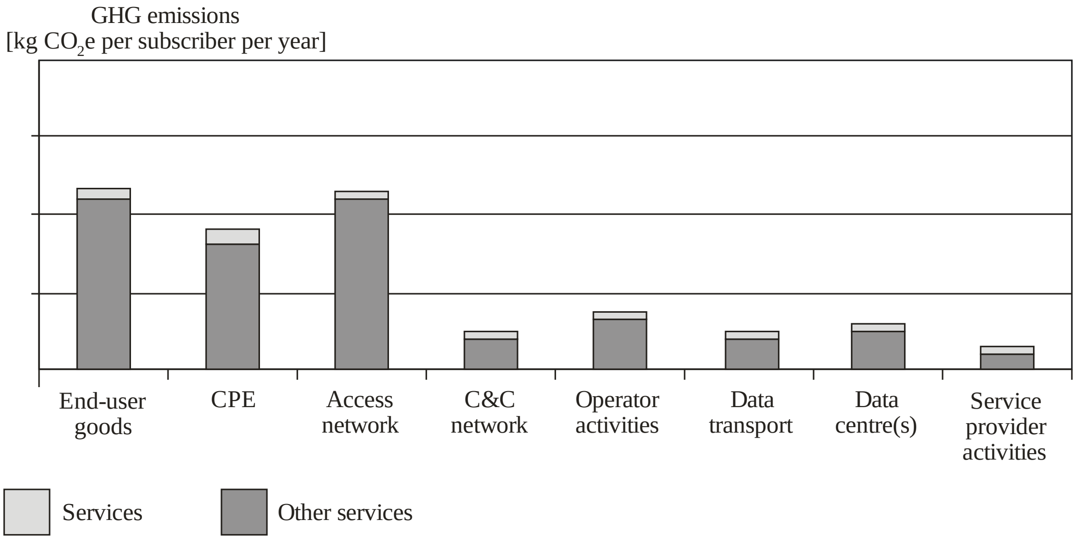

Figure 20: Example of a reporting structure for ICT services

There is typically a multitude of services running over a telecommunications network. Assessing the impact of a single service most likely needs to be done by using allocations. Guidance for doing allocations in the context of services is given in clause 6.3.3.9.

If the eight checklist items outlined in clause 6.2.3.1 are kept apart in the assessment and in the reporting then Figure 21 shows an example of a possible reporting format.

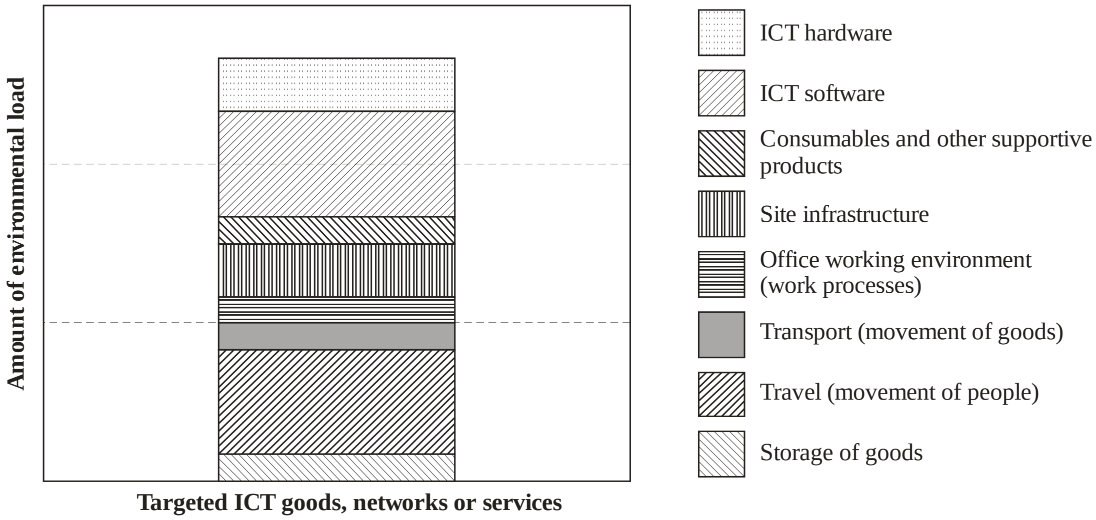

Figure 21: Example of results of an LCA per functional unit separating checklist items

9.4.2 Total results

For each environmental impact category studied, a diagram should be prepared splitting the impact of different parts of the network. Figure 22a and Figure 22b show examples of ICT Service LCA reporting.

Operating lifetime is important also for Services, but it is associated with the lifetime of the different nodes, which shall be reported. Reporting should be made in accordance with Table L.11 which also describes the studied Network(s).

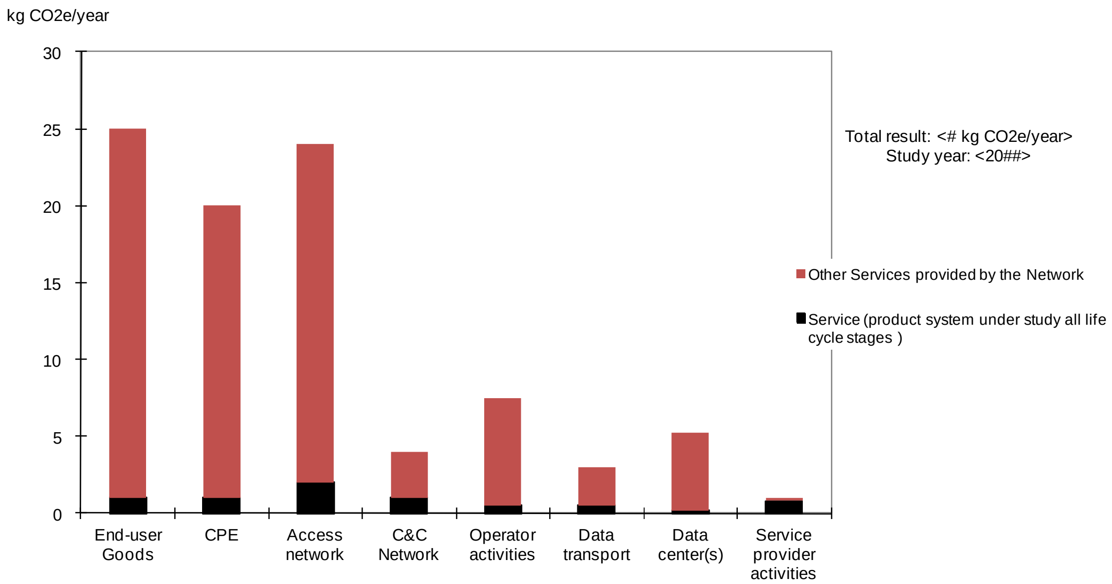

Figure 22a: Environmental impact category indicator result diagram example for Services (diagram for Global Warming Potential (GWP100) (CO2e))

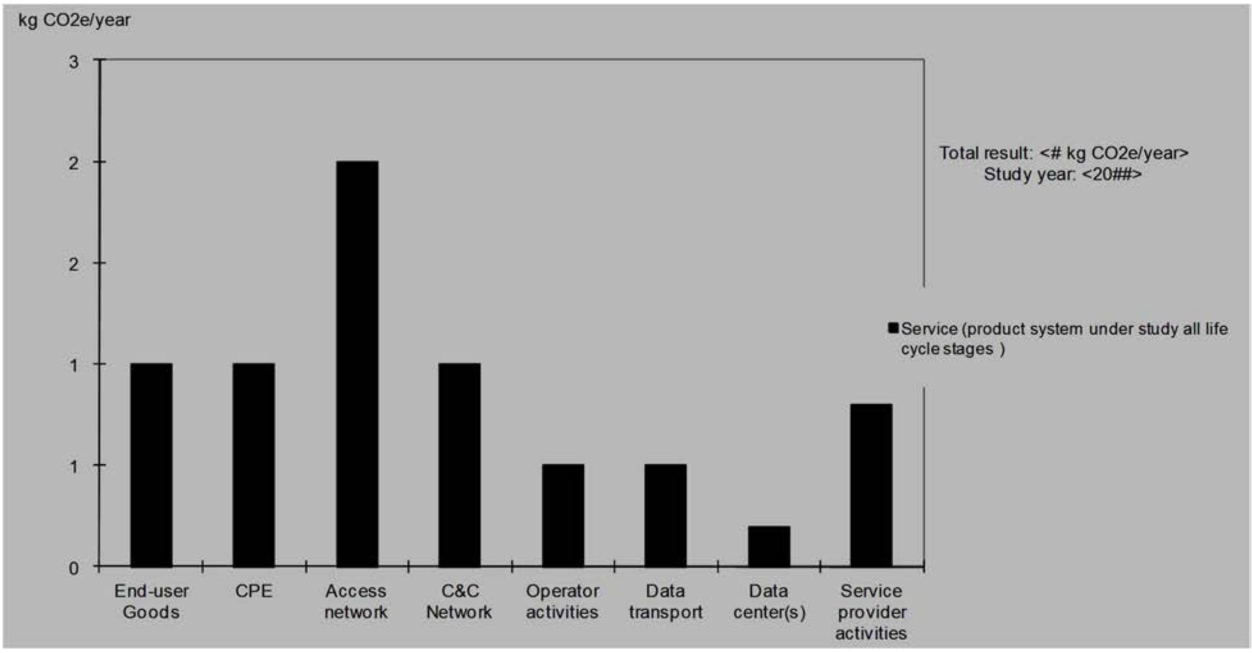

Figure 22b: Environmental impact category indicator result diagram example for Services (diagram for Global Warming Potential (GWP100) (CO2e))

Figure 22a and Figure 22b should be used alternatively depending on the scope of the assessment. Figure 22a and Figure 22b shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation in the scope and clause 5.3.

Allocation of Network data to the Service shall be reported. It should be reported according to Table L.13.

Additionally a diagram summarizing distribution of impact category indicators between life cycle stages for the Service product system under study shall be presented together with absolute figures as shown in the Table L.10. Figure 23 provides an example.

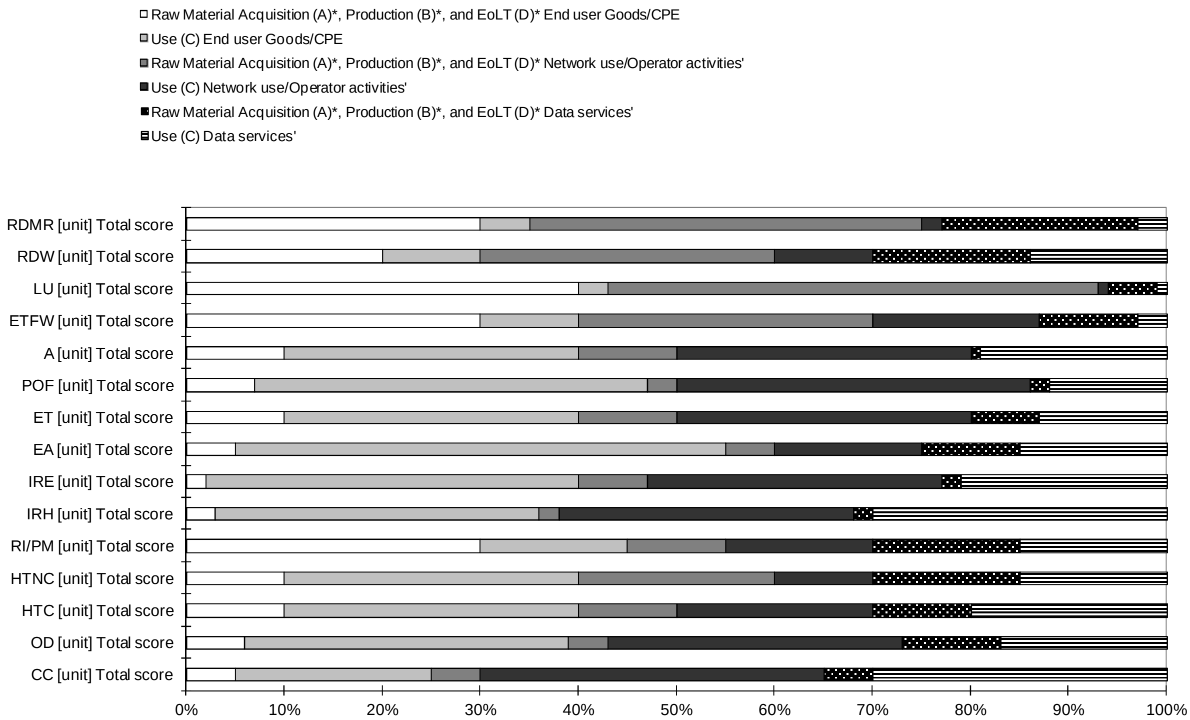

Figure 23: Environmental impact category indicators examples overview for Services

Figure 23 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation in the scope and clause 5.3.

In addition to the Service reporting described above, the general reporting principles for Networks shall apply.

10 Critical review

Critical review is a process to verify whether an LCA has met the requirements for methodology, data, interpretation and reporting and whether it is consistent with the main principles (relevance, completeness, consistency, accuracy and transparency). Any critical review shall be performed according to the requirements of ISO 14040 [1] and ISO 14044 [2] and in the present document. The scope and type of critical review desired shall be defined in accordance with ISO 14044 [2], clauses 4.2.3.8 and 6.

In case of comparative assertions intended for public disclosure, the report is one resulting from the application of the present document, of the LCA should be reviewed by a panel of interested external parties. In this case, the LCA practitioner should refer to ISO 14040 [1] and ISO 14044 [2] for further details.

Part II: Comparative analysis/LCA between ICT and reference product system (baseline scenario): framework and guidance

11 General description of comparative analysis

11.1 Need for comparative analysis

With the growth of ICT, the use of ICT goods, networks and service will continue to increase as will the associated environmental load, also referred to as the first order effect. This effect represents the life cycle environmental load emerging from processes such as design, production and installation of software and hardware, installation of ICT goods and networks and from disposal and recycling, as well as from the use stage. However, by its second order effects, ICT offers the potential to replace or rationalize more energy and resource intensive processes and is in many cases expected to deliver a net positive impact on the environment. Recommendation ITU-T L.1480 [i.25] provides guidance for assessing second order effects when the use of ICT solutions impact GHG emissions of other sectors. In addition, Recommendation ITU-T L.1480 [i.25] guides also the assessment of higher order effects such as rebound.

Comparative LCAs between an ICT based system and a reference product system (e.g. comparison between a face-to-face business meeting including air transport and the ICT Service video conference) aim to compare LCA results for different products, systems, or services that offer the same or similar functions.

In general the time perspective applied as well as the scale of introducing the ICT based product system is crucial to the modelling. These perspectives may vary with study scope and purpose, e.g. a small-scale application of a video conferencing system will not in the near future impact the amount of air-planes used, while a large-scale application may have a considerable impact in a medium time frame.

Infrastructure, e.g. highways for transportation, is generally assumed to exist independently of introduction of new services and shall be excluded. However in some LCAs focusing on large scale effects of Services, infrastructure effects may be applicable to the studied product system (i.e. for an LCA trying to examine the effects of large-scale, long-term implications of a wide application of video conferencing). In those cases infrastructure associated impacts should be reported separately.

The handling of time perspective and scale shall be disclosed and motivated in the present document.

To be able to quantify the net environmental impact when introducing an ICT solution the environmental impact of both the ICT product system itself and of the reference product system shall be assessed from a life cycle perspective. For further guidance refer to Part I. Potentially the reference product system could be any product system including another ICT based system.

The net environmental impact resulting from the introduction of ICTs is calculated as the difference between the environmental load of the reference product system which could be avoided by introducing the ICT based system and the environmental load of the ICT based system itself.

To make sure that the comparative assessment gives a relevant result, the full life cycle of both systems shall always be considered. However, cut-off may be performed according to clause 12.2.3.

Correct comparisons also require that the same goal, scope, system boundaries and functional unit are used for both product systems.

From an LCA perspective the reference product system and the ICT service based system shall mimic each other as far as possible and the LCA practitioner shall model both systems in an unbiased way. In reality the two product systems may differ with respect to quality, e.g. the experience of a face-to-face meeting is different from that of a video conference meeting.

Usually, the most challenging part for a comparative assessment is to collect real-world data for the use stage both for the reference system and for the ICT based system. Lack of real-world data can be bridged by scenarios. The impact from the scenarios on the results is preferably evaluated by the use of sensitivity analysis, where parameters for scenarios/assumptions made are varied to track their importance for results and conclusions.

Considering the complexities associated with comparative assessments, restrictions as to the interpretation of the results and the equivalence of the ICT and reference product systems are to be carefully observed, to avoid misinterpretation of results.

11.2 Target systems for comparative analysis

Two different applications for comparative assessment are targeted by the present document:

- *Case 1 - Comparison between a reference product system (non-ICT) and an ICT good, network or service product system*
- *Case 2 - Comparison between two ICT goods or two ICT networks or two ICT services.*

Corresponding to this Recommendation, ITU-T L.1480 provides further guidance. Currently, Recommendation ITU-T L.1480 [i.25] focuses only on Greenhouse Gas (GHG) emissions and provides guidance for assessing how the use of Information and Communication Technology (ICT) solutions impacts GHG emissions of other sectors covering the net second order effect (i.e. the resulting second order effect after accounting for emissions due to the first order effects of the ICT solution), and the higher order effects such as rebound.

The LCA practitioner should take care in understanding the intended effect of the studied ICT solution when compared to a reference product system containing another ICT solution. If the intended effect of the ICT solution refers to effect associated with activities in other sector than ICT sector, this would be qualified as an enablement effect (impacts on other sectors). In that case, Recommendation ITU-T L.1480 [i.25] provisions are applicable.

In another situation, when the intended effect refers to effect associated with activities belonging to the ICT sector, this could not be qualified as an enablement effect but shall be qualified as reduction of first order effects as this only impacts the footprint of the ICT sector. These effects are not second order effects (which refer to effects on emissions other than those associated with first order effects of ICTs) and thus Recommendation ITU-T L.1480 [i.25] is not applicable. In the case of a reduction of first order effects, the comparative assessment would correspond to Case 2 (comparison between two ICT product systems).

First case: comparison between a reference product system (non ICT) and an ICT Good, Network or Service product system".

In this case, the product systems are the reference product system (non ICT) and the ICT good, Network or Service product system. The former is the business-as-usual case (so called baseline case) where no ICT good, Network or Service is applied. The latter is the case where the ICT goods Networks and Services is applied. The purpose of this comparison is to understand the second order effects when introducing an ICT good, Network or Service product system as a replacement or optimization for a reference product system. Such effects include a reduction in environmental impact in terms of GHG emission savings in for instance, commuting, air flights, hotel stays, etc.

Second case: comparison between two ICT goods or two ICT networks or two ICT services.

In this case, the two target systems are different ICT goods or ICT networks or ICT services. One may be an older ICT good, ICT network or ICT service, the other a newer one. Goods shall be compared with other goods, ICT networks shall be compared between themselves and ICT services shall be compared between themselves.

11.3 Principles of comparisons between systems (comparative analysis)

11.3.1 First case: comparison between a reference product system (non-ICT) and an ICT good, network or service product system

In this case, in order to assess the second order effects of the ICT solution a comparative study between the reference product system (non ICT) and the ICT solution is conducted. In this comparative LCA study, the scope of the LCA study shall be defined in such a way that the two systems can be compared. Systems shall be compared using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures and cut-off rules. Any differences between systems regarding these parameters shall be identified and reported.

Both first order and second order effects should be considered when comparing a scenario based on the use of a reference product system and the situation after adoption of ICT goods, networks and services.

Using ICTs has the potential to enhance energy efficiency and reduce the need, for instance, for transport and travel, etc. To assess the impact on the second order effects, it is important to consider environmental load reduction effects by using ICT. The most important effects are listed in clause 12.5 and Annex U. In addition, other load reduction effects may also be relevant and should then be considered as well.

11.3.2 Second case: comparison between two ICT goods or two ICT networks or two ICT services

In this case also, the scope of the LCA study shall be defined in such a way that the two systems can be compared. Both systems shall be assessed using the same functional unit and equivalent methodological considerations, such as system boundary, data quality, allocation procedures and cut-off rules. Any differences between systems regarding these parameters shall be identified and reported.

When a product has several life cycles, it is essential to include all the effects of the refurbishment in the assessment of its environmental impact. These effects shall be included into each of the applicable life cycle stages and into cumulative cradle to grave assessment.

NOTE: The effects of refurbishment can be positive or negative with respect to the reasonable (average) renewals of the product with new material.

Annex Z shows one example of an analysis with different refurbishment configurations.

11.3.3 Common principles

In the case of comparative analysis, if the purpose is to assess the difference of impact between the two product systems, rather than the total impact of each product system, processes or input/output data may be excluded if they are the same in both product systems.

A schematic illustration of a comparative assessment is shown in Figure 24. Figure 24 indicates that the reference product system and the ICT goods, networks and services product system are assessed separately and then compared.

The assessment of the ICT based system shall be performed in accordance with Part I.

When making comparisons, it is important to keep in mind that the functional unit used shall be applicable to both the reference product system and the system of ICT goods, networks and services.

For the reference product system applicable requirements in the present document shall be applied, e.g. requirements regarding data quality, cut-off, etc. To get further guidance on system boundaries and other product system specific considerations (for the reference product system) sector specific standards should be used if available.

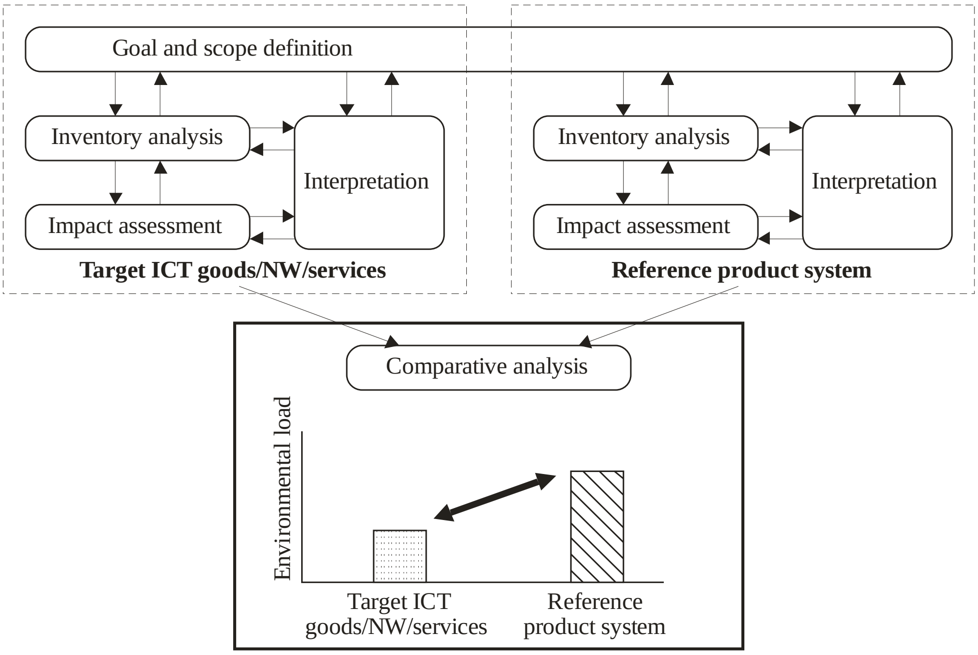

Figure 24: Comparative assessment of a reference product system and an ICT goods, networks and services product system

11.4 Procedures of comparisons between systems (comparative analysis)

As indicated above the assessment procedure contains several steps:

- Definition of goal, functional unit and scenarios.
- Definition of system boundaries for each product system.
- Life Cycle Inventory including data collection for each product system.
- Life Cycle Impact Assessment for each product system.
- Life Cycle Interpretation including comparison.

12 Methodological framework of comparative analysis

12.1 General requirements

In the comparative situation, the full life cycle applies to both the ICT product system and the baseline system, unless cut-off is allowed in accordance with the cut-off rules outlined in clause 12.2.3.

12.2 Goal and scope definition

12.2.0 Introduction

Goal definition includes defining the reason for conducting the comparative analysis, the target audiences and the intended use of the results.

Defining the scope includes defining the system boundaries of the ICT goods, networks and services product system and the reference product system.

All the requirements stipulated in Part I for a system boundary definition shall be applied.

12.2.1 Functional unit

The functional unit shall take into account the general rules outlined in Part I, clause 6.2.2 and ISO 14044 [2], clause 4.2.3.2.

Additionally, the functional unit shall be defined so that it is applicable both to the ICT goods, networks and services product system and the reference product system. E.g. when comparing a video conferencing system with a travelling based reference product system, an appropriate functional unit may be one meeting or the total number of meetings during one year.

The reference flow shall be defined to quantify the functional unit. In other words, for the functional unit of one meeting, for instance, the reference flow for the systems of ICT goods, networks and services and the reference product system shall be defined.

12.2.2 System boundaries

Two different system boundaries shall be defined which are applicable for the ICT goods, networks and services product system and for the reference product systems respectively.

The use stage scenarios need to model the user and the user profile for both systems. Key parameters for the systems of ICT goods, networks and services could include e.g. number of users and amount of data traffic. For the reference product system parameters such as distance travelled, average number of participants and, building area may be relevant.

A meeting can for example be characterized by the required energy consumption integrated over the average meeting duration, the average number of participants and the cumulative distance travelled.

As the electricity mix differs between different regions, countries and world average, considerations shall be paid to which electricity is used when assessing the environmental impact of the ICT goods, networks and services product system and the reference product systems.

For the ICT goods, networks and services product system the system boundaries outlined in Part I, clause 6.2.3 applies.

12.2.3 Cut-off

12.2.3.1 General

Generally, the cut-off rules in Part I (see clause 6.2.4 for details) shall apply for both ICT goods, networks and services and the reference product system.

If a reference value is introduced for cut-off in accordance with clause 6.2.4 and is based on the reference product system, it could be referred to as the cut-off value of the reference product system.

12.2.3.2 Identification of life cycle stages and items important for comparison

Using ICTs has the potential to enhance the energy efficiency and reduce the need for transport and travel, etc. One important consideration for the cut-off therefore concerns the handling of second order effects. In addition to considering the first order effects in the cut-off as outlined in Part I, second order effects need also be considered before cut-off. Both for the reference product system and for the ICT goods, networks and services, these effects are important to consider to avoid cut-off of processes within the life cycle which significantly impacts difference in environmental load between the scenarios related to such effects.

In the case of comparative analysis, if the purpose is to assess the difference of impacts between the two product systems, rather than the total impact of each product system, processes or input/output data may be excluded if they are the same in both product systems.

12.2.4 Allocation

Generally, the allocation rules in Part I shall apply for ICT goods, networks and services.

12.2.5 Data quality requirements

The data quality requirements in Part I, clause 6.2.5, are applicable to both systems compared.

Applicable data sources may be databases, field studies, published LCA results and relevant statistics.

12.3 Life cycle inventory

The calculation for the inventory analysis shall be performed in accordance with Part I, clause 6.3.

12.4 Life cycle impact assessment

The life cycle impact assessment is to be performed in accordance with Part I, clause 7.

12.5 Life cycle interpretation

12.5.1 General

The interpretation of results includes analysis of how the methodology was applied and should be performed in line with ISO 14040 [1] and ISO 14044 [2] and includes e.g. conclusions, assumptions, limitations, uncertainty and data quality.

The impact of scenarios as well as of assumptions related to allocation should also be analysed. For example, interpretation should include whether the allocation of data are based on primary or secondary data, if models are used and across which life cycle processes of an ICT product they have been applied.

Results of a comparative analysis between a reference product system and systems of an ICT goods, networks and services product system can be obtained by calculating the difference in environmental impact between the reference product system and the systems of ICT goods, networks and services. The difference is termed second order effect. Equation (1) shows the calculation formula.

$$EI_{difference,i} = EI_{reference,i} - EI_{ICT\ goods,\ networks,\ and\ services,i} \qquad (1)$$

where:

EI	=	environmental impact;
i	=	i-th comparison category;
$EI_{difference,i}$	=	i-th second order effect;
$EI_{reference,i}$	=	i-th EI of the reference product system;
$EI_{ICT\ goods,\ networks,\ and\ services,i}$	=	i-th EI of the systems of ICT goods, networks and services.

Summing up $EI_{difference,i}$ over i gives total $EI_{difference}$ or the second order effect of the systems of ICT goods, networks and services over the reference product system. Equation 2 shows the formula for calculating the second order effect.

$$Total\,EI_{difference} = \sum EI_{difference,i} \qquad (2)$$

A positive result (Total $EI_{difference}$ is positive) indicates a positive impact on the environment and a negative value (Total $EI_{difference}$ is negative) represents a negative impact. A positive second order effect indicates the reduction of the environmental impact due to the introduction of the ICT product system. A negative second order effect indicates the opposite.

The number of comparison items are up to the discretion of the LCA practitioner and the structuring of data may vary between LCAs.

Table 7 shows an example of comparison categories, based on six comparison items and the potential corresponding second order effects. Depending on the type of ICT product system and corresponding reference product system, these categories may not be used and other categories may be added. Additionally, the LCA practitioner may choose to structure the data based on other factors, e.g. per sub-network type.

Table 7: Comparison category and its second order effects

Comparison categories	Second order effects
Consumption of goods	By reducing goods consumption (paper, etc.), EI related to goods can be reduced.
Energy consumption	By enhancing the efficiency of power and energy use, EI related to power. Can be reduced.
Movement of people	By reducing the movement of people, EI required for transportation can be reduced.
Movement and storage of goods	By reducing the movement of goods, EI required for transportation can be reduced.
Improved work efficiency	By using office space efficiently, power consumption for lighting, air conditioning, etc. can be reduced, thus reducing EI.
Waste	By reducing waste emissions, EI for waste disposal, etc. can be reduced.

Annex U lists examples for calculating second order effects for the six comparison categories. Recommendation ITU-T L.1480 [i.25] gives further guidance for provisioning and calculating second order effects.

12.5.2 Sensitivity analysis

For the handling of sensitivity analysis refer to Part I, clause 8.3.

Especially when modelled data are used, different scenarios should be assessed to establish a range of potential outcomes to limit the uncertainty. For instance, to understand the impact of an ICT solution, it is advisable to assess how its impact varies with the scale of adoption, considering different relevant scenarios.

12.5.3 Uncertainty analysis

For the handling of uncertainty analysis refer to Part I, clause 8.2.

13 Reporting

In addition to general reporting rules outlined in Part I, clause 9, the following specific consideration applies for comparative assessment.

When the result of a comparative analysis between an ICT system and a reference product system (another ICT system or a non-ICT system) is reported as an environmental impact assessment, the environmental impact should detail the life cycle stages. It may be detailed according to checklist items if assessed in an LCA of ICT goods, networks and services product system, in accordance with the goal and scope of the LCA.

Any cut-off made during a study shall be clearly stated in the study report, e.g. the exclusion of life cycle processes which are considered insignificant should be justified.

The results may either be given as absolute amounts or as a relative difference between the systems. Thus, instead of reporting the calculated absolute amount of environmental impact, a relative difference (possibly as a percentage) between the impact from the ICT system and the impact from the reference product system may be presented.

Some examples are shown below.

The percentage of change in environmental impact through the introduction of ICTs may be calculated as a result of the following equation.

Percentage change in environmental impact through the introduction of ICT systems is given by Equation (3):

$$\text{ICT goods, networks and services} = EI_{difference}/EI_{reference} \times 100 \qquad (3)$$

where EI is the assessed environmental impact.

The calculation result shown by Figure 25 indicates a positive impact on the environment when the percentage change value is positive and a negative impact on the environment when it is negative.

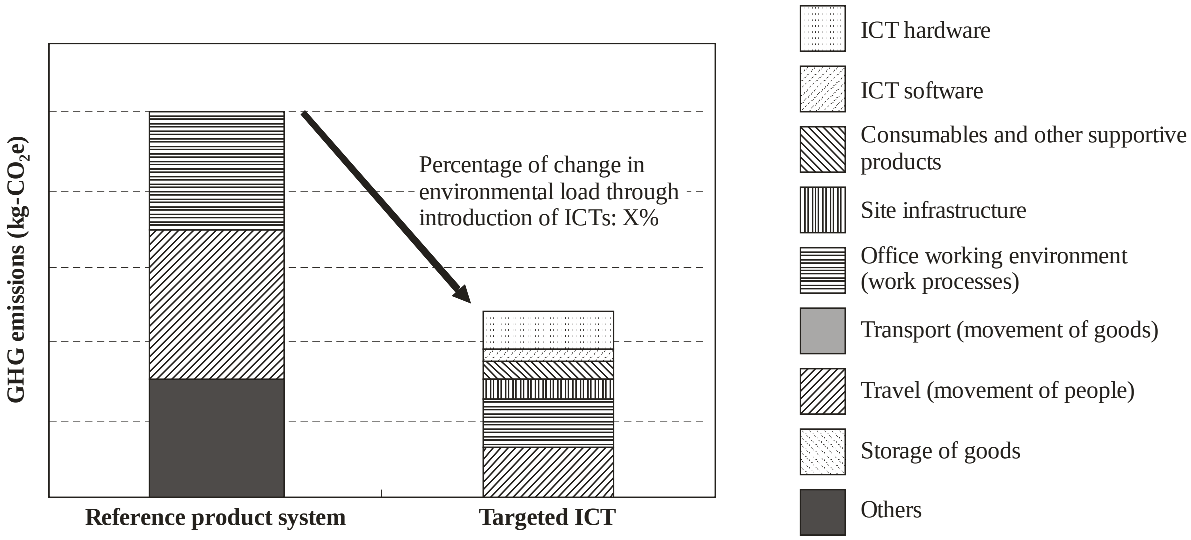

Figure 25: Example of comparative analysis between an ICT goods, networks and services product system and a reference product system with checklist items

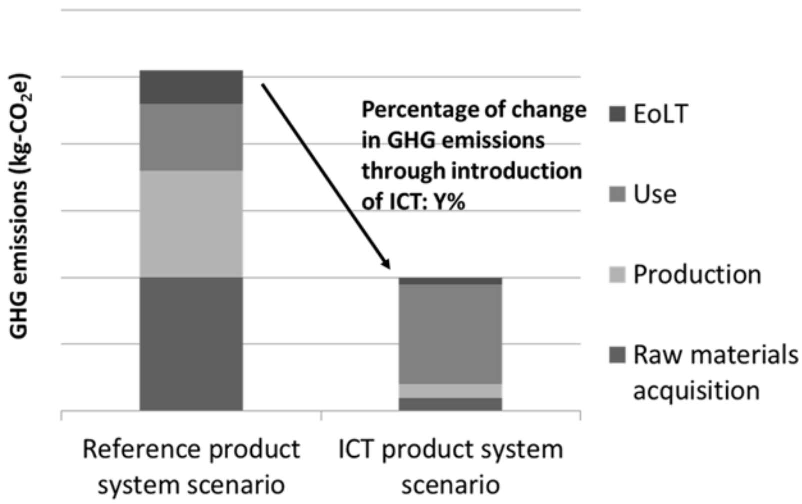

Figure 26: Example of comparative analysis between an ICT product system and a reference product system with stages of a life cycle

14 Critical review

The critical review should be performed in accordance with principles outlined in Part I, clause10 for the ICT product system, the reference product system and the comparison between them.

Annex A (normative): Details regarding the handling of software

This Annex details some central aspects which shall be considered when assessing the environmental impacts of software.

Life cycle stages and allocation principles for software.

For each of the software categories described in the main text its intended use and sales volumes (i.e. number of licences/packages) need to be considered.

Design, development and production stages should be considered in LCAs of ICT goods, networks and services. Moreover, for commercial software products the environmental impact of the procurement stage should also be considered.

Activities associated with the use of software.

The following items are examples of activities related to software design and production that cause an environmental impact and which shall be considered:

- Electricity consumption of ICT goods such as computers, communication goods and printers.
- Electricity consumption of offices such as air conditioning and illumination.
- Consumption of the consumables such as paper or printer toner.
- Recycling and disposal of waste.

The above activities are applicable both to purchased software and software developed in-house.

Procedures for data collection.

The preferred choice for data collection is to use primary data from the supplier.

For software made by the organization using it, primary data as outlined above (e.g. electricity consumption, etc.), is available to the user for design and development stages.

In this case, the environmental impact for these activities may be calculated using the below formula (Equation A.1) by adding up the different environmental impact for different activities:

$$Ea=E1+E2+E3+ \text{---------} +En \qquad (A.1)$$

- Ea: Quantity of environmental load for software design and production
- E1, E2, E3, En: Quantity of environmental load for each activity

For procured software, the following method based on addition of environmental load per software can be applied (Equation A.2):

$$Eb=O+B1+B2+M1+M2 \qquad (A.2)$$

- Eb: Quantity of environmental load of all software (CO_2 emission, etc.).
- O, B1, B2, M1, M2: Quantity of environmental load of the individual software to be procured (CO_2 emission, etc.).

However, if such data are not available, the procedures below can be applied.

If GHG emission data is available for some software from a supplier, the load of other software may be estimated based on the selling prices and the known environmental load values, according to the following formula (Equation A.3):

$$Eb=(W/p1)\times S1 \qquad (A.3)$$

- Eb: Quantity of environmental load of all software (CO_2 emission, etc.).

- W: Total amount of all software to be procured (selling price, etc.).
- p1: Amount of software for which their environmental loads are known (CO_2 emission, etc.).
- S1: Quantity of the environmental load of software (w1) well-known quantity of environmental load (CO_2 emission, etc.).

An alternative method to overcome data shortage would be to make estimates based on economical input-output tables for environmental analysis, i.e. based on environment load emission values provided in tables of economical statistics, also considering the cost of software to be targeted. The following formula (Equation A.4) applies:

$$S = w1 \times k \qquad \text{(A.4)}$$

- S: Environmental load with the design and production of software.
- w1: Price of software to be targeted.
- k: The emission factor in CO_2 emission per price of software in currency unit.

Annex B (normative): Modelling of unit processes

Data shall be collected, for each unit process that is included within the system boundary, in accordance with Annex B.

A unit process typically represents a facility where a product is produced, but it can also represent, e.g. an office or a store - or even an activity or a place where a service is produced. A unit process can also be a vehicle or a "mobile facility" that transports products. Non-production facilities are especially important to the ICT sector [i.16] as a large percentage of the total work is related to research and development (including software), operation, maintenance, etc.

A unit process can be modelled as shown in Figure B.1. The generic unit process model includes a number of inputs and outputs and can be referred to as a facility LCI model or - shorter - a facility model.

NOTE: E.g. the Part unit Processes in Table E.1.

In many cases a facility handles not only the product system targeted by the LCA but also other product systems In this situation, the facility data needs to be allocated to the studied/targeted product system in an appropriate way. For allocation rules see to clause 6.3.3.

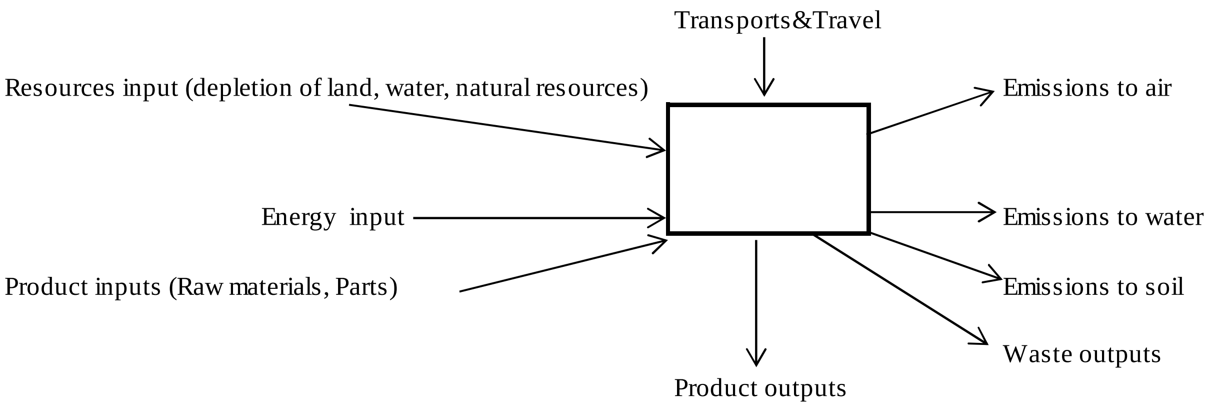

Figure B.1: The generic unit process model

Emissions to the environment and impact on or use or depletion of resource objects are referred to as elementary flows. All other inputs and outputs are defined as product flows.

Each input of fuel and products, as well as each output of waste, may involve transportation which is then part of the input/output data connected to the unit process.

Applicable support activities should also be considered for a production facility if applicable.

Emissions (elementary flows)

The following emissions shall be taken into account if applicable to the studied impact category(ies):

- Emissions to air.
- Emissions to water.
- Emissions to soil.

Non-material emissions like radiation, odour and noise are beyond scope of the present document as well as direct impact on health.

Resource objects (elementary flows)

The following resource objects shall be taken into account if applicable to the studied impact category(ies):

- Material resource use (see RDMR, Resource Depletion Mineral Resources, table 5).

- Energy resource use (see RDMR, Resource Depletion fossil, table 5).

Additionally, the following resource objects should be taken into account if applicable to the studied impact category(ies):

- Fresh water use (see Resource Depletion (RDW), Water).
- Land use.

Species, biodiversity and eco-system depletion as well as aesthetical values are beyond the scope of the present document.

A list of emissions and resource objects that shall be included, if applicable to the studied product system and impact category(ies), can be found in Table G.1.

Energy, product and services inputs

Further, the following inputs shall also be included if applicable to the studied impact category(ies):

- Electricity.
- Other forms of delivered energy (district heating and cooling).
- Fuels (typically indicates the fuels are incinerated on-facility or in a vehicle connected to the facility).
- Primary products (products that are part of the final product in operation).
- Secondary products (products that are not part of the final product in operation, e.g. 2-propanol used as cleaning agent for PCBAs).
- Transports, travel and other services (can be seen as a special non-material secondary product input).

Product, water and waste output

Finally, the following flows shall also be included if applicable to the studied impact category(ies):

- Water discharge (to municipal sewage or recipient).
- Waste fractions (residual waste fractions or waste fractions that need further treatment, also including material recycling and energy recovery).
- Product output (the main purpose with the unit process or activity).

A mandatory list of generic activities (unit processes) that have been found to be of importance for LCA of *ICT goods, Networks* and *Services* can be found in Annex D.

An informative list of typical *ICT goods, Support goods and Network goods* can be found in Annexes O and P.

Annex C (normative): Support activities

Whenever support activities are included in the study scope the guidance in Annex C shall be considered.

All activities during the life cycle of an ICT goods, network or service, performed by an organization, are related to different kinds of organizational activities which in the present document are referred to as *support activities*.

The term *support activities* refers to activities that are specific to the goods network or service, but also to other general organizational activities needed to operate the company. The former could be e.g. marketing, sales, research and development; the later could be data support, human resources support; communications, financial department, etc.

Both these categories are associated with the use of buildings and travelling/transports, i.e. use of energy and material resources.

The impact from specific activities could either be estimated based on detailed knowledge of the organizational structure (bottom-up), or by allocation from information regarding the total amount of employees in the organization and their impact (top-down).

Optionally also impact from consultants and services used by the organization could be considered.

Any support activities included in the LCA scope shall be clearly reported in term of organization activities considered.

The support activities for ICT manufacturer, operator and service providers have been given specific names:

- ICT manufacturer support activities.
- Operator support activities.
- Service provider support activities.

This is to highlight their importance. They have also been structured separately in Figure 2, Figure 5 and Figure 6. For other life cycle activities the support activities are embedded in the activity itself.

As most activities during the life cycle are associated with support activities, the support activities could be seen as generic activities. However, in contrast to other generic processes (like travelling, transports, etc.), the activity data for support activities are very much specific to the organization performing it and need to be modelled specifically for different organizations.

Annex D (normative): Generic processes

Table D.1 defines the generic processes (G1 to G7) which shall be included if applicable in LCAs for *ICT goods*, *Networks* and *Services*, as well as examples of categories and examples of unit processes to be included. Generic processes are processes that are applicable several times during the life cycle and could be used for several life cycle stages and even several times per stage. As an example the generic raw material process G5 is applicable to any raw material used during any life cycle stage, including the raw materials used during the Raw material acquisition stage (denoted A in Table 2).

Table D.1: Generic processes for LCA of ICT goods

Generic process	Generic process categories	Unit processes (for each category)	Product flow unit	Important issues
G1. Transports and Travel	Road Air Ship Train	Mandatory: Direct (during transport) emissions, Fuel supply chain (see note 1) Optional: Vehicle production, Infrastructure production	tonne×km, kg×km, Ctonne×km	Chargeable mass = Ctonne×km (function that also considers volume or density) (see note 3)
G2. Electricity	National, regional and local producer electricity mixes	Mandatory: Fuel supply chain (see note 1), "Raw Material Acquisition+ +Production+Distribution" where applicable for local renewable electricity generation, Direct emissions (during electricity production) Optional: power plant production, dam production, the grid production, nuclear waste treatment	kWh	This is also applicable to local production of electricity e.g. off-grid site electricity generation using e.g. photovoltaic modules and wind turbines
G3. Fuels	Oil Diesel Petrol Jet-fuel LPG LNG Coal Gas	Mandatory: Fuel supply chain (see note 1)	mass, energy content	
G4. Other energy	District heating (hot water) District heating (steam) District cooling (cold water) as electricity	Mandatory: Fuel supply chain, Direct emissions during energy/electricity production Optional: Power plant production, Infrastructure production	kWh	
G5. Raw material acquisition	See Annex H	Mandatory: Extraction Processing	mass	

Generic process	Generic process categories	Unit processes (for each category)	Product flow unit	Important issues
G6. End-of-life treatment	G6.1 EHW (Environmentally Hazardous Waste) treatment: EHW (destruction and energy recovery) Special EHW landfill G6.2 Other Waste treatment: Diverse material recycling Editorial: clarification needed to differ from G7 Energy recovery (e.g. incineration, see note) Landfill See Annex F for goods EoLT	G6.1: Recovery/treatment G6.2: Recycling/recovery/treatment	mass, (energy content)	
G7. Raw material recycling	Metal recycling Other material recycling	Mandatory: Smelting Refining Optional: Plastic, paper		Other material shall be considered
NOTE 1: Extraction and Production and Distribution (transports). NOTE 2: Energy recovery of incineration processes is optional. NOTE 3: For each transport the LCA practitioner should assess the studied good mass or volume whichever is the limiting factor for the transport and also the vehicle maximum payload and/or available volume respectively. In case the limiting factor is not known both should be assessed. If mass is the limiting factor the *"Product flow unit"* can directly be assessed with a kg×km / tonne×km formula. Otherwise, if volume is the limiting factor the *"Product flow unit"* should be assessed by adding a loading rate factor.				

Annex E (normative): Part types of ICT goods

Table E.1 lists the applicable parts and assembly types which shall be taken into account when performing an LCA of ICT goods, if applicable to the ICT good (not ICT network). It also lists the corresponding part and assembly categories and unit processes. However, parts which are found insignificant according to the cut-off rules may be excluded. The list is to be regarded as a mandatory list and additional processes and parts may be identified and included as well, e.g. fuel cells.

The intention of the list is to state what shall be considered to make sure that important parts are not forgotten.

The intention is not to put requirements on modelling. In practice, it is often convenient to model the production processes for part categories separately but other modelling is possible as long as the impact from the part category is included in the overall results. For raw materials acquisition it may be impractical to model goods at a part category level.

At the time of publication, some of the requirements in Annex E are considered as challenging due to LCA tool limitations, lack of data, limitations in data granularity, etc. It is thus recognized that compliance to all requirements in Annex E may not be possible at the time the present document is published.

Deviation(s) from the requirements shall be clearly motivated and reported.

Table E.1: Mandatory set of parts and Assembly unit processes for LCA of ICT goods

Part/Assembly	Part/Assembly categories	Unit processes (for each Part/assembly category)	Product flow unit	Important parameters which influence LCI data
B1.1.1 Batteries (see note 8)	Lead batteries Lithium batteries Nickel-Cadmium batteries Nickel-metal hydride batteries	Raw Material Acquisition, Battery cell assembly (see note 1), Battery module (pack) assembly (see note 2)	Piece (see note 7), energy content, mass	Size
B1.1.2 Cables	Coaxial cables Fibre cables Power cables Network/signal cables *Connectors*	Raw Material Acquisition, Cable final assembly	Mass, Piece (see note 7)	Length
B1.1.3 Electro-mechanics	*Connectors* Electric motors Chargers Speakers Microphones Camera objectives Hard Disc Drives Lighting (lamps)	Raw Material Acquisition, Part final assembly	Mass, Piece (see note 7)	

Part/Assembly	Part/Assembly categories	Unit processes (for each Part/assembly category)	Product flow unit	Important parameters which influence LCI data
B1.1.4 Integrated circuits (Ics)	Processors, DSPs ASICs Memories Microprocessors Transistors and diodes	Front-end: Special IC Raw Materials Acquisition, Wafer production, Chip production ("the wafer fab") Back-end: Raw Material Acquisition, IC encapsulation	Piece, Mass. Front-end: Die area [cm^2] where readily available or mass independent from package type where the die area is not available. Die area refers to the total area within the IC package. If die area is not available the total component mass is used for both frontend and backend. Back-end: piece package type or mass independent from package type where the die area is not available. (see note 3). Transistors and diodes: Piece, mass, or as for Ics for front-end and back-end (see note 7)	Yield in chip production. Business activities. Factory and machinery.
B1.1.5 Mechanics/ Materials	Nuts, bolts, screws Fronts Frames Racks Cabinets Towers Containers Solder	Raw Material Acquisition, Part final assembly	Mass, Piece (see note 7)	
B1.1.6 Displays	PDP LCD (see note 4) LED OLED	Raw Materials Acquisition Raw Materials Acquisition for special display panel materials, Display module assembly, Display panel assembly	Mass, active area, piece (see note 7)	Yield Business activities, Factory and machinery
B1.1.7 PCB	Plastic Ceramic Flex-film	Raw Materials Acquisition, Raw materials Acquisition for special PCB materials, Raw materials Acquisition for PCB semi-produced composite materials, PCB final assembly	Mass, area of multilayer PCB, piece (see note 7)	Yield Business activities, Factory and machinery
B1.1.8 Other PCBA components	Resistors Capacitors Inductors Relays LEDs Potentiometers Quartz crystal oscillators	Raw Material Acquisition, Part final assembly	Mass, Piece (see note 7)	
B1.1.9 Packaging materials	Paper Cardboard Plastics Wood Steel	Raw Material Acquisition	Mass, volume (see note 5)	Lifetime, Re-use, energy recovery

Part/Assembly	Part/Assembly categories	Unit processes (for each Part/assembly category)	Product flow unit	Important parameters which influence LCI data
B1.1.10 Black box modules	Products, devices, modules bought by ICT goods producer, or other actors in the supply chain, as complete products (e.g. cameras, modules, memories, printer cartridges. These products can also be complete ICT goods such as mobile phones and Network equipment as well as storage devices, disk drives or power supply units)	"Cradle-to-gate" LCA from supplier (see note 6)	Mass, Piece (see note 7)	Size, mass, technology
B1.1.11 Software module For further guidance see Annex A	Software	Development: e.g. daily way to work for programmer, business trips for programmer, electricity usage of ICT goods used by programmer, office lighting. Production: e.g. manuals production, Data medium production, Download size if software is available as download.	Megabyte	
B1.2 Assembly	PCBA Module Assembly, Final Assembly	Assembly process Warehousing, Packaging.		

NOTE 1: Example: Battery cell assembly could include the cell plant production energy and the transport of cells to battery module (pack) assembly. In the battery cell assembly usually anode, cathode, separator and electrolyte and plastic parts are used to make the cell.

NOTE 2: Example: Battery module (pack) assembly could include assembly plant production energy, transport to B1.2. In battery module (pack) assembly usually the battery cell, PCBAs, cables and containers are used to make the battery module (pack).

NOTE 3: Example 1: A BGA289 package. Die area 0.166 cm^2. GWP per BGA289 = CO_2e/die area in cm^2 × 0,166 + CO_2e/piece BGA package type back-end process.
Example 2: A "stacked chip" package. Total die area 12 cm^2. GWP per "stacked chip" package = CO_2e/die area in cm^2 × 12 + CO_2e/piece "stacked chip" package type back-end process.
Example of alternative assessment, FCBGA1024 package. Die area 2,8 cm^2. Mass 12,6 grams.
GWP per FCBGA1024 = 2,8 cm^2 × kg CO_2e/(cm^2×masklayer) × 1/front-end yield × masklayers for technology node (Scope 1,2,3 front-end) + 0,0126 kg × 1/back-end yield × kg CO_2e/kg IC (Scope 1,2,3 back-end).
Example of alternative assessment, SOIC 8 package. Die area not yet available. Mass 0,08 grams.
GWP per SOIC8 = 0,00008 kg × kg CO_2e/kg IC (Scope 1,2,3 front-end and back-end, considering front-end and back-end yields).

NOTE 4: Example: CO_2e for an LCD Display in a mobile phone, active area 33 cm^2 = CO_2e/active area display module in cm^2 (mobile phone displays) × 33 cm^2 + CO_2e/piece display panel (mobile phone display panels) × 1 piece.

NOTE 5: Relates to transport.

NOTE 6: The use of black box module data for ICT goods in a study needs to be transparently motivated and reported with respect to compliance to the present document. Example: A Network Operator may use black box module data for a set-top-box, a mobile phone manufacturer may use black box module data for a camera, a data centre operator may use black box module data for UPS and they need to report the compliance of this data to the present document and motivate any deviation.

NOTE 7: Piece as product flow unit (allocation basis) is applicable if the Part factory produces one unique Part type.

NOTE 8: It is acceptable to consider the battery as a black box.

Annex F (normative): EoLT processes

Table F.1 defines for ICT goods the different specific EoLT processes which shall be included (if applicable to the goal and scope and studied product system). Mandatory process categories and corresponding EoLT process are listed in the table for each EoLT process. The list is to be regarded as a minimum mandatory list and more EoLT processes/process categories/unit processes may be included. Usually *D3 Other EoLT* consists of combinations of G6.1 and G6.2.

NOTE: At the time of publication, some of the requirements in Annex F are considered as challenging due to LCA tool limitations, lack of data, limitations in data granularity etc. It is thus recognized that compliance to all requirements in Annex F may not be possible at the time the present document is published.

Deviation(s) from the requirements shall be clearly motivated and reported.

Table F.1: EoLT processes for LCA of ICT goods

	Process categories	EoLT process unit processes (for each category)	Goods flow unit	Important issues
D. EoLT	D1. Preparation for extended operating lifetime D2. ICT specific EoLT D2.1 Storage/Disassembly/Dismantling/Shredding D2.2 Recycling D2.2.1 Battery recycling ICT specific metal/mechanical parts/fractions EoLT D2.2.2 PCBA recycling D2.2.3 Cable recycling D2.2.4 Mechanics recycling D2.2.5 Other ICT recycling D3. Other EoLT	Recycling, recovery and treatment	Piece/ mass	In case of reuse and refurbishment, "D1 preparation of ICT goods for extended operating lifetime" includes a decision point where the ICT good is checked if it should proceed to next life with reuse, refurbishment or proceed with recycling and other EoLT processes. The refurbishment process falls under "B1 ICT goods production" for next life of the ICT goods.

Annex G (normative): Elementary flows (emissions and resources)

List of elementary flows in LCA of ICT.

Table G.1 contains elementary flows which shall be taken into account in LCA analyses for ICT. More flows could be relevant and the list refers to the mandatory LCI flows. The most commonly used name, chemical name or abbreviation has been put first followed by other common names/abbreviations. The substance names listed in Table G.1 shall be used in the present document.

For appropriate reporting format refer to Table L.9.

NOTE: At the time of publication, some of the requirements in Table G.1 are considered as challenging. It is thus recognized that compliance to these requirements may not be possible at the time the present document is published.

Deviation(s) from the requirements shall be clearly motivated and reported.

The unit is mass (unless stated otherwise): g, kg and tonne.

Table G.1: Elementary flows in LCAs of ICT

Inventory		
Substance	Measure unit	Contribution to Mid-point Impact Assessment Category(ies) (Table 5, clause 7)
Aluminium (resource)	kg	*RDMR, LU*
Ammonia (to air)	kg	*A*
As (to air)	kg	*HTC, ETFW*
As (to water)	kg	*HTC, ETFW*
As (to soil)	kg	*HTC, ETFW*
Benzene (to air)	kg	*HTC, ETFW*
BOD (to water)	kg	*EA*
Cd (to air)	kg	*HTC, ETFW*
Cd (to water)	kg	*HTC, ETFW*
Cd (to soil)	kg	*HTC, ETFW*
Cr (to water)	kg	*HTC, ETFW*
Cr (to soil)	kg	*HTC, ETFW*
CClF3, (CFC-13) (to air)	kg	*OD, CC*
CCl3F, (CFC-11) (to air)	kg	*OD, CC*
CCl2F2, (CFC-12) (to air)	kg	*OD, CC*
Cl2FC-CClF2, (CFC-113) (to air)	kg	*OD, CC*
C2F6 (CFC-116) (to air)	kg	*OD, CC*
C2H2F4, HFC-134a (to air)	kg	*OD, CC*
C2H3F3, HFC-143a (to air)	kg	*OD, CC*
C2H1F5, HFC-125 (to air)	kg	*OD, CC*
C2H3Cl2F, HCFC-141b (to air)	kg	*OD, CC*
CF_2ClBr, Halon 1211 (to air)	kg	*OD, CC*
CF_3Br, Halon 1301 (to air)	kg	*OD, CC*
CF_4, CFC-14 (to air)	kg	*OD, CC*
CH_3Cl_3, HCFC-140 (to air)	kg	*OD, CC*
CH_4, Methane (to air)	kg	*CC*
CHF_2Cl, HCFC-22 (to air)	kg	*OD, CC*
CHF_3, HFC-23 (to air)	kg	*OD, CC*
Cl- (to water)	kg	*HTNC, ETFW, A*
Cl- (to ground)	kg	*HTNC, ETFW, A*
CO, Carbon monoxide (to air)	kg	*HTNC, POF, CC*
CO_2 (to air)	kg	*CC, A*
Coal (resource)	kg, TOE, MJ	*RDMR, LU*
Copper (resource)	kg	*RDMR, LU*
Copper (to air)	kg	*HTNC, ETFW*
Copper (to water)	kg	*HTNC, ETFW*

Inventory		
Substance	Measure unit	Contribution to Mid-point Impact Assessment Category(ies) (Table 5, clause 7)
COD (to water)	kg	*EA*
EHW = Environmental hazardous (waste)	kg	*LU*
EHW Ashes, special EHW landfill (waste)	kg	*LU*
EHW Metal hydroxides (MeOH), special EHW landfill (waste)	kg	*LU*
EHW Slag, special EHW landfill (waste)	kg	*LU*
Ethylene (air)	kg	*POF*
Ethylene oxide (air)	kg	*HTNC, ETFW*
Formaldehyde, CH2O (to air)	kg	*HTC, POF*
Gas (resource)	kg, TOE, MJ	*RDMR, LU*
Gold (resource)	kg	*RDMR, LU*
Hg (to air)	kg	*HTC, ETFW*
Hg (to water)	kg	*HTC, ETFW*
Hg (to soil)	kg	*HTC, ETFW*
Hydrogen chloride (to air)	kg	*A, HTNC*
Iron (to air)	kg	*HTNC*
Iron (resource)	kg	*RDMR*
Iron (to water)	kg	*HTNC*
Iron (to soil)	kg	*HTNC*
Land occupation, agricultural	m^2×year	*LU*
Land occupation, urban	m^2×year	*LU*
Metals (unspecified) (to water)	kg	*HTNC, HTC, ETFW*
Metals (unspecified) (to soil)	kg	*HTNC, HTC, ETFW*
Mineral (waste)	kg	*LU*
Mo (to water)	kg	*HTNC, ETFW*
Mo (to soil)	kg	*HTNC, ETFW*
N_2O (to air)	kg	*CC, OD*
NF_3 (to air)	kg	*CC, OD*
Nickel (resource)	kg	*RDMR, LU*
Nickel (to water)	kg	*HTNC, ETFW*
Nickel (to soil)	kg	*HTNC, ETFW*
N-total (to water)	kg	*EA, ET*
Nitrate, NO_3^- (to water)	kg	*EA*
NMVOC, non-Methane VOC (to air)	kg	*POF, RI/PM, HTNC*
NMHC, non-Methane hydrocarbons (to air)	kg	*HTNC, HTC, POF*
NO_x (to air)	kg	*CC, EA, ET, POF, HTNC, ETFW*
Oil (to soil)	kg	*HTC*
Oil (resource)	kg, TOE, MJ	*RDMR, LU*
Oil (to water)	kg	*HTC*
Other CFCs/HFCs/HCFCs/PFCs (to air)	kg	*OD, CC*
Other (new) "high GWPs/ODPs" (to air)	kg	*OD, CC*
PAH, all kinds (to air)	kg	*HTC*
Palladium (resource)	kg	*RDMR, LU*
Platinum(resource)	kg	*RDMR*
Particulates, all kinds (to water)	kg	*HTC, HTNC, ETFW*
Particulates, all kinds (to air)	kg	*CC, HTC,ETFW, POF, RI/PM*
Pb (resource)	kg	*RDMR*
Pb (to air)	kg	*HTNC, ETFW*
Pb (to water)	kg	*HTNC, ETFW*
Pb (to soil)	kg	*HTNC, ETFW*
PF_3 (to air)	kg	*CC, OD*
Phosphate, PO_4^{3-}- (to water)	kg	*EA, ET*
P-total (to water)	kg	*EA, ET*
Radioactive (low, volume) (waste)	kg	*IRH, IRE*
Radioactive (medium, volume) (waste)	kg	*IRH, IRE*
Radioactive (high, volume) (waste)	kg	*IRH. IRE*
Selenium (to water)	kg	*HTNC, ETFW*
Selenium (to soil)	kg	*HTNC, ETFW*

Inventory		
Substance	Measure unit	Contribution to Mid-point Impact Assessment Category(ies) (Table 5, clause 7)
Silver (resource)	kg	*RDMR, LU*
Solid waste to landfill (waste)	kg	*LU*
SF_6 (to air)	kg	*CC, OD*
SO_2 (to air)	kg	*A, POF, HTNC, ETFW, RI/PM*
Sox (to air)	kg	*A, POF, HTNC,,ETFW, RI/PM*
TCDDe ("Dioxin" equivalents) (to air)	kg	*HTC*
Tin (resource)	kg	*RDMR*
Titanium (to water)	kg	*HTNC, ETFW*
Titanium (to soil)	kg	*HTNC, ETFW*
Toluene (to air)	kg	*POF, HTC, HTNC*
Uranium (resource)	kg, MJ, TOE	*RDMR*
Water, lake (resource)	m^3	*RDW*
Water, river (resource)	m^3	*RDW*
Water, well, in soil (resource)	m^3	*RDW*
Water, unspecified, natural origin (resource)	m^3	*RDW*
Zinc (to water)	kg	*HTNC, ETFW*
Zinc (resource)	kg	*RDMR*
Zinc (to soil)	kg	*HTNC, ETFW*
Zinc (to air)	kg	*HTNC, ETFW*

The recommended unit is mass (unless otherwise stated): g, kg, tonne.

For global warming potential factors refer to the latest IPCC information available, at the time of publishing of the present document [i.10].

Other elementary flows which are of interest may be added when enough scientific consensus is available.

For energy the following resources shall apply:

- Oil
- Gas
- Coal
- Uranium
- Energy related to hydro-electric power
- Biofuels
- For renewable energy sources use generated energy

Different qualities of fossil fuels have different contents of C/H (coal/hydrogen) and then also different energy content measured in kgOE or TOE or MJ.

The recommended unit is kgOE, TOE (kg or tonne oil equivalents) or MJ.

Annex H (normative): List of Raw materials

Table H.1 lists a minimum Raw Materials *groups* (chemicals, fuels, metals, plastics, packaging materials and additives) which shall be taken into account in LCAs of ICT goods, if applicable to the studied ICT product system.

Table H.1 would be too long if all specific materials would be listed as there are many variants of each chemical, fuel, metal and alloy, plastic and additives. Therefore each material name in Table H.1 refers to a *group* of Raw Materials and not specific Chemical Abstracts Service (CAS) code materials.

These Raw Materials *groups* are either part of the material content of the ICT goods/Support goods or used as ancillary materials throughout the life cycle.

Table H.1: Cradle-to-gate groups of Raw Materials to be included in LCA of ICT goods

Chemicals	Metals and alloys
Nitrogen gas (N2)	Aluminium
Oxygen gas (O2)	Brass
Hydrogen gas (H2)	Bronze
Argon gas (Ar)	Cadmium
Acetone	Chromium
CaO	Copper
H2SO4	Gallium
H2O2	Gold
HydroCloric Acid (HCl)	Indium
FeCl3	Lead
IsoPropyleneAlcohol	Lithium
Ethylene glycol	Magnesium
HydroFluoric acid	Mercury
H3PO4	Nickel
HNO3	Palladium
NaOH	Platinum
…	Silicon
…	Silver
Fuels	Solder - SAC (tin silver copper)
Heating oil	Solder - Sn/Pb
Bunker oil / ship diesel	Solder - SnZn
Diesel	Steel - Cr3+ plated
Petrol	Steel - powder coated
Jet fuel	Steel - zinc plated
LPG	Steel - stainless steel
LNG	Tin
"Biofuels"	Zinc
For renewable energy sources use generated energy	Hard metal (W-Co)
Uranium	
Energy related to hydro-electric power	
…	
Plastics	**Others**
Acrylonitrile butadiene styrene (ABS)	Concrete
Epoxy	Packaging materials
Polycarbonate (PC)	Ceramics
Polyethylene (PE) - HD	Paper
Polyethylene (PE) - LD	Cardboard
Polypropylene (PP)	Wood
Polystyrene (PS)	Wood board
Polyurethane (PUR)	Glass
Polyester (e.g. PET)	Glassfibre
PVC	
Silicone rubber	**Additives and others**
Styrene acrylonitrile (SAN)	Paper additives
PA (Nylone)	Plastic additives
PTFE (Teflone)	High purity grades of materials/chemicals and gases

Chemicals	Metals and alloys
PMMA	Cooling media, fire extinguisher media (High GWPs/ODPs)
…	

Different qualities of fossil fuels have different contents of C/H (coal/hydrogen) and then also different energy content measured in kgOE or TOE or MJ.

The recommended unit is kgOE, TOE (kg or tonne oil equivalents) or MJ.

Annex I:
Void

Annex J (normative): ICT network overview

An ICT network is commonly described in terms of boxes, each of which is associated with a specific function or a set of coherent functions. Typically, major network functions could be represented as shown below. The network elements below shown in Figure J.1 are part of existing ICT networks and shall be studied when defining the studied product system. However, the present document is not restricted to these ICT network elements but will also apply when assessing any existing or future ICT networks.

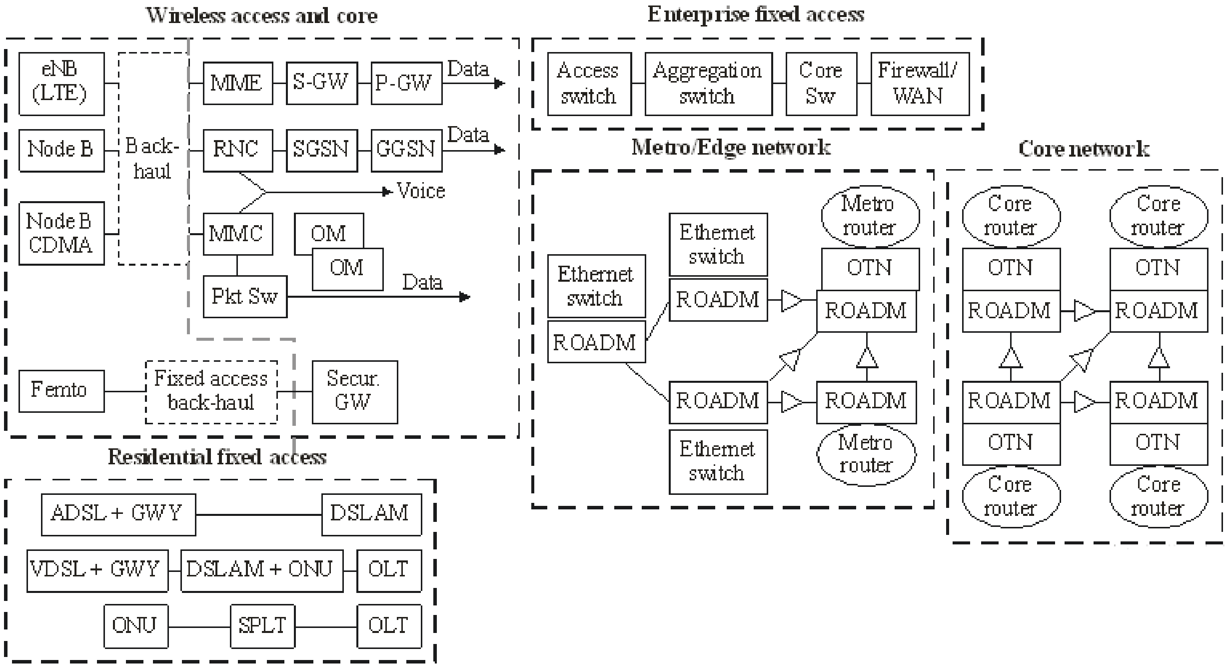

Figure J.1: Example of an ICT network reference model

A wireless access and core network consists of an access and a core domain. Examples of wireless technologies include GSM, W-CDMA, LTE. Typically, for LTE/EPC the core network (known as the evolved packet system) provides IP connectivity using the access network (E-UTRAN). For GSM and UMTS, the core network consists of a circuit switched domain (comprising MSC/VLR) and a packet switched domain (GPRS core comprising SGSN, GGSN) which supports interworking with IP-based networks. The mobile access network consists of physical entities which manage the radio resource (BTS/BSC, node B/RNC, enode B) and provide the user with mechanisms to access the core network.

The residential fixed access network provides the end user with an access to the network carrying digital signals used for voice band and digital data.

The metro/edge network provides connectivity and transport to large areas with a high concentration of business customers. These ICT networks provide the bridge between the long-haul environment and the access environment.

The enterprise fixed access network includes a Local Area Network (LAN) used to connect an end system to an edge router. There are many different types of LAN technology and Ethernet technology is currently by far the most prevalent access technology in enterprise networks. The edge router is then routing packets that have destinations outside of the LAN.

The long-haul network interconnects cities and regions covering hundreds of kilometres between several central offices. It includes core routers operating in the Internet backbone and forwarding IP packets at a very high speed through optical transport infrastructures.

From an end-user perspective, some other devices are used when they are offered as an end-to-end service. Typically, terminal devices (mobile phones, fixed phone sets, personal computers, printers, scanners) are needed to initiate a call, to surf the Internet or to print documents. GPS devices are also required to propose optimized routes when driving a vehicle. Moreover, it is expected that innovative services will be provided in the future to the general public that will drastically change the environmental impact of end users (such as smart meters for example). Also, enterprises are using a variety of goods for running their business (PBX switches, PC, printers and scanners).

An example of functions of a wireless mobile telecommunication network is shown in Figure J.2.

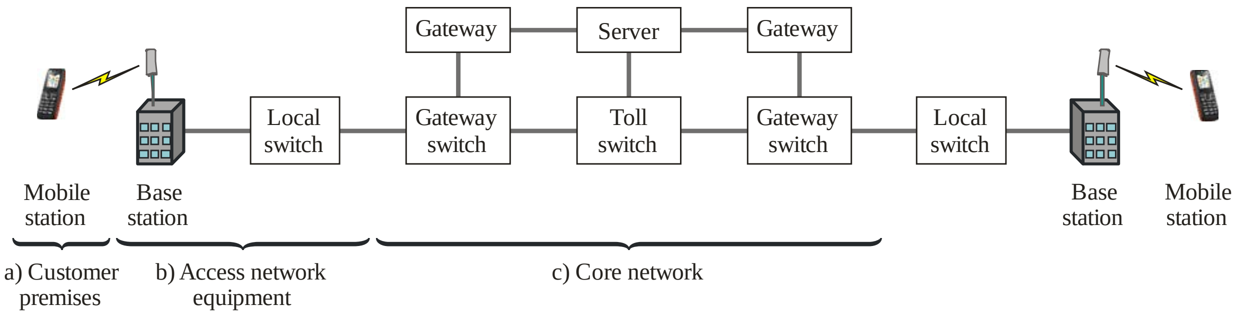

Figure J.2: Example of functions of wireless mobile telecommunication network

Annex K (normative): A method for assessing the environmental load of the working environment

K.0 Introduction to environmental load of the working environment

This Annex describes a methodology to assess the environmental load of the working environment:

- This methodology shall be studied for assessing the working environment related impacts related to ICT goods, networks and services Part I (clause 6).
- It may also be used in order to assess the impacts related to the working environment when performing a comparison implying better office space usage thanks to ICT (Part II, clause 11).

An example of an assessment of the environmental impact of the working environment based on this methodology is provided in Annex U.

K.1 Purpose of targeting the working environment in the assessment of ICT goods, networks and services

The working environment is one of the important checklist items to consider when assessing the environmental impact of ICT goods, networks and services in Part I.

In addition, improved work efficiency thanks to ICT goods, networks and services is listed as a category for comparison in Part II. To perform a comparison, an assessment of the working environment is often necessary.

Employment and work styles are undergoing a transformation in many countries and there are several types of office spaces in addition to the traditional ones, such as Small Offices Home Offices (SOHO), mobile office, etc.

K.2 Functional unit

A functional unit of the "working environment" may be defined as a "provision of working space and working environment for one year".

Another functional unit of the "working environment" may be defined as a "provision of working space and working environment for one year per person".

K.3 System boundary

A system boundary for evaluating the working environment may be described as shown in Figure K.1. Once the functional unit is defined, energy consumption should be calculated by considering the energy consumption of the heating system, air conditioning system, other motive powers (e.g. for automatic doors, elevators), lighting and appliances used for business purposes and related to targeted work. As for other energy consumption data, GHG emissions should then be derived from the energy consumption values.

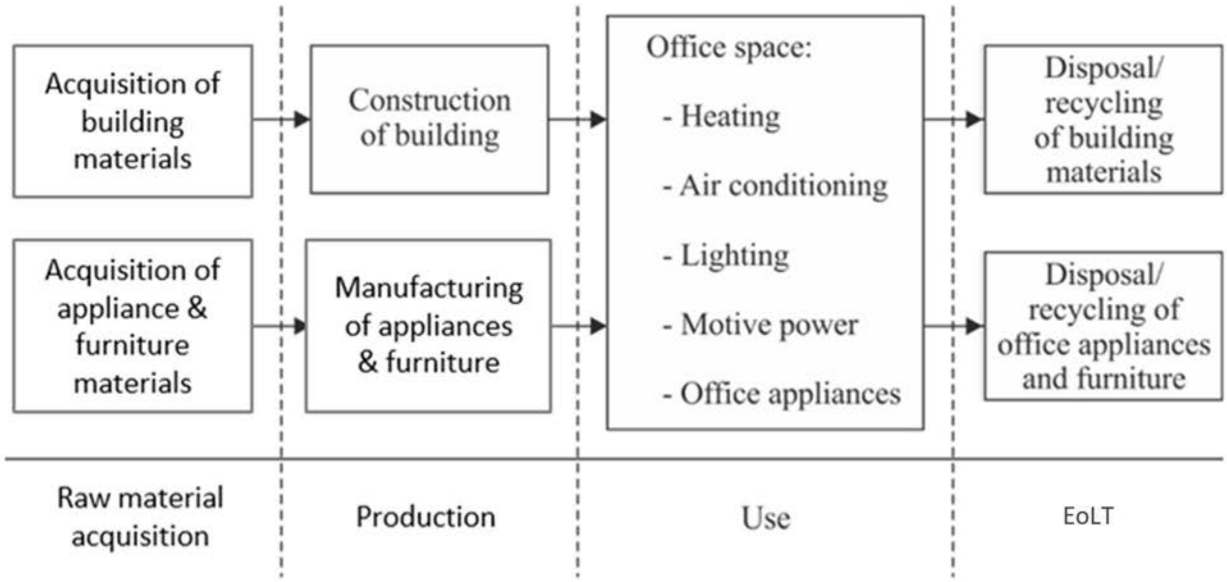

Figure K.1: System boundary of working environment

K.4 Life Cycle Inventory (LCI)

K.4.1 Data collection

To evaluate the energy consumption and GHG emissions of the working environment (whether at the office or at home), data on energy consumption, the space occupied by each person and the number of working hours per year could be calculated based on available statistical data.

K.4.2 Data calculation

Regarding the environmental impact of the working environment, energy consumption should first be assessed for all activities within the system boundaries, e.g. heating; air conditioning; lighting; motive power, etc.

NOTE: Depending on the type of data available (aggregated or distributed), classification into these activities may not be applicable.

Secondly, energy consumption should be classified into fuel categories in accordance with Annex H.

Thirdly, energy consumption and GHG emissions should be calculated for each fuel category in:

- Energy (J).
- GHG emission (kg-CO_2e).

Finally, total energy consumption and GHG emissions should be calculated by adding the environmental impact of all fuel categories.

K.4.3 Allocation procedure

To evaluate energy consumption and GHG emissions of offices at home, an allocation between working activities and other activities is required. This distinction between working activities and other activities should be based on appropriate assumptions and should be documented.

Overall, publicly available statistical data to be considered for allocation in a home office:

- working style;
- working hours;
- percentage of workers who work only at home or at home and also at the office.

Considering the above-mentioned factors, the home office impact intensity would be obtained by allocating the environmental load to the working activities and household activities.

Annex L (normative): Reporting formats

This Annex contains tables that shall be used to report the result of the assessment.

In line with indications in the main text related to LCA tool limitations, etc., at the time of publication, it may be challenging to fulfil fully certain reporting tables included in this Annex. It is thus recognized that compliance to all reporting requirements may not be possible at the time the present document is published.

Deviation(s) from the requirements shall be clearly motivated and reported.

Table L.1: Cover page

REPORTING			
	Yes	NO	Description/references to page
General information			
Company name and contact information			
Project name			
Product System			
Product System related information			
Product System function			
Product system description			
Product picture (optional)			
Date of completion of assessment (DD/MM/YYYY)			
Compliant with ETSI ES 203 199 (the present document)			*<put version of the specification>*
LCA tool used			
External Review (yes/no)			
Reviewers			
Goal definition			
Reason for carrying the study			
Target audience(s)			
Comparative assessment			
Scope definition			
Functional unit			
Reference flow			
System boundaries			
Environmental impact categories			
List of Optional and recommended stages considered			
Cut off criteria			
Resource used and emission profile			
Generic data sources			
Data collection procedure			
Technical process flow diagram			
Unit process description			
Calculation procedure			
Allocation procedure including the handling of multi functionality			
Data quality			
Data gap			
Environmental impact assessment			
Assessment results			
Normalization (optional)			
Weighting (optional)			
Interpretation			
Uncertainty aspects including results from sensitivity analyses			
Conclusion including identification of hot spots			

Table L.2: Reporting format for included life cycle stages, activities and generic processes

Tag	Life cycle stage/ Process	Unit process	Included (Yes/No)	Electricity mix (specific/ country/world average	Support activities included (Yes/No)	Transport activities included (Yes/No) G1	Other generic activities included (Yes/No) G2-7	Motivation/ Comment
A	Goods Raw Material Acquisition							
A1	Raw material extraction							
A2	Raw material processing							
B	Production							
B1	ICT goods production							
B1.1		Parts production (for further details refer to Annex E)						
B1.2		Assembly						
B1.3		ICT manufacturer support activities						
B2	Support goods production							
B2.1		Support Goods manufacturing						
B3	ICT specific Site construction							
C	Use							
C1	ICT goods use							
C2	Support goods use							
C3	Operator support activities							
C4	Service provider support activities							
D	Goods End of Life Treatment							
D1	Preparation for extended operating lifetime							
D2	ICT specific EoLT							
D2.1		Storage/Disassembly/Dismantling/ Shredding						
D2.2		Recycling						
D3	Other EoLT							

Table L.3: Reporting format for Generic processes for LCA of ICT goods

Generic process	Generic process categories included (see note 1)	Unit processes included (for each generic process category) (see note 1)	Important issues (see note 2)
G1. Transports and Travel			E.g. clarify comprehensiveness of the used emission factors
G2. Electricity			E.g. clarify comprehensiveness of the used emission factors
G3. Fuels			E.g. clarify comprehensiveness of the used emission factors
G4. Other energy			E.g. clarify comprehensiveness of the used emission factors
G5. Raw material acquisition			
G6. End-of-life treatment			
G7. Raw material recycling			
NOTE 1: Annex D gives examples of generic process categories and unit processes to be included if applicable. NOTE 2: Include description of data source for each generic process category, e.g. from commercial LCI databases.			

Table L.4: Reporting format for transports/travel

Mode	CO_2e emission factor (see note 4)	Raw material acquisition transports		Production stage transports excluding final transport		Final transport (see note 1) (Production to use stage)		Use stage transports		EoLT transports		Total transports		Total travel (see note 6)	
		Transport work (see note 2) {tonne×km}	GWP100 {kg CO_2e} (see note 7)	Transport work {tonne×km}	GWP100 {kg CO_2e}	Transport work {tonne×km}	GWP100 {kg CO_2e}	Transport work {tonne×km}	GWP 100 {kg CO_2e}	Transport work {tonne×km}	GWP 100 {kg CO_2e}	Transport distance (see note 3) {km}	GWP100 {kg CO_2e}	Travel distance {km}	GWP100 {kg CO_2e}
Air															
Other1 (see note 5)															
Other2 (see note 5)															

NOTE 1: The final transport of ICT goods from assembly to operator, including pre- and post transports connected to the main transport.
NOTE 2: Average in terms of distance, transport mode, load factor, chargeable mass, etc.
NOTE 3: Average in terms of distance, transport mode, load factor, chargeable mass, etc.
NOTE 4: This includes direct fuel consumption and also fuel supply chain.
NOTE 5: Specify used transport mode.
NOTE 6: Includes all kinds of travel throughout life cycles, e.g. commuting, business travel and maintenance travel when applicable. Specify travels taken into account.
NOTE 7: Other impact categories to be added as applicable.

Table L.5: Reporting format for raw materials

	Total input (g, kg, tonne)	Content in product (see note 1) (%)	Recycled raw material used (see note 2) (%)	Recycling of total input (see note 3) (%)	Reference
Iron/Steel alloys					
Aluminium alloys					
Copper alloys					
Silver					
Gold					
ICT product system Raw materials (optional)					
Raw material 1					
Raw material ...					
Raw material n					
Auxiliary Raw Materials (production materials etc.) (optional)					
Auxiliary material 1					
Auxiliary material …					
Auxiliary material n					
Packaging materials(optional)					
Packaging material 1					
Packaging material …					
Packaging material n					
NOTE 1: Percentage of total input material present in the product after the production process, i.e. total input minus the related production waste. NOTE 2: The amount of recycled raw material used in the production process, this include the raw material contained in the product and the related production waste. NOTE 3: Total recycling of all input materials, i.e. recycling of manufacturing waste and recycling of total content in final product during EOL. NOTE 4: The reporting format of Table L.5 may not be easily supported by LCA tools and due to lack of data. In this case the LCA practitioner may report the raw material usage differently, e.g. on the basis of the material content declaration of the ICT equipment instead of the total input. However, all deviations from the reporting format of Table L.5 shall be outlined and motivated.					

For a full list of materials that could optionally be reported in Table L.5, refer to Annex H.

Table L.6: Reporting format for parts production

	Part categories included (see note 1)	Part Unit processes included (see note 1)	Handling of special issues (see note 2)
B1.1.1 Batteries			
B1.1.2 Cables			
B1.1.3 Electro-mechanics			
B1.1.4 Integrated circuits (Ics)			
B1.1.5 Mechanics / materials			
B1.1.6 Displays			
B1.1.7 Printed circuit boards (PCBs)			
B1.1.8 Other PBA components			
B1.1.9 Packaging materials			
B1.1.10 Black box modules			

Annex E gives a list of part categories and part unit processes which shall be included when applicable.

NOTE 1: Include description of data source and data set for each part category, e.g. from commercial databases.

Table L.7: Reporting format for use stage energy consumption

	Energy consumption {kWh/year}	Source {long term average/standardized measurement/ modelled	Motivation/ comment
ICT goods			
Support goods			

NOTE 2: If the reporting above comes into conflict with confidentiality considerations the data should be recorded internally and made available to potential 3rd party peer reviewers.

Table L.8: Reporting format for EoLT stage

	Process categories included	Process Unit processes included	Handling of special issues
D1. Preparation for extended operating lifetime of ICT goods			
D2. ICT specific EoLT			
D3. Other EoLT			

Annex F gives a list of process categories and unit processes which shall be included when applicable.

Table L.9: Reporting format for LCI results

	TOTAL	Raw materials acquisition	Production	Use	EoLT
Primary energy use (see note)					
Total electricity use					
Land use (optional)					
Fresh water use (optional)					
LCI data 1 (optional)					
LCI data …(optional)					
LCI data n (optional)					
NOTE: Primary energy usage is appropriate to express as Cumulative Energy Demand.					

Table L.10: Impact category indicators

Mid-point category indicator	Impact category indicator value	LCIA methodology reference
Global warming potential	# kg CO2e	IPCC Climate Change 2013: [i.10]
Etc.		

Table L.11: Reporting format for Network description

	List of Included ICT goods	List of Included infrastructure	Quantity [unit] (see note)	Operating Lifetime [year]
End-user goods and CPE				
End-user goods			# [piece]	
CPE			# [piece]	
Operator Network and activities				
Access network			# [sites]	
Control and core network			# [subscriber]	
Operator activities			# [employ]	
Data Services				
Data transport			# [GB]	
Data centre(s)			# [GB]	
Service provider(s) activities			# [subscriber]	
NOTE: More appropriate units can be selected depending on the case analysed.				

Table L.12: Reporting format for Network Energy consumption

	ICT goods energy consumption	Support goods energy consumption	Source {long term average/ standardized measurement/ modelled}
End-user goods and CPE			
End-user goods			
CPE			
Operator Network and activities			
Access network			
Control and core network			
Operator activities			
Data Services			
Data transport			
Data centre(s)			
Service provider(s) activities			

NOTE 3: If the reporting above comes into conflict with confidentiality considerations the data should be recorded internally and made available to potential 3rd party peer reviewers.

Table L.13: Reporting format for Service hardware allocation

End-user goods and CPE	Allocation method	Allocation of use stage [%]	Allocation of all non-use stages [%]
End-user goods and CPE			
End-user goods			
CPE			
Operator Network and activities			
Access network			
Control & core network			
Operator activities			
Data Services			
Data transport			
Data centre(s)		Specific data centre(s) data mandatory	
Service provider(s) activities		Specific service provider(s) data mandatory	

Annex M (informative): Examples of Allocation Procedures

M.1 Allocation examples for Recycling of Materials

M.1.1 Introduction

NOTE: A factor: factor allocating burdens and credits from recycling and primary material production between the life cycle supplying and using recycled material.

The examples in Figure M.1 and Figure M.2 are applying different allocation methods for one scenario. The example (Table M.1) is referring to climate change but the same principles apply to all impact categories.

Table M.1: Allocation scenario (example)

Parameter	Value
Total raw material input	1 kg
R1	40 %, Share of recycled materials used in the Raw Materials acquisition stage
R2	90 %, Share of material recycled in the EoLT stage
E_v	80 kg CO_2e/kg, based on Life Cycle Inventory for Primary Material Production
$E_{recycled}$	10 kg CO_2e/kg, Life Cycle Inventory for Recycling Process of the Recycled Material
$E_{recycled, EoL}$	0,1 kg CO_2e/kg, Life Cycle Inventory for Recycling Process at EoL
A	Allocation factor of burden and credits between supplier and user of recycled materials
Q_{sin}	1, Quality of ingoing secondary material
Q_{sout}	1, Quality of outgoing secondary material
Q_p	1, Quality of outgoing primary material

It is also assumed that the ***total* Raw Material input** includes both goods Raw Material Acquisition and Generic Raw Material Acquisition and further Production waste is included in the EoLT waste.

Equation M.1 gives the LCIs for Equipment Raw Material Acquisition (A) + Raw Material Acquisition (G5) and Equation M.2 the LCI for Raw Material Recycling (G7).

$$\text{LCI for Equipment Raw Material Acquisition (A) + Raw Material Acquisition (G5)} = (1-R1) \times E_v + R1 \times ((A \times E_{recycled} + (1-A) \times E_v \times Q_{sin}/Q_p)) \quad (M.1)$$

$$\text{LCI for Raw Material Recycling (G7)} = (1-A) \times R2 \times (E_{recycled,\ EoL} - E_v \times Q_{sout}/Q_p) \quad (M.2)$$

M.1.2 Example of the 100/0 and 0/100 methods

An example of *Raw Material Acquisition* and *Raw Material Recycling* with the 100/0 and the 0/100 methods is given below in Figure M.1.

Some of the 100/0 values are calculated as:

52 = (1 - 40 %) × 80 + 40 % × ((**1** × 10 + (1 - **1**) × 80 × 1/1))

0 = (1 - **1**) × 90 % × (1 - 80 × 1/1)

Some of the 0/100 values are calculated as:

80 = (1 - 40 %) × 80 + 40 % × ((**0** × 10 + (1 - **0**) × 80 × 1/1))

-71,1 = (1 - **0**) × 90 % × (1 - 80 × 1/1)

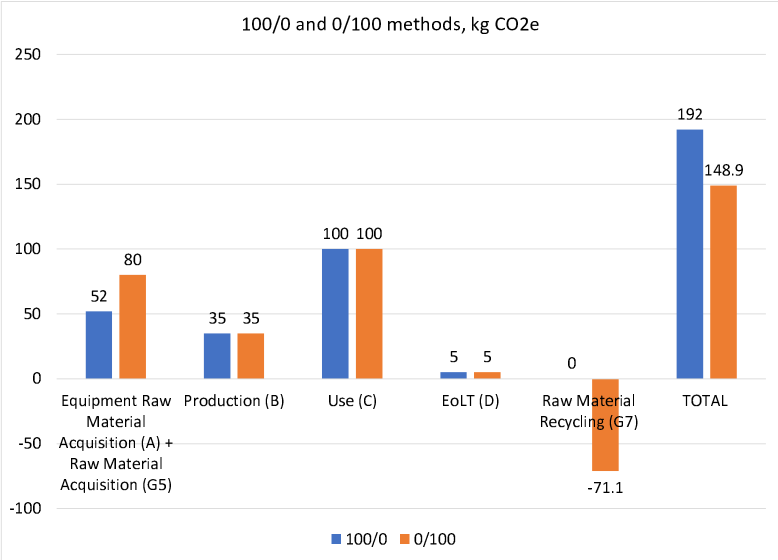

Figure M.1: Example showing the 100/0 method and the 0/100 method

M.1.3 Example of the 50/50, 20/80 and 80/20 methods

Examples of *Raw Material Acquisition* and *Raw Material Recycling* with the 50/50, 20/80 and 80/20 methods are given below in Figure M.2. The methods differently show the importance of the Raw Material Acquisition and the Raw Material Recycling processes.

Some of the 50/50 values are calculated as:

66 = (1 - 40 %) × 80 + 40 % × ((**0,5** × 10 + (1 - **0,5**) × 80 × 1/1))

-35,55 = (1 - **0,5**) × 90 % × (1 - 80 × 1/1)

Some of the 20/80 values are calculated as:

74,4 = (1 - 40 %) × 80 + 40 % × ((**0,2** × 10 + (1 - **0,2**) × 80 × 1/1))

-56,88 = (1 - **0,2**) × 90 % × (1 - 80 × 1/1)

Some of the 80/20 values are calculated as:

57,6 = (1 - 40 %) × 80 + 40 % × ((**0,8** × 10 + (1 - **0,8**) × 80 × 1/1))

-14,22 = (1 - **0,8**) × 90 % × (1 - 80 × 1/1)

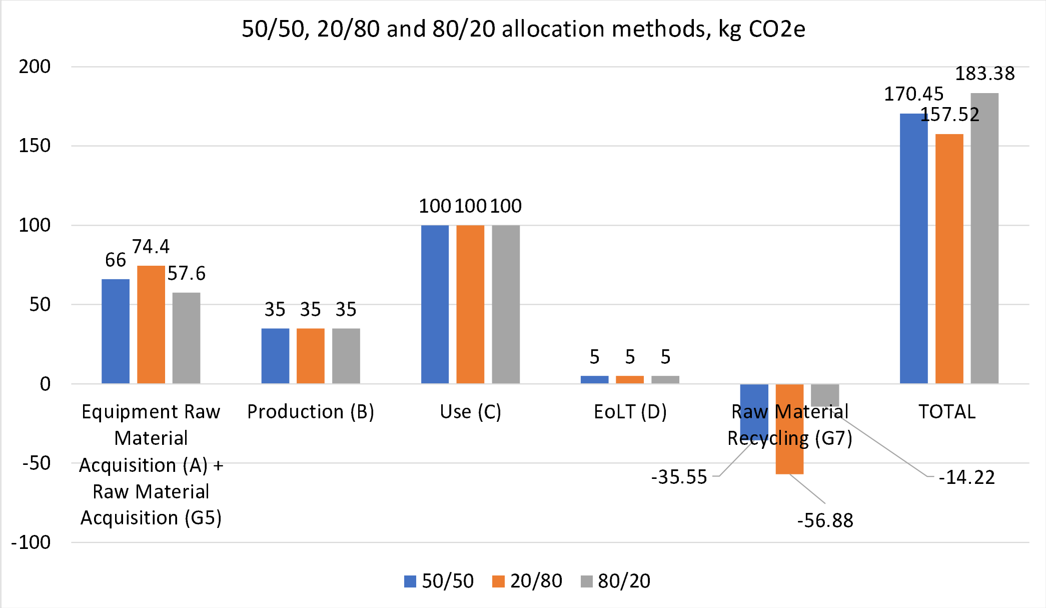

Figure M.2: Example of the 50/50, 20/80 and 80/20 methods

The 50/50 method focuses equally on recycling rate and recycled content and should be used when the allocation factor for the material at hand is unknown.

The 20/80 method focuses mostly on recycling rate and should be used when the supply of recyclable materials is low.

The 80/20 method focuses mostly on recycled content and should be used when the supply of recyclable materials is high.

Table M.2 gives an example of the 50/50 method with USGS average numbers applied to recycled contents (R1) and 90 % Raw Material Recycling (R2) assumed for the studied product.

NOTE: The applicability of USGS average numbers varies case by case i.e. depending on the conditions of the equipment the USGS average numbers may be more or less representative to the actual conditions. However, for raw materials the exact recycling conditions are usually hard to track for a specific ICT good, network or service.

Table M.2: Example of the 50/50 method for 1 kg material

	Raw Material Acquisition, E_v [CO_2e/kg]	**Raw Material Recycling Process of Recycled Material (Reprocessing / Remelting), $E_{recycled}$ [CO_2e/kg]**	**Recycling Process at EoL (Sorting, Disassembly), $E_{recycled, EoL}$ [CO_2e/kg]**	**USGS average recycling [%], R1 (see note)**	**Results with 90 % recovery efficiency (R2) in Raw Material Recycling and 50/50 method [CO_2e]**
Steel	2,5	0,5 to 1	0,05 to 0,1	50	0,89 to 1,05
Copper	7	1,5 to 2	0,15 to 0,2	30	3,09 to 3,19
Aluminium	12	1,5	0,15	35	4,83
NOTE: For most up to date USGS average numbers refer to USGS.					

Annex N (informative): Life cycle stages overview

An overview figure showing the contents and connections between all life cycle stages are shown below in Figure N.1.

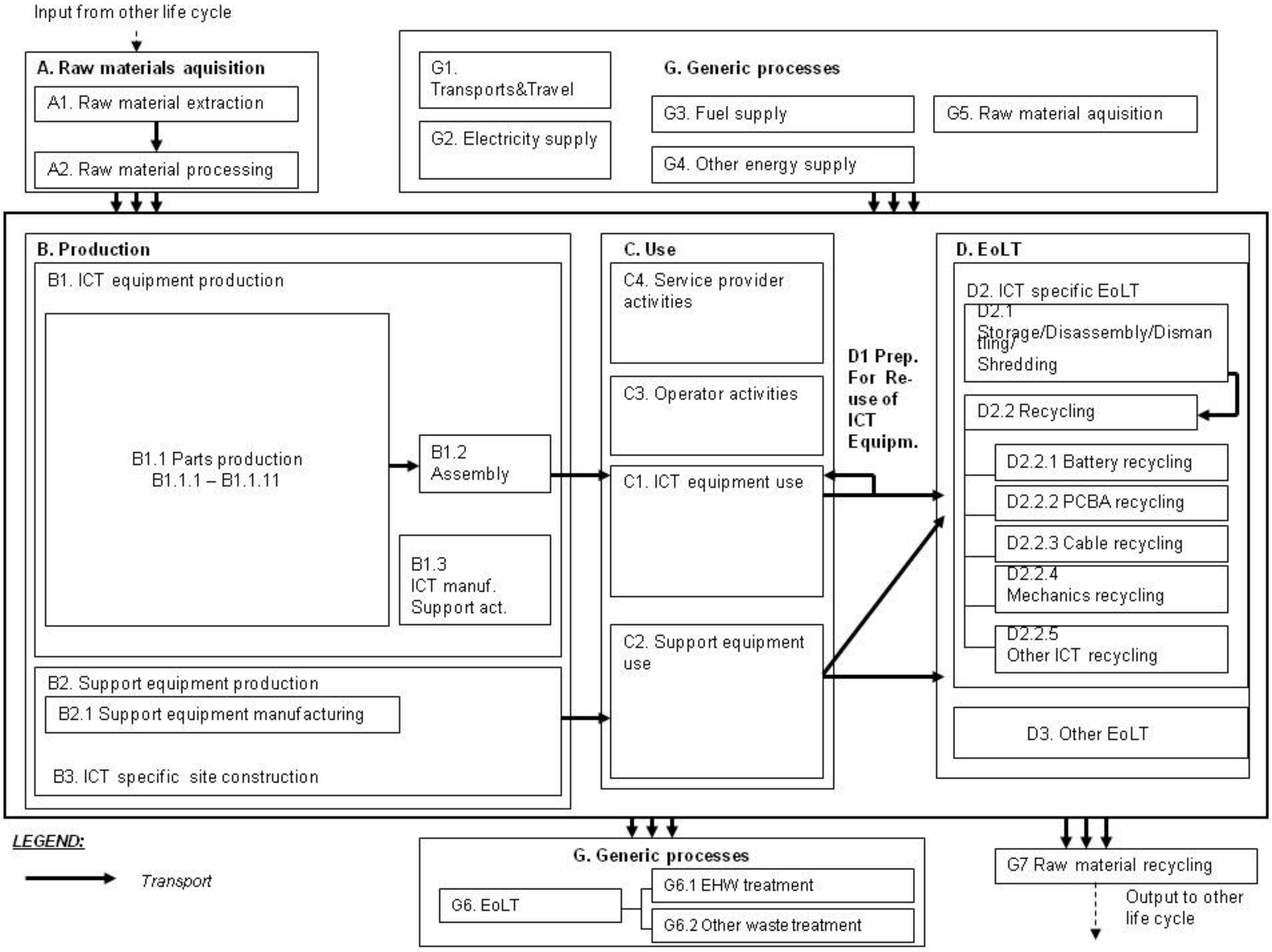

Figure N.1: Connection between all life cycle stages

Annex O (informative): Examples of goods and black box modules

O.0 Introduction to examples of goods and black box modules

This list summarizes entities frequently used in LCAs of ICT. The list is not a complete set of ICT goods but is rather an example to indicate the broad range of applicable ICT goods and Support goods to be considered.

Each goods type may be further divided into more specific goods types.

O.1 End-user goods

- Mobile phone or standard mobile phone.
- Smartphone.
- Tablet device (phone/e-reader/PC).
- Net book PC.
- Laptop PC.
- Desktop PC.
- TV.
- Any device that can connect to home or Networks.

O.2 CPE

- Fixed wireless terminal (FWT, typically 1 3G+ in and 4 LAN + WLAN out).
- Modem.
- Router (Typically 1 WAN in and 4 LAN + WLAN out).
- IPTV box and/or STB for IPTV.
- Combo products (e.g. a 3-play or home gateway box: modem/router/IPTV).
- Fibre access (ONU) and combo products including fibre access.

O.3 Network site goods (from base station sites to data centres)

- Base station goods.
- Transmission goods (e.g. STM-1, radio link).
- RAN control and core goods (BSC, RNC, SGSN, GGSN, HLR, MSC, etc.).
- Fixed access node (FAN) goods (POTS, xDSL, FTTx/OLT).

- Telecom switches and telecom servers (services).
- Edge/Metro routers/switches.
- Core routers/switches.
- Optical high capacity transport goods (WDM).
- Servers.
- Data switches.
- Storage array network goods.

O.4 Examples of ICT specific black box modules

- Cable set/module (cable + connectors).
- Memory module.
- Camera module.
- Display module.
- Charger device.
- AC/DC adapter incl. power cord.
- Fan unit.
- Hard Disc Drive.
- Optical disc player.
- Transceiver module.
- Power Amplifier module.
- Power Supply Unit.

O.5 Site support goods

NOTE: Some of these units are ICT specific; others have a more generic application.

- Antenna towers.
- Antennas and Feeders.
- Lighting guides.
- Buildings, shelters and other mechanical structures.
- Diesel generators and tanks.
- Rectifiers, UPS, Battery.
- cooling system.
- Monitoring system.

Annex P (informative): Examples of Networks and Network goods

Table P.1: Examples of Networks

Network type	Examples
Access networks (see note 1)	Fixed telephony (or POTS, Plain Old Telephony System) Fixed broadband access (DSL) Mobile broadband access (2G (e.g. GSM), 3G (e.g. WCDMA/HSPA) etc.) (see note 2) Cable TV (CATV) broadband Fibre (FTTx) or City LAN Enterprise LAN
Mobile Control and core nodes	Control and core nodes for mobile Control and core nodes for IPTV, VoIP, etc.
Data transport (see note 3)	All other transmission (excluding transmission associated with the access nodes) IP edge/metro/core network (switches and routers) Submarine optical fibre cables and land terminal stations
Data centres (see note 4)	Servers, storage and network goods ("switches and routers") Cooling, power and back-up power goods
NOTE 1: Including transmission between the access nodes, which is allocated to the access networks (e.g. PDH, SDH, WDM and network link elements like STM/MUX, radio links and WDM elements and repeaters). NOTE 2: The mobile control nodes which are in reality part of the access networks are in this physical view structured together with the core nodes as they often share sites. NOTE 3: Data transport is a collective term used for all transmission and IP network goods that are used. NOTE 4: The term data centre (s) can include all sizes of server networks, from enterprise data centres down to "a server in a closet".	

Table P.2: Examples of Network goods

Network type	Access nodes	Infrastructure	Control & core nodes
POTS network	RSS, remote subscriber switch Subscriber part of local exchanges	"Copper" cable network Telecomm building/container	Local and higher order Exchanges Telephony and VoIP C&C nodes
Fixed broadband network	DSLAM goods installed in POTS RSS/	Re-use of POTS infrastructure	n.a.
2G mobile network	2G base stations	Antenna towers Site building Container	BSC MSC, HLR, SGSN, GGSN, MGW
3G mobile network	3G base stations	*Same as 2G above*	RNC MSC, HLR, SGSN, GGSN, MGW
4G mobile network	4G base stations	*Same as 2G above*	
Fibre / City LANnetwork		Fibre network	
CATV broadband network		Coax cable network	Fibre nodes

Annex Q (informative): Energy mix

One of the main environmental impacts of ICTs affecting climate change is GHG emissions from electric power consumption. These GHG emissions depend on sources of electric power generations such as coal, oil, natural gas and nuclear. Conditions of electric power generation are quite different among countries. Also, even in the same country or region, annual GHG emission intensity differs; this is due mainly to the amount of nuclear power generation and renewable energy installed. Therefore, environmental impact assessment of ICTs needs to be carried out carefully when the assessment target includes regions or terms in which GHG emission intensity differs. The impacts should be assessed in energy units for the sake of performing objective and fair assessments. However, this requirement to assess ICT impacts in energy units is not intended to permit a comparative assertion for commercial competition.

Annex R (informative): Example of data quality indicators

Table R.1 shows an example of Data Quality Indicators. There are several ways to mathematically evaluate the Data Quality of an entire LCA and estimate which Data Quality Indicators are most important for the overall Data Quality, but in many cases only a qualitative approach is possible due to lack of quantitative data. The present document lists which Data Quality Indicators should be taken into account for such calculations. There may be more applicable Data Quality Indicators than listed in Table R.1.

Table R.1: Matrix for data quality assessment

Data Quality Indicator	Applicable clause	Comment				
Methodological appropriateness and consistency	Entire specification/ document	Indication of how much in line the applied LCI methods and methodological choices are with the goal and scope of the data. Also how consistently the methods have been applied across all data.				
Completeness	6.2.4	Indication of the % of applicable LCI flows in Table G.1 which are included in the LCI. Also degree of coverage of an LCIA indicator in Table L.10.				
Uncertainty	8.2	Indication of the variability of the data elements used in the LCA.				
Acquisition method	6.2.5	Indication of how the data used have been obtained. The range is roughly from directly measured to nonqualified estimations.				
Supplier independence	6.2.5	Indication of the verifiability of the data. The range is roughly from verified data from independent source to unverified information.				
Data representativeness	6.2.5	Indication of the number of facilities and time range from which the data have been collected. Range is roughly from "representative data from a sufficient number of facilities over and adequate time period" to "information with unknown representativeness from a small number of facilities from a shorter time periods".				
Data age/timeliness	6.2.5	< 3 years	< 6 years	< 10 years	< 15 years	Age unknown
Geographical correlation	6.2.5	Data from the exact area	Average data from a larger area	Data from an area with similar production conditions	Data from an area with slightly similar production conditions	Unknown area
Technological correlation	6.2.5	Data from process studied of the exact company	Data from process studied of company with similar technology	Data from process studied of company with different technology	Data from process related to company with similar technology	Data from process related to company with different technology
Rule of inclusion/exclusion (Elements/Flows/ Unit process)	6.2.4	Indication of how homogeneously and transparently the cut-off criteria have been applied.				

Annex S (informative): Uncertainties of life cycle assessments for ICT goods, networks and services

Uncertainty is an important aspect of a life cycle assessment of ICT goods, networks and services.

The uncertainty of an LCA can be divided into three categories:

- parameter uncertainty;
- scenario uncertainty;
- model uncertainty.

Parameter uncertainty: This is related to uncertainties in input-data and provides a measure of how close the data and calculated emissions are to the real data and emissions. This includes uncertainties in the inventory analysis and uncertainties when translating inventory flows into environmental impact potential. The influence of parameter uncertainty on the final result can be assessed analytically or by simulations. One example of parameter uncertainty is the uncertainty associated with the conversion from the emissions of carbon dioxide (CO_2) and other GHGs into carbon dioxide equivalents (CO_2e).

Scenario uncertainty: This represents a variation of results depending on methodological choices, e.g. LCI modelling principles, allocation procedures and cut-off decisions. The scenario uncertainty can be quantified through sensitivity analysis. Sources of scenario uncertainties include e.g. the allocation method for data for production facilities, overhead activities (see note 1) and vehicle use to the product system studied (see note 2) and also use of old data to represent current activities.

NOTE 1: Often based on economic data.

NOTE 2: Emission data for a site is typically measured at the site level and not for individual processes and products.

Model uncertainty: This arises from insufficient knowledge of the studied system, leading to omission of data or incorrect assumptions. Model uncertainties are difficult to quantify. Aviation emissions such as NO_X and soot and effects such as land use are examples of emissions/effects usually left out because of a lack of knowledge. One source of model uncertainty much discussed is the possible inclusion of emissions from infrastructure and the supply chain for travel and transportation activities (see note 3).

NOTE 3: Decisions regarding which activities to include in the life cycle is part of the system boundary setting of a study.

Some important uncertainty sources for different life cycle stages.

The table below summarizes some important uncertainty sources associated with different life cycle stages. Some of them are described further below Table S.1.

Table S.1: Important uncertainty sources of the different life cycle stages

Life cycle stage	Activities included	Important uncertainty sources
Raw material acquisition	Raw material extraction Raw material processing	Long supply chain without direct commercial relationship to ICT industry. Variations in geographical location. World market variations beyond the control of ICT.
Production	ICT goods production Support goods production	Large supplier base which changes continuously over product system lifetime based on price, availability etc. Allocation of facility data between product systems and processes.
Use	ICT goods use Support goods use Support activities	Life time, geographical location, traffic scenario model. Large variations between operators regarding site and network design and energy consumption. Electricity production model and power supply variations.
End of life treatment	ICT specific EoLT Other EoLT	Future processes principally unknown. Significant variations between suppliers and regions. Allocation of facility data between product systems and processes.

Within the Raw material acquisition and Production stages it is very challenging to collect all product system specific data for the whole upstream supply chain (see note 4). Raw material acquisition depends on long supply chains related to world market variations beyond the control of the ICT sector and the supplier base changes continuously over the different product systems' lifetime based on price, availability, etc. Emissions are therefore generally estimated based on assumptions and generic product models (see note 5). Such a process generates both parameter uncertainties within the data collected and scenario uncertainties regarding the selection of data to collect. In addition model uncertainties are incorporated if the generic model is associated with insufficient knowledge.

NOTE 4: A magnitude of thousand facilities could be associated with the supply chain of a major ICT company.

NOTE 5: An LCA study can involve hundred models using thousands of parameters.

For the use stage estimated, product system lifetimes / operating lifetimes for the goods featuring in the studied product system can generate essential scenario uncertainties. A two-fold increase of the studied product system's lifetime will result in a two-fold increase of emissions from studied product system operation if lifetime results are presented. Model uncertainties related to product system operation also include assumptions regarding the electricity production and amount of traffic.

End of Life Treatment (EoLT) and transport typically include model uncertainties related to a lack of comprehensive sub-supplier data. For EoLT there are significant variations between suppliers, especially between regions and future treatment processes are principally unknown.

Annex T (informative): Opportunities and limitations in the use of LCAs for ICT goods, networks and services

A Life Cycle Assessment (LCA) is a systematic methodology which gives an understanding of the relative importance of the different life cycle stages/activities. LCAs assist companies in determining where to put their efforts to improve life cycle environmental performance and also to monitor how this performance changes over time. However, it is important to keep in mind that the results of an LCA are always model-based representations of real environmental impact and the absolute impact of a certain product, network, service or organization is beyond reach. This is true for all kinds of product systems, but especially so for the complex product systems of the ICT sector.

An LCA addresses potential environmental impact; an LCA does not predict absolute or precise environmental impact due to the relative expression of potential impacts to a reference unit, the integration of environmental data over space and time, the inherent uncertainty in modelling environmental impact and the fact that some possible environmental impacts are clearly future impacts (ISO 14040 [1], clause 4.3).

In practice, it is virtually impossible to collect enough data for an assessment to give the absolute performance of a product system. Even then, the results would still have model and scenario uncertainty.

Consequently, any LCA result is only valid under the assumptions of the study and is still associated with substantial uncertainty, which needs to be considered so the outcome of the assessment is interpreted in a correct way.

EXAMPLE 1: An environmental performance parameter is assessed in two different studies for two goods, A and B. The calculated difference in performance between A and B is 25 %. The estimated uncertainty of the parameter is 50 %. In this case it is not possible to judge if A or B is a better good with respect to the assessed parameter, although the result value indicates a clear difference.

EXAMPLE 2: An environmental performance parameter is assessed for a scenario with an ICT service applied and a scenario without the service applied (business-as-usual scenario). The estimated uncertainty of the parameter is 50 % in this case as well, but the calculated improvement in performance when applying the ICT service is a factor of ten. In this case it can be concluded that the scenario with the ICT service clearly has the best performance even though the uncertainty of the performance parameter impacts the absolute value of the performance.

The above examples illustrates that both uncertainty analysis and sensitivity analysis are important tools to understand the results of a study and what conclusions can be made.

Appropriate use of LCAs

Due to these conditions, LCAs should primarily be used for the following purposes:

- Identification of opportunities to improve the environmental performance of goods, networks, services and organizations.
- Information to decision-makers in industry, government or non-government organizations about typical environmental performance of a product system/organization to assist their policy choices.
- Selection of relevant indicators of environmental performance for monitoring.
- Understanding of the potential impact of new services and solutions.
- Understanding of improvements between generations.

Contrarily, an LCA is less suitable for:

- quantitative benchmarking between studies;
- aggregation of results between studies;

NOTE: With sufficient accuracy.

- product system performance legislation (measurable parameters more appropriate); and
- labelling of ICT goods, networks and services.

Annex U (informative): Examples for calculating second order effects

In the present Annex examples are given for calculating second order effects using fictitious values for the difference between the reference product system and the ICT goods, networks and services product system. Conversion factors used were from the LCI database.

Equation U.1 shows a formula for calculating the second order effect, $EI_{difference}$:

$$EI_{difference,i} = EI_{reference,i} - EI_{\text{ICT goods, networks, and services},i} \quad \text{(U.1)}$$

In the present Annex, equation V.1 is applied to various second order effects:

(1) Consumption of goods (paper, CDs, DVDs, etc.)

If the consumed good is paper:

$EI_{difference,i=1}$ = (amount of paper consumed$_{reference}$ - amount of paper consumed $_{\text{ICT goods, networks, and services}}$) (kg paper/fu) × conversion factor (EI/kg paper)

Where:

fu = functional unit

Conversion factor = factor converting inventory data into impact data, e.g. greenhouse gas emission factor in the case of global warming impact.

EXAMPLE 1:

Net amount of paper consumed (difference between the reference and the ICT service)

= 10 kg paper/fu

Conversion factor for paper = 1,3 kg CO_2e/kg paper

$$EI_{difference,i = 1} = 10 \text{ kg paper/fu} \times 1{,}3 \text{ kg } CO_2\text{e/kg} = 13 \text{ kg } CO_2\text{e/fu}$$

(2) Power consumption/energy consumption (electricity, gasoline, kerosene, light oil, heavy oil, town gas, etc.)

If the consumed power is electricity:

$EI_{difference,i=2}$ = (amount of electricity consumed$_{reference}$ - amount of electricity consumed $_{\text{ICT goods, networks, and services}}$) (kWh/fu) × conversion factor (EI/kWh)

EXAMPLE 2:

Net amount of power consumed (difference between the reference and the ICT service) = –300 kWh/fu

Conversion factor for electricity = 0,49 kg CO_2e/kWh

$$EI_{difference,i=2} = -300 \text{ kWh/fu} \times 0{,}49 \text{ kg } CO_2\text{e/kWh} = -147 \text{ kg } CO_2\text{e/fu}$$

(3) Movement of people (car, bus, railroad, aircraft, etc.)

If the movement of people is done by car:

$EI_{difference,i=3}$ = (number of passengers × distance travelled$_{reference}$ - number of passengers × distance travelled$_{\text{ICT goods, networks, and services}}$) (passenger-km/fu) × conversion factor (EI/passenger-km)

EXAMPLE 3:

Net passenger-km travelled (difference between the reference and the ICT service) = 2 000 passenger-km/fu

Conversion factor for a passenger car = 0,10 kg CO_2e/passenger-km

$EI_{difference,i=3}$ = 2 000 passenger-km/fu × 0,10 kg CO_2e/passenger-km = 200 kg CO_2e/fu

(4) Movement and storage of goods (mail, truck, railroad cargo, air cargo, cargo ship, etc.)

If the movement of goods is done using a 10-tonne truck:

$EI_{difference,i=4}$ = (tonnes of goods transported × distance transported$_{reference}$ - tonnes of goods transported × distance transported$_{ICT\ goods,\ networks,\ and\ services}$) (tonne-km/fu) × conversion factor (EI/tonne-km)

EXAMPLE 4:

Net tonne-km transported (difference between the reference and the ICT service) = 1 000 tonne-km/fu

Conversion factor for a 10 tonne truck = 0,1 kg CO_2e/tonne-km

$$EI_{difference,i=4} = 1\,000 \text{ tonne-km/fu} \times 0{,}10 \text{ kg } CO_2\text{e/tonne-km} = 100 \text{ kg } CO_2\text{e/fu}$$

If the storage of goods affects the consumption of electricity

$EI_{difference,i=6}$ = (amount of electricity consumed$_{reference}$ - amount of electricity consumed$_{ICT\ goods,\ networks,\ and\ services}$)(kWh/fu) × conversion factor (EI/kWh)

EXAMPLE 5:

Net amount of power consumed (difference between the reference and the ICT service) = 100 kWh/fu

Conversion factor for electricity = 0,49 kg CO_2e/kWh

$$EI_{difference,i=6} = 100 \text{ kWh/fu} \times 0{,}49 \text{ kg } CO_2\text{e/kWh} = 49 \text{ kg } CO_2\text{e/fu}$$

(5) Improved work efficiency (electricity, office area, etc.)

If improved efficiency occurs in the area of electricity:

$EI_{difference,i=5}$ = (amount of electricity consumed$_{reference}$ - amount of electricity consumed$_{ICT\ goods,\ networks,\ and\ services}$)(kWh/fu) × conversion factor (EI/kWh)

EXAMPLE 6:

Net amount of power consumed (difference between the reference and the ICT service) = 200 kWh/fu

Conversion factor for electricity = 0,49 kg CO_2e/kWh

$$EI_{difference,i=5} = 200 \text{ kWh/fu} \times 0{,}49 \text{ kg } CO_2\text{e/kWh} = 98 \text{ kg } CO_2\text{e/fu}$$

If the improved efficiency affects the area of the office space:

$EI_{difference,i=7}$ = (area of office space$_{reference}$ - area of office space $_{ICT\ goods,\ networks,\ and\ services}$)($m^2$/fu) × conversion factor (EI/m^2)

EXAMPLE 7:

Net area of office space reduced (difference between the reference and the ICT service) = 100 m^2/fu

Conversion factor for office space area = 2,0 kg CO_2e/m^2

$$EI_{difference,i=7} = 100 \text{ m}^2\text{/fu} \times 2{,}0 \text{ kg } CO_2\text{e/m}^2 = 200 \text{ kg } CO_2\text{e/fu}$$

(6) Waste (wastepaper, garbage, plastic, industrial waste, etc.)

If the concerned waste is waste plastic for incineration:

$EI_{difference,i=8}$ = (amount of waste plastic$_{reference}$ - amount of waste plastic $_{ICT\ goods,\ networks,\ and\ services}$) (kg waste plastic/fu) × conversion factor (EI/kg waste plastic)

EXAMPLE 8:

Net amount of waste plastic (difference between the reference and the ICT service) = 10 kg waste plastic/fu

Conversion factor for waste plastic = 2,8 kg CO_2e/kg waste plastic

$$EI_{difference,i=8} = 10 \text{ kg waste plastic /fu} \times 2{,}8 \text{ kg } CO_2e/kg = 28 \text{ kg } CO_2e/fu$$

Summing up the $EI_{difference}$ for the all the comparison categories gives the second order effects of the ICT goods, networks and services product system compared with the reference product system. Table U.1 lists second order effects for each comparison category.

Table U.1: Second order effects for each comparison category

	Comparison category	Second order effect (kg CO_2e)
1	Consumption of goods (paper)	13
2	Energy consumption (electricity)	-147
3	Movement of people (passenger car)	200
4	Movement of goods (10-tonne truck) and storage of goods (electricity)	149
5	Improved work efficiency (electricity and work space)	298
6	Waste (waste plastic for incineration)	28
	Total	541

Thus, the second order effects of the ICT goods, networks and services product system are 541 kg CO_2e/fu. The EI difference can also be calculated and presented with respect to life cycle stages and components of the systems of ICT goods, networks and services as shown in Figure 25 and Figure 26 in clause 13.

Annex V (informative): GWP values 100 year time frame (informative)

The most up to date GWP 100 year values as of May 2014 are shown in Table V.1.

Table V.1: GWP 100 year values for some GHGs

GHG	GWP 100 years values from IPCC 5th Assessment Report (AR) page 731, [i.10]) (IPCC 4th AR 2007 page 212)
Carbon Dioxide	1 (1)
Methane	32 (25)
Nitrous Oxide	298 (298)
Hydrofluorocarbons HFC- 134a	1 550 (1 430)
Perfluorocarbons	7 390 - 12 200 (7 390 - 12 200)
Sulphur Hexaflouride	22,800 (22,800)
Nitrogen Trifluoride	17,200 (n/a)

Annex W (informative): Summary of requirements

Table W.1 summarizes all requirements present in the main body of the present document. In addition the present document contains numerous recommendations which also need consideration.

Table W.1: Summary of the requirement of the present document

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
Introduction	Deviation(s) from the requirements shall be clearly motivated and reported.			
5.2	Full compliance towards the present document can be claimed if all mandatory requirements are fulfilled.			
5.3	A third-party review is also needed if the comparison result is to be externally communicated.			
5.3	In case of comparative assessment between ICT goods LCAs the operating lifetime shall be set equal.			
6.1	The requirements of the present document shall apply as well as those of ISO 14040 [1] and ISO 14044 [2].			
6.1.1	The following four high-level life cycle stages (RMA, P, U, EOLT) shall apply to ICT goods, Networks and Services and shall be assessed as applicable in LCAs based on the present document in accordance with the goal and scope.			
6.1.1	Table 2 in clause 6.2.3.1 defines the detailed life cycle stages which further defines the system boundary and which are to be considered when assessing the life cycle impact of ICT goods, networks and services. In particular, it is important to cover all processes whose relevance is marked as mandatory in that table.			
6.1.1	The data collected shall be structured in such a way that the GHG emissions and energy consumption/ environmental impact arising from the transport processes could be reported transparently as far as possible.			
6.1.1	Transports and energy supplies shall be included in all life cycle stages.			
6.1.1	At the time of publication, to collect appropriate data related to raw materials transport and to separate data related to raw material acquisition stage and production stage is considered challenging due to LCA tool limitations, lack of data, limitations in data granularity and the nature of ICT supply chains. Deviation(s) from this requirement shall be clearly motivated and reported.			
6.1	instance transports of goods between production and use stages shall be taken into account.			
6.1.2	The ICT goods, networks and services product system to be assessed shall be clearly described as well as relevant functions and characteristics.			
6.1.2.1	For the ICT good under study, applicable types of parts, as well as amounts of these, shall be defined.			
6.1.2.2	In the goal and scope phase it shall be outlined which network building blocks are covered.			
6.1.2.2	For the ICT network under study, applicable types of nodes and infrastructure, as well as amounts of these, shall be defined.			
6.1.2.3	For the ICT service under study, applicable types of ICT network elements and infrastructure, as well as amounts of these, shall be defined.			
6.1.3.1	Software shall be considered as well as hardware.			
6.1.3.1	For specific software applications, such as music distribution applications, the software is to be seen as an ICT service and shall be assessed according to the requirements outlined for services.			
6.1.3.1	In these cases the hardware needed to operate the software shall be considered as well.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
6.1.3.1	For users of generic operating systems embedded in products, the life cycle impact of usage of this software may be considered as negligible. However, for the developer of this software the impact of the usage of this software shall be taken into account.			
6.1.3	Operating lifetime is critical for the interpretation of the results of LCAs and shall therefore always be reported when presenting LCA results.			
6.1.3	Operating lifetime estimates and assumptions shall also be clearly described in the reporting.			
6.2.1	During the LCA scoping phase the building blocks of the ICT goods, Networks or Services shall be identified.			
6.2.2.1	The functional unit shall be chosen in accordance with the goal and scope of the LCA.			
6.2.2.1	The functional unit requires inclusion of the relevant quantifiable properties and the technical/functional performance of the system. This means that the operating lifetime of all included ICT goods shall be specified			
6.2.2.1	the number of users/subscribers supported by the Network and the traffic profile shall be included where applicable.			
6.2.2.1	The functional unit shall be clearly defined and measurable.			
6.2.2.1	The reference flow shall reflect the functional unit chosen			
6.2.2.2	The functional unit shall be chosen in the context of goal and scope of the LCA and shall be further clarified by system boundary and cut-off rules.			
6.2.2.2	To comply with the present document, the following functional unit shall be applied where applicable. Annual ICT goods use (per one year of ICT good use), or total ICT good use per lifetime of ICT good.			
6.2.2.2	For relevant LCA results realistic use scenarios shall be captured.			
6.2.2.3	ICT networks can be seen as a system composed of different types of ICT goods. For the purpose of the present document the following functional unit shall be applied where applicable for ICT networks used during at least one year: • annual network use.			
6.2.2.3	For relevant LCA results realistic use scenarios shall be captured.			
6.2.2.4	For the purpose of the present document, the following functional unit shall be applied where applicable. Annual Service use.			
6.2.2.4	For relevant LCA results realistic use scenarios shall be captured.			
6.2.2.4	Corresponding realistic use scenarios shall be defined.			
6.2.2.4	The annual service use shall be defined with respect to the usage scenario to make it possible to define the reference flow			
6.2.3.1	The selection of the system boundary shall be consistent with the goal of the study.			
6.2.3.1	Consequently, the system boundaries here define the life cycle stages and the unit processes that shall be taken into account in an LCA of an ICT product system.			
6.2.3.1	Table 2 includes further details the life cycle stages to be included in LCAs of ICT goods, Networks and Services. The different life cycle stages are further described in clauses 6.2.3.4.2 to 6.2.3.4.5. Mandatory in Table 2 means that the life cycle stage shall be included.			
6.2.3.1	Mandatory life cycle stages or unit processes shall not be cut-off before considered for inclusion by using alternate data.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
6.2.3.1	In Table 2 "Mandatory" means that the life cycle stage, if applicable to the studied product system, shall always be taken into account in an LCA for ICT.			
6.2.3.3.1	In order to set the system boundary of ICT goods the life cycle stages listed in clause 6.1.1 shall be detailed.			
6.2.3.3.1	As stated in clause 6.1.3, the environmental impact from both hardware and software shall be considered, if applicable.			
6.2.3.3.1	For the ICT good under study, applicable types of parts, as well as amounts of these, shall be defined.			
6.2.3.3.2	Table H.1 provides a mandatory set of Raw Materials (both ICT specific and generic) which shall be included in the LCA of ICT goods.			
6.2.3.3.3	Annex E lists a mandatory set of Parts to be included where applicable to the studied ICT product system, when performing an LCA of ICT goods, as well as mandatory Part unit processes which shall be included for each Part.			
6.2.3.3.3	As an example, if batteries are part of the studied ICT goods product system they shall be included in within the system boundary and for every battery the Battery Cell manufacturing and Battery module manufacturing shall be included.			
6.2.3.3.3	The Assembly (B1.2) shall include as minimum PCBA Module Assembly, Final Assembly, Warehousing and Packaging.			
6.2.3.3.3	In case Support goods is part of the studied product system, Support goods Production (B2) is mandatory.			
6.2.3.3.3	Support goods (B2.1) which shall be included if applicable to the studied product system are at least air conditioners, cables and power supply systems.			
6.2.3.3.3	As stated in Table 2 Construction of ICT specific Site (B3) is mandatory if the ICT specific site is included in the studied product system.			
6.2.3.3.3	Site building blocks needed for B3.1, which at least shall be included if applicable to the studied product system, are antenna towers, fences and shelters.			
6.2.3.3.4	The Raw Material Acquisition and Production for the additional PCBAs used during the operating lifetime of the ICT goods are mandatory.			
6.2.3.3.5	As shown in Figure 11, Preparation of ICT goods for Re-use of ICT goods (D1), ICT specific EoLT (D2) and Other EoLT (D3) are within the mandatory system boundary for EoLT.			
6.2.3.3.5	Annex F lists a mandatory set of EoLT processes to be included where applicable when performing an LCA of ICT goods which includes the EoLT stage.			
6.2.3.3.5	It is thus recognized that compliance to all requirements in Annex F may not be possible at the time the present document is published. Deviation(s) from the requirements shall be clearly motivated and reported.			
6.2.3.4	The Network shall be defined in terms of ICT goods, Support goods and ICT infrastructure (e.g. cables duct).			
6.2.3.4	For each included product types number of units shall be defined as well as corresponding lifetime			
6.2.3.4	For assessment of Networks, operator activities shall always be included.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
6.2.3.5.1	In addition to the use of ICT goods and networks, an ICT service may also have additional impacts associated with application software development, use of consumables, infrastructure for sales and logistics, associated travel and transport (in addition to those already included for the ICT goods and networks) which shall also be included as appropriate.			
6.2.3.5.1	The impact of the data centres where the service is operated shall be assessed.			
6.2.3.5.1	The data centre shall be studied and assessed in the same way as other ICT goods.			
6.2.3.5.1	The system boundary of the ICT services provided by the ICT network shall be established based on either the actual use scenario of the ICT services, if available, or on an estimated use scenario.			
6.2.3.5.2	Energy consumption, material inputs and environmental releases shall be assessed in accordance with the system boundary.			
6.2.4	Cut-offs shall be avoided as far as possible.			
6.2.4	ISO 14044 [2], clause 4.2.3.3 recommendations shall be used as closely as possible.			
6.2.4	All cut-off criteria stated by ISO 14040 [1] and ISO 14044 [2] are to be considered before cut-off of a certain process - and the process shall be included if significant to at least one criterion.			
6.2.4	The intention of the present document is to include all mandatory activities of Table 2. If these activities are not included such cut-offs shall be clearly motivated.			
6.2.4	Any cut-off made shall be clearly described and documented.			
6.2.5.1	A qualitative description of the data quality and any efforts taken to improve it shall be disclosed while considering the following data quality indicators: • Methodological appropriateness and consistency • Completeness (total LCA level) • Uncertainty • Data representativeness • Data age (timeliness) • Acquisition method • Supplier independence • Geographical correlation • Technological correlation • Cut-off rules (rules of inclusion/exclusion)			
6.2.5.2	In general data age and technology are especially important in LCAs for ICT goods, Networks and Services due to the fast technology evolution and the growth in network traffic. E.g. for data traffic, up-to-date figures shall always be used			
6.2.5.2	For support activities (e.g. ICT manufacturer support activities and operator support activities) primary data shall be used for all individual processes under the financial or operational control of the organization undertaking the LCA			
6.2.5.2	and data shall be representative of the processes for which they are collected.			
6.2.5.1	In selecting emission factors for use in calculating GHG emissions under this methodology the following guidance shall be followed: Emission factors used should be the most up to date from publicly available sources.			
6.2.5.1	Where emission factors are sourced from non public sources, or are not the most up to date ones, a justification for their use shall be provided.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
6.2.5.1	The specific GWP values used shall be those taken from the latest UN IPCC reports. For further guidance see Table W.1.			
6.3.1.1	Data shall be collected for each unit process that is included within the system boundary in accordance with Annex B.			
6.3.1.1	Data shall be collected for all mandatory processes outlined in Table 2.			
6.3.1.1	When data has been collected from public sources, the source shall be referenced.			
6.3.1.2	Data shall be collected at least for the processes marked with mandatory in Table 2, unless these are found negligible in accordance with the cut-off rules.			
6.3.1.2.1	it should be noted that, for many products (especially end-user goods), periods of idling and power off may be significant and are important to consider when modelling the traffic profile/ model the usage profile and shall be included if applicable.			
6.3.1.4	Use time, goods type, data traffic and network access type give important statistical data that needs to be collected in order to quantify the use of ICT systems.			
6.3.1.2.3	When calculating the potential environmental impact the LCA practitioner is encouraged to use the most accurate data for the energy mix that is applicable to the ICT goods under assessment. Particularly the use stage shall use the applicable electricity mix to calculate the potential environmental impact from the use stage more exactly.			
6.3.2.1	The general requirements for data calculations in ISO 14040 [1] and ISO 14044 [2] shall be applied.			
6.3.2.1	All calculation procedures shall be explicitly documented and the assumptions made shall be clearly stated and explained.			
6.3.2.1	The same calculation procedures shall be consistently applied throughout the study.			
6.3.2.1	A check on data validity shall be conducted during the process of data collection to confirm that the data quality requirements for the intended application have been fulfilled.			
6.3.2.3	the evaluation of the environmental load shall consider both a fixed part which is independent of the usage and a variable part which correlates to the usage			
6.3.3.1	The same allocation method shall be used for all environmental loads for all products from a common process.			
6.3.3.1	The study shall identify the processes shared with other product systems and deal with them according to the stepwise procedure presented below.			
6.3.3.2	Data for generic processes (G1 to G7) shall be allocated as a whole (i.e. for the full lifecycle for the generic process) to the associated life cycle stage of the product system.			
6.3.3.2	However all Raw Material Acquisition (G5) shall be allocated to the life cycle stage Raw Material Acquisition (A).			
6.3.3.3	Data for relevant part of the organization/operation shall be allocated to the relevant part of the project/product system life cycle.			
6.3.3.3	If no detailed information on organization/operation is available the allocation shall be based on organizational/economic data.			
6.3.3.8	End-user goods (e.g. PCs, smart phones) which is accessing more than one ICT Network (e.g. 3G, WLAN) shall be allocated to these ICT Networks based on use time.			
6.3.3.8	The assumptions regarding use time for access to different ICT Networks and off line work shall be described and motivated.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
6.3.3.8	Impact from shared Network resources (e.g. transmission goods, core nodes and data centres) shall be allocated to an access Network based on data traffic.			
6.3.3.8	The assumptions regarding data traffic shall be described and motivated.			
6.3.3.9	The impact from each ICT network supporting the service should be allocated to the service based on access use time or data traffic. More specifically, the following allocation principle of ICT Network data to an ICT Service shall be used: Data for End-users goods: to be allocated based on active use time of the ICT Service. Etc.			
6.3.3.9	Data traffic is also preferred for e.g. mobile access networks as mobile access networks show a large dependency between data traffic and energy consumption and need a traffic model that takes data traffic into account.			
6.3.3.9	Data for data centres and Service provider activities: The data centre(s) where the ICT Service is operated as well as the service provider activities shall be allocated based on number of subscriptions and service users or amount of data/transactions.			
7	ISO states that the selection of impact categories shall reflect a comprehensive set of environmental issues related to the product system being studied, taking the goal and scope into consideration.			
7	In the LCA it shall be ensured that the inventory elementary flows (see Annex G are correctly linked with appropriate LCIA characterization factors.			
7	For climate change, the most recent global warming characterization factors from the Intergovernmental Panel on Climate Change [b-IPCC] for each GHG shall be used and the timeframe should be 100 years.			
7	The mid-point category Climate change is mandatory.			
7	For other impact categories there is no methodological consensus in the LCA community, thus the LCA practitioner shall decide which impact categories to consider and how to calculate them, based on the studied ICT product system and purpose of the LCA study.			
7	All impact categories and category indicators included shall be disclosed (Table L.10) and justified.			
8.2	the sources of uncertainty and methodological choices made shall be assessed and disclosed.			
8.3	The results of the LCI or LCIA phases shall be interpreted according to the goal and scope of the study.			
8.3	The interpretation shall include a sensitivity check of the significant inputs, outputs and methodological choices and defined use scenarios, in order to understand the uncertainty of the results.			
9.1	The reporting of ICT product systems shall fulfil the reporting rules as defined by ISO 14040 [1] and ISO 14044 [2].			
9.1	In the case of reporting, a public GHG inventory report, the key accounting principles (relevance, accuracy, completeness, consistency and transparency) shall be met.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
9.1	In addition to the reporting obligations outlined by ISO 14040 [1] and ISO 14044 [2], the report shall include the following information: • contact information; • studied goods, networks and services product system name and description; • type of inventory (i.e. final product cradle-to-grave or intermediate product cradle-to-gate inventory); • goals of the study. The reporting of results shall include: • total GHG emissions reported as amount of CO2e per functional unit for ICT good, network and service that have been assessed; • percentage for each life cycle stage contributing to the total results; • electricity (with use stage separated from the other stages); • primary energy (see note); • fuels; • value and sources of emission factors for CO2 and CO2e and Global Warming Potential (GWP) metric used in the report; • other data, justifications and explanations as stated throughout this report. NOTE: Primary energy and electricity cannot be summarized because electricity is contributing to the total primary energy.			
9.1	In addition the rules outlined in this clause and what is stated in Annex L shall be followed for reporting of studies claiming compliance with the present document.			
9.1	The report resulting from the application of the present document shall contain a compliance statement saying either that the LCA fully complies with the present document (in case of full compliance) or that the LCA partially complies with the present document with the exceptions transparently listed and justified partial compliance).			
9.1	The extent in which Support activities and other optional/recommended activities are excluded for different parts of the life cycle shall be clearly described and for recommendations also motivated in the study report.			
9.1	For each product system (including ICT goods, Network and Service) the following aspects, being of special importance to ICT applications, shall be transparently motivated and described in accordance with the principles defined in this clause: • Operating lifetime: All lifetime assumptions shall be stated and motivated.			
9.1	Cut-off: Any cut-off made shall be clearly stated and motivated.			
9.1	Allocations: Basis for allocations made shall be described, especially for recycling, use of recycled materials, distribution of facility data and support activities.			
9.1	Data sources: Data sources (i.e. specific/generic) shall be clearly stated and deviations towards Table 2 shall be motivated.			
9.1	For each product system (including ICT goods, Network and Service) an additional diagram shall be presented whenever optional activities in Table 2 have been included.			
9.1	The emission factors used shall be clearly stated. The source used and the year they represent shall be clearly stated.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
9.1	In the case of emission factors for grid electricity the source, year and location (specific, country, global average) shall be clearly stated.			
9.1	Where emission factors are sourced from non public sources, or are not the most up to date ones, a justification for their use shall be provided.			
9.2.1	For each impact category studied, diagrams corresponding to Figure 14a and Figure 14b shall be reported for the corresponding category indicator result.			
9.2.1	Due to the importance of operating lifetime to results, information regarding this shall always be present in the diagram, together with some other basic modelling statements including total result for the indicator, LCA study year operating lifetime, etc. as shown below.			
9.2.1	Figure 14a and Figure 14b shall be presented whenever optional activities/processes from Table 2 have been included in the studied product system.			
9.2.1	For transports, the total result including all transports throughout the life cycle Annex L (Table L.4) shall be stated in the immediate proximity of the diagram (Figure 14a and Figure 14b).			
9.2.1	If used data sets do not report transports separately any missing transport shall be listed and motivated.			
9.2.1	Figure 16 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal".			
9.2.1	A diagram summarizing distribution of selected environmental impact category indicators between life cycle stages shall be prepared together with absolute figures as shown in Table L.10.			
9.2.1	Figure 18 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation in the scope.			
9.2.2.1	Any deviation to Table 2 and clause 6.2.3 with respect to mandatory life cycle stages/unit processes shall be clearly stated and motivated.			
9.2.2.1	Additionally, inclusion of generic processes for the different life cycle stages shall be clearly stated and reported.			
9.2.2.1	Deviations for Generic processes shall be reported according to Table L.3.			
9.2.2.2	The use of raw materials shall be transparently reported as outlined below.			
9.2.2.2	The most important metals from recycling point of view shall always be included. For appropriate reporting format refer to Table L.5.			
9.2.2.2	Deviation(s) from the requirements shall be clearly motivated and reported.			
9.2.2.3.1	Compliance to Table E.1 shall be reported according to below and any deviation shall be described and motivated. Compliance to Table E.1 shall be reported according to below and any deviation shall be described and motivated.			
9.2.2.4.1	Compliance to Table E.1 shall be reported according to below and any deviation shall be described and motivated.			
9.2.2.4.1	The model of distribution over time of different usage modes including power off and idle and the rationale for those shall be transparently reported. For appropriate reporting format refer to Table L.7.			
9.2.2.4.2	The rationale for the energy consumption values for the Support goods use shall be transparently described and motivated. For appropriate reporting format refer to Table L.7			
9.2.2.5	If EoLT is included any deviations towards Annex F shall be transparently reported and motivated. For appropriate reporting format refer to Table L.3.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
9.2.3	For LCI the following items shall be reported transparently: total use of primary energy and electricity.			
9.2.3	Additionally, results for elementary flows according to Table G.1 could be transparently reported on an optional basis. If such reporting is not made it is mandatory to describe unexpected results, lack of data and other findings associated with the elementary flows.			
9.3.1	Operating lifetime is important also for Networks, but is associated with the lifetime of the different nodes, which shall be reported.			
9.3.1	It shall be reported following the format of Table L.11 which also describes the studied Network.			
9.3.1	Figure 18 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal".			
9.3.1	Additionally a diagram summarizing distribution of environmental impact category indicators between life cycle stages shall be prepared together with absolute figures as shown in Table L.10.			
9.3.1	Figure 19 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal".			
9.3.1	Details of network energy consumption shall be reported with a split of different elements of the network. An example of table for Reporting is provided in Table L.12.			
9.4.1	Operating lifetime is important also for Services, but it is associated with the lifetime of the different nodes, which shall be reported.			
9.4.1	Allocation of Network data to the Service shall be reported. It should be reported according to Table L.13.			
9.4.1	Additionally a diagram summarizing distribution of impact category indicators between life cycle stages for the Service product system under study shall be presented together with absolute figures as shown in the Table L.10.			
9.4.1	Figure 22a and Figure 22b shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal".			
10	Any critical review shall be performed according to the requirements in ISO 14040 [1] and ISO 14044 [2] and in the present document.			
10	The scope and type of critical review desired shall be defined in accordance with ISO 14044 [2], clauses 4.2.3.8 and 6.			
11.1	Infrastructure, e.g. highways for transportation, is generally assumed to exist independently of introduction of new services and shall be excluded.			
11.1	The handling of time perspective and scale shall be disclosed and motivated in the present document.			
11.1	To be able to quantify the net environmental impact when introducing an ICT based Service the environmental impact of both the ICT Service itself and of the reference product system need to/shall be assessed from a life cycle perspective.			
11.1	To make sure that the comparative assessment gives a relevant result, the full life cycle of both systems shall always be considered.			
11.1	From an LCA perspective the reference product system and the ICT service based system shall mimic each other as far as possible.			
11.1	and the LCA practitioner shall model both systems in an unbiased way.			
11.2	Goods shall be compared with other goods.			
11.2	ICT networks shall be compared between themselves.			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
11.2	and ICT services shall be compared between themselves.			
11.3.1	In this comparative LCA study, the scope of the LCA study shall be defined in such a way that the two systems can be compared.			
11.3.1	Systems shall be compared using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures and cut-off rules.			
11.3.1	Any differences between systems regarding these parameters shall be identified and reported.			
11.3.2	Also in this case, the scope of the LCA study shall be defined in such a way that the two systems can be compared.			
11.3.2	Both systems shall be assessed using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures and cut-off rules.			
11.3.2	Any differences between systems regarding these parameters shall be identified and reported.			
11.3.3	The assessment of the ICT based system shall be performed in accordance with Part I.			
11.3.3	When making comparisons, it is important to keep in mind that the functional unit used shall be applicable to both the reference product system and the system of ICT goods, networks and services.			
11.3.3	For the reference product system applicable requirements in the present document shall be applied, e.g. requirements regarding data quality, cut-off, etc.			
12.2	All the requirements stipulated in Part I for a system boundary definition shall be applied.			
12.2.1	The functional unit shall take into account the general rules outlined in Part I, clause 6.2.2 "Functional unit" and ISO 14044 [2] clause 4.2.3.2.			
12.2.1	Additionally, the functional unit shall be defined so that it is applicable both to the ICT goods, networks and services product system and the reference product system.			
12.2.1	The reference flow shall be defined to quantify the functional unit.			
12.2.1	In other words, for the functional unit of one meeting, for instance, the reference flow for the systems of ICT goods, networks and services and the reference product system shall be defined.			
12.2.2	Two different system boundaries shall be defined which are applicable for the ICT goods, networks and services product system and for the reference product systems respectively.			
12.2.2	considerations shall be paid to which electricity is used when assessing the environmental impact of the ICT goods, networks and services product system and the reference product systems.			
12.3	The calculation for the inventory analysis shall be performed in accordance with Part I, clause 6.3.			
12.4	The calculation for the inventory analysis shall be performed in accordance with Part I, clause 6.3.			
13	Any cut-off made during a study shall be clearly stated in the study report, e.g. the exclusion of life cycle processes which are considered insignificant should be justified.			
Annex B	A mandatory list of generic activities (unit processes) that have been found to be of importance for LCA of ICT goods, Networks and Services can be found in Annex D.			
Annex B	The following emissions shall be taken into account if applicable to the studied impact category(ies): • Emissions to air • Emissions to water • Emissions to soil			

Clause in ETSI ES 203 199 (the present document)	Requirement	Fulfilled	Not fulfilled	Explanation/Motivation
Annex B	The following resource objects shall be taken into account if applicable to the studied impact category(ies): Material resource use (or material depletion) Energy resource use (or energy resources depletion)			
Annex B	A list of emissions and resource objects that shall be included, if applicable to the studied product system and impact category(ies), can be found in Table G.1.			
Annex B	Further, the following inputs shall also be included if applicable to the studied impact category(ies): Electricity. Other forms of delivered energy (district heating and cooling). Fuels (typically indicates the fuels are incinerated on-facility or in a vehicle connected to the facility). Primary products (products that are part of the final product in operation). Secondary products (products that are not part of the final product in operation). Transports, travel and other services (can be seen as a special non-material secondary product input).			
Annex B	Finally, the following flows shall also be included if applicable to the studied impact category(ies): • Water discharge (to municipal sewage or recipient). • Waste fractions (residual waste fractions or waste fractions that need further treatment, also including material recycling and energy recovery). • Product output (the main purpose with the unit process or activity).			
Annex C	Any support activities included in the LCA scope shall be clearly reported in term of organization activities considered.			
Annex D	G7….Other material shall be considered.			
Annex E	Table E.1 lists the applicable parts and assembly types which shall be taken into account when performing an LCA of ICT goods, if applicable to the ICT good (not ICT network). It also lists the corresponding part and assembly categories and unit processes.			
Annex G	Table G.1 contains elementary flows which shall be taken into account in LCA analyses for ICT.			
Annex G	The substance names listed in Table G.1 shall be used in the present document.			
Annex G	Deviation(s) from the requirements shall be clearly motivated and reported.			
Annex H	Table H.1 lists a minimum Raw Materials groups (chemicals, fuels, metals, plastics, packaging materials and additives) which shall be taken into account in LCAs of ICT goods, if applicable to the studied ICT product system.			
Annex L	This Annex contains tables that shall be used to report the result of the assessment.			
Annex L	Deviation(s) from the requirements shall be clearly motivated and reported.			

Annex X (informative): The relation between LCA and Circular Economy for ICT

The present document, as well as other leading LCA standards such as ISO 14044 [2], can handle LCA modelling of different material efficiency practices to some extent for the system at hand to show possible benefits and drawbacks. It is possible to use the present document as framework for deriving the very different LCA profiles of ICT goods.

The common understanding is that LCA can handle some aspects of circularity but other tools are useful to provide a wider understanding [i.20]. LCA alone may not always be enough to study Circular Economy strategies. LCA should be combined with other method from industry ecology, complex systems science and circularity indicators.

The trend is that traditional LCAs are complemented by circularity measurements Key Performance Indicators like Product Circularity Indicator [i.20], [i.15], Recommendation ITU-T L.1023 [i.13] or whichever circularity indicator by which the LCA practitioner chose to evaluate the resource effectiveness of the product system at hand.

For goods environmental footprint, LCA is the recommended tool. The LCA practitioner needs to make suitable assumptions to use LCA for goods which is refurbished and reused. LCA based on ISO 14044 [2] has been used in the ICT sector to study the effect of extending product lifetimes [i.21], [i.18], [i.19], [i.14] and the present document provides further guidance for assessing the effect of multiple (re)uses of the goods.

The conclusion is that the present document can be used to evaluate the effect of some main circularity aspects if all assumptions, especially regarding system boundary and functional unit are shown.

Annex Y (informative): Application scenarios for LCA of ICT goods with extended operating lifetime and multiple life cycles

Y.1 Introduction

ICT goods can undergo several forms of extension of operating lifetime, e.g. reuse or refurbishment sometimes with the change of ownership. Products that are reused or refurbished will enter a new life cycle as part of extended operating lifetime. LCA is useful for different analysis purposes for these ICT goods. Depending on the goal of the LCA study, some potential application scenarios for LCA are e.g.:

- Cradle-to-grave LCA of a ICT goods with extended operating lifetime
- LCA of first life cycle of a ICT goods with multiple life cycles
- LCA of second life cycle of a ICT goods with multiple life cycles
- Comparative LCA of a ICT goods with extended operating lifetime

This is not an exhaustive list of potential application scenarios of LCA use. However, the list illustrates the dynamic nature of LCA applicability and approach required depending on the intended use of LCA results, end of life scenarios selected, operating lifetime, and the respective life cycle(s) of the ICT goods.

The above listed application scenarios are further explained in the following clauses.

Y.2 LCA covering cradle-to-grave of a ICT goods with extended operating lifetime

The purpose of LCA covering cradle-to-grave is to evaluate the environmental impact throughout the whole life of the goods from raw material acquisition to the final waste treatment. LCA covering cradle-to-grave can be used as one of the product development and improvement tools to study the differences in the environmental impact of design choices and the resulting environmental impact reduction due to reduction of material and energy consumption, supply chain optimization, different end-of-life treatment scenarios and extended operating lifetime of the goods. It helps to assess and report the environmental impact of ICT goods, identify hotspots and opportunities for improvement in product design to manufacture more sustainable products.

As the name suggests, the scope of LCA covering cradle-to-grave consists of entire life cycles of the goods starting from raw material acquisition to the final end-of-life and typically consists of multiple life cycles through reuse and refurbishment. LCA covering cradle-to-grave of ICT goods can be done by redefining the functional unit to incorporate extended operating lifetime. Both goods with single life cycle and multiple life cycles can be assessed with this approach.

Y.3 LCA of first life cycle of a ICT goods with multiple life cycles

LCA can be used to assess the environmental impact of first life cycle of a ICT goods with extended operating lifetime. These ICT goods help in recirculating the product and materials back to the system at the end of their use creating a closed-loop system where goods at their highest level and materials are continually kept in use and recycled instead of being discarded after the first use. Multiple reuse and refurbishment cycles of a product are possible after the first use. Products that are reused or refurbished will enter a new life cycle as a part of extended operating lifetime and LCA of second life cycle is used to assess the environmental impact of new life cycle.

The scope of LCA of first life cycle of ICT goods includes cradle-to-<end of first life cycle> (which includes "A Goods raw material acquisition", "B Production", "C Use" and "D EoLT" (partial) stages of first life), after this point the product enters a new life cycle.

For a transparent assessment analysis of the environmental impact of ICT goods, separation of impact into correct life cycles and life cycle stages is important. The assessment of the first life cycle environmental impact can be done when the product is returned for reuse or refurbishment after its first use.

Y.4 LCA of second life cycle of a ICT goods with multiple life cycles

LCA can be used to assess the environmental impact of second life cycle of a ICT goods with extended operating lifetime. When goods are returned after its first use for refurbishment and/or for reuse, needed actions are performed for the goods to enter the second use with extended operating lifetime. Refurbishment involves preparing the goods for a second use with necessary actions, e.g. replacing needed parts in the goods.

The scope of this assessment approach is from right after the end of the first life cycle (which is the start of the second life cycle) until the end of the second life cycle or from the start of the second life cycle to grave (which includes "B Production, "C Use" and "D EoLT" stages of second life). The environmental impact due to refurbishment of the goods including the parts production of newly added parts and delivery of the goods after refurbishment for the second use is also considered for the LCA of second life cycle of a ICT goods.

This assessment can be best performed when the goods is returned after its first use. This approach is particularly useful for the environmental impact assessment of refurbished or reused goods when ownership of the goods changes. It also gives indication of the benefit of reuse or refurbishment compared to a new goods.

Y.5 Comparative LCA of a ICT goods with extended operating lifetime

The purpose of comparative LCA as described in Part II is to compare the environmental impact of two or more products offering the same or similar function usually to identify the one with lower environmental impact. It helps to identify the trade-offs and potential intended and unintended consequences of different choices made during design and production processes. Comparative LCA of ICT goods can be done by comparing the environmental impact of ICT goods with extended operating lifetime, to the appropriate number of new goods with combined operating lifetime equal to the extended operating lifetime. To ensure relevant and representative results with the comparative LCA, the system boundaries need to be identical, the same functional unit needs to be applied and equal operating lifetime of the compared product systems need to be included in the assessment, etc. The conditions for comparability is further defined in Part II and in the Scope.

Depending on the intended use of the comparative LCA results, it is also a common practice to exclude the stages and processes that are identical across the compared functional units and only include the relevant life cycle stages and processes. Therefore, the scope of comparative LCA could be a cradle-to-grave, cradle-to-gate, gate-to-grave, cradle-to-end of first life cycle, start of the next life cycle to end of the next life cycle, or start of the last life cycle-to-grave, etc.

Comparative LCA can be used to compare the environmental impact of ICT goods with extended operating lifetime to a relevant number of new goods, LCA of second life cycle of a ICT goods with extended operating lifetime compared to a new good, or impact of ICT goods compared to a non-ICT system using the same functional unit, operating lifetime, system boundaries, and other equivalent methodological considerations for both systems. See Part II of the present document for more information about comparative LCA.

Annex Z (informative): Example analysis of different refurbishment configurations

This Annex provides an example analysis using comparative LCA when assessing refurbished products.

The consequences of different refurbishment configurations are analysed in x-ADEME [i.29] on "Assessment of the environmental impact of a set of refurbished products" (French version), which studied the cases of smartphones, fixed PCs, mobile PCs and tablets (September 2022).

x-ADEME [i.29] accounts not only the carbon impacts, but also the impacts on depletion of abiotic resources (mineral, metal, fossil resources), acidification and the ionizing radiation emitted.

Regarding the impact in terms of greenhouse gas emissions, x-ADEME [i.29] produces for example for smartphones the graph below depending on the frequency of purchase and considering a depreciation approach.

As indicated in the ADEME report: "this approach involves transferring and depreciating some of the impacts of manufacturing and end of life of the new device to the refurbished product, if refurbishment takes place before the theoretical end of the usage period in the first cycle." In x-ADEME [i.29], the observed average lifespan of new smartphones is 3 years, and two years for refurbished ones (Table 27 in x-ADEME [i.29]). It also indicates that the average global warming potential over the entire life cycle of a new smartphone is 85,2 kgCO_2e, and that of refurbishing operations is 7,61 kgCO_2e.

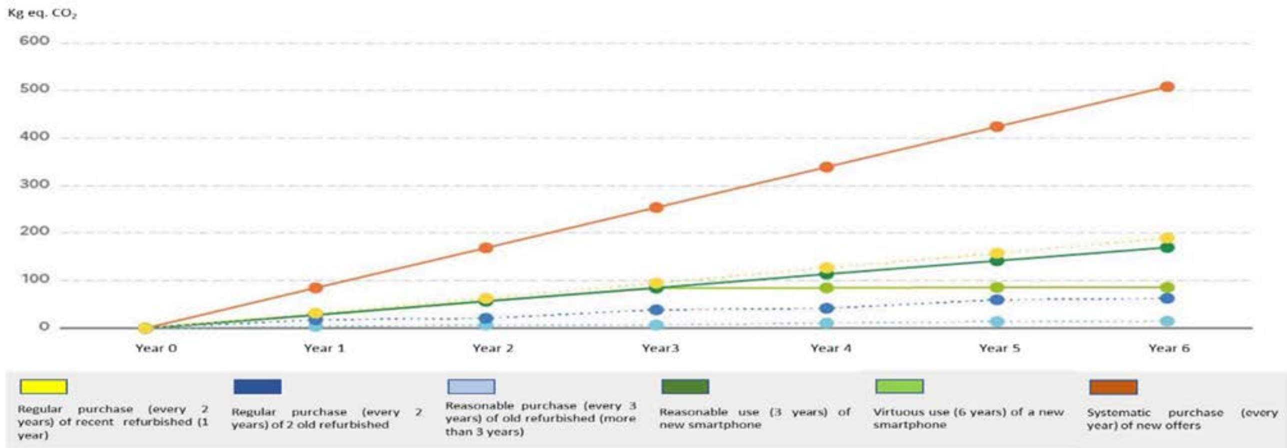

Figure Z.1: Comparison of reference smartphone - depreciation approach - 6 year market results for GHG emissions

The present document mentions that the impact of refurbishment, taking into account the depreciation period of the first lifespan, is calculated as follows:

$$Impact_{refurbished} = \frac{(Impact_{remaining\ to\ be\ imputed\ 1st\ life\ new} + Impact_{refurbishment})}{Usage\ period_{refurbished}} + Impact_{annual\ usage} \quad (Z.1)$$

Where:

$$Impact_{remaining\ to\ be\ imputed\ 1st\ life\ new} = \frac{(Impact_{manufacturing+end\ of\ life\ new})}{D_{1hypothesis}} \times (D_{1hypothesis} - D_{1real}) \quad (Z.2)$$

$D_{1hypothesis}$ = Usage period in the theoretical first lifetime observed on the market

= Usage period beyond which it can be considered that refurbishment automatically extends the lifespan

D_{1real} = Usage period in the actual first lifespan

= Usage period prior to collection and change of owner

EXAMPLE: Buying a recent (1 year old) refurbished device every two years will have a CO_2e impact slightly higher than the average use of buying a new smartphone every 3 years, due to refurbishing operations, even if the lifespans of smartphones are the same (Figure Z.1). The lowest impacts are reached by increasing the average lifespan of new devices, as illustrated in cases called "regular" and "reasonable" purchase (blue dotted lines), where the lifespans of devices are respectively 4 and 6 years.

Therefore, to assess the environmental effects of the existence of a refurbishing process, at least the following three effects should be part of the assessment:

i) the impact of refurbishing operations (repair, transport, marketing, raw materials, etc.) in each life cycle stages;

ii) the effect of previous equipment life(s), as early refurbishment accelerates the replacement of the equipment with one that is new;

iii) the operating lifetimes of the compared product systems are equal.

Annex AA (informative): Bibliography

- European Commission - Joint Research Centre - Institute for Environment and Sustainability JRC58190: "International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance". First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010
- Document C(2021)9332 Commission Recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations C/2021/9332 final, Sections 4.4.8 and 4.4.9 in Annex I.

History

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V1.1.1	November 2011	Publication as ETSI TS 103 199
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