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Life Cycle Assessment (LCA) of ICT equipment, networks and services;
General methodology and common requirements

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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Environmental Engineering (EE).

Introduction

Environmental Life Cycle Assessment (LCA) is a system analytical method and model by which the potential environmental effects related to ICT Equipment, Networks, and Services can be estimated. 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.2]. This handbook will also be referred to with special ICT considerations in mind.

The present document will help LCA practitioners to perform and report their LCAs of *ICT Equipment*, 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 Equipment, Networks, and Services.

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

- Assessment of product system environmental loadings.
- Assessment of primary energy consumption.
- Identification of life cycle stages with high significance.
- Comparisons of specific ICT Equipment, Networks, or Services.

The structure of this LCA methodology specification for ICT Equipment, Networks, and Services is shown in Figure 1.

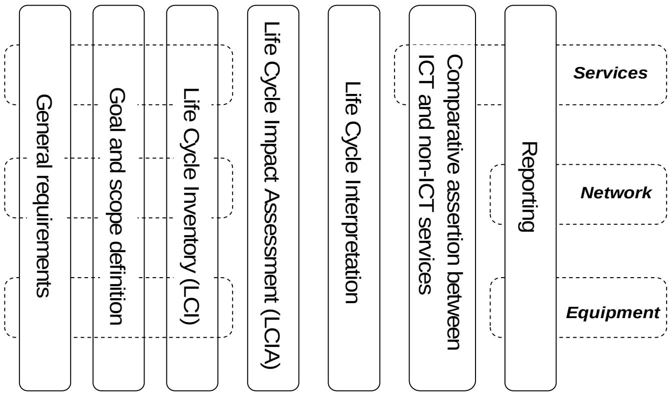


Figure 1: Structure of LCA methodology specification for ICT Equipment,Networks and Services

In accordance with ISO 14040 [1] and ISO 14044 [2], the present document consists of the following parts:

- General requirements: High level requirements of LCAs.
- Goal and scope definition: Requirements on functional unit, system boundaries and data quality.
- Life Cycle Inventory (LCI): Requirements on data collection, calculation and allocation.
- Life Cycle Impact Assessment (LCIA): Requirements on impact categories.
- Life Cycle Interpretation: Requirements on interpretation of results.
- Comparative Assertion between ICT and reference product systems.
- Reporting: Requirements on reporting.

All applicable parts are then divided into the three main applicable product system categories; *ICT Equipment, Networks,* and *Services*.

1 Scope

The present document aims to:

- harmonize the LCAs of *ICT Equipment*, *Networks* and *Services*;
- increase the quality of the LCA by adding ICT specific requirements to those of ISO 14040 [1] and ISO 14044 [2];
- facilitate communication of LCAs of *ICT Equipment*, *Networks* and *Services*;
- increase the credibility of LCAs of *ICT Equipment*, *Networks* and *Services*.

While recognizing ISO 14040 [1] and ISO 14044 [2] as normative references, the present document establishes generic and specific requirements for LCA of *ICT Equipment*, *Networks* and *Services*. The present document is valid for all types of *Equipment* which is/could be part of a *Network* including *end-user Equipment*.

2 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 reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://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.

2.1 Normative references

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

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 (V1.1.1): "Environmental Engineering (EE) Energy Efficiency of Wireless Access Network Equipment".

[i.2] European Commission Joint Research Centre (2011) International Reference Life Cycle Data (ILCD) System Handbook: "General Guide for Life Cycle Assessment - Detailed Guidance". 1st edn., Dictus Publishing (17 June 2011).

[i.3] European Commission Joint Research Centre (2011) International Reference Life Cycle Data System (ILCD) Handbook: "Framework and Requirements for Life Cycle Impact Assessment Models and Indicators". 1st edn. Dictus Publishing (17 June 2011).

[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".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in ISO 14040 [1], ISO 14044 [2], the ILCD Handbook, Table 1 [i.2] and the following apply.

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

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.

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

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

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: Legal lifetime.

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

EXAMPLE: Laptop, mobile phone.

NOTE: See clause J.1 for examples.

extended operating lifetime: aggregated duration of the actual use periods of the first user and consecutive use periods associated with extended use

extended use: equipment is used again by a new user or in a new context potentially with refurbishment

fresh water: water from river, lakes or subsoil water

generic data: data from any relevant data source which need not be specific for ICT applications and processes

NOTE: Generic data are always secondary.

ICT Equipment: tangible equipment 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.

ICT manufacturer: organisation which has the financial and organisational control of the design and production of an ICT Equipment

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

ICT specific infrastructure: basic structures needed for the operation of the Equipment, 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 stage: One of several consecutive and interlinked stages of a product system

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

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

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

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

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

operator: organization operating Networks and ICT Equipment

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.

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 equipment but could be used for any kind of equipment

part: constituent of ICT Equipment and Support Equipment

EXAMPLE: Cable.

part category: classified part type

EXAMPLE: Fibre cable.

primary data: quantified value of a unit process or an activity within the product system obtained from a direct measurement or a calculation based on direct measurements at its original source

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: natural resources which can be used for energy production

primary raw material: material which origins from natural resources

process category: classified process type

EXAMPLE: Landfill, Air, Ship and Train.

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

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: primary or secondary raw material that is used to produce a Part or Equipment

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 which could be significant to the result should be included in the LCA

recycling rate of disposed raw material: rate with which disposed equipment 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.

re-use: equipment is used again partially or as a whole potentially involving refurbishing in the EoLT

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

secondary data: quantified value of a unit process or an activity within the product system obtained from sources other than direct measurement at its original source

NOTE: Such sources can include databases (a list of LCA databases (publicly available and licence based) provided by the EU can be found at http://lca.jrc.ec.europa.eu/lcainfohub/databaseList.vm), published literature, national inventories, and other generic sources.

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

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

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

NOTE: This data could be either primary or secondary.

storage time: time which the equipment is stored before and after its use stage

support activity: activities supporting unit processes associated with the function of the Equipment, 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 Equipment: A device, system or object needed to realize the function of support the use of ICT Equipment

EXAMPLE: Equipment for power supply and temperature regulation.

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

the 100/0 method: allocation method that allocates the primary Raw Material Acquisition processes fully to the studied product system, i.e. no recycled Raw Material is assumed as input to the studied life cycle

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, i.e. 100 % recycled Raw Material is assumed as input to the studied life cycle

the 50/50 method: allocation method that allocates the primary Raw Material Acquisition processes equally to the introducer (initial life cycle that introduces the primary Raw Material) and the "depleter" (the last lifecycle in which the Raw Material is not recycled) i.e. the recycling of Raw Materials is allocated equally to the studied life cycle and the product system losing/introducing the material

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 (refer to ISO)

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

3.2 Abbreviations

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

3G	Third generation telecom networks
4G	Fourth generation telecom networks
BGA	Ball Grid Array
BOD	Biochemical Oxygen Demand
BOM	Bill of Materials
BSC	Base Station Control site
CAS	Chemical Abstracts Service
CATV	Cable Access Television
CC	Climate Change
CED	Cumulative Energy Demand
CFC	Chloro Fluoro Carbons
CN	Core Network
COD	Chemical Oxygen Demand
CODEC	COmpression/DECompression
CPE	Customer Premises Equipment
CPU	Central Processing Unit
DALY	Disability Adjusted Life Years
DB	Dichlorobenzene
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
EA	Eutrophication Aquatic
EHW	Environmentally Hazardous Waste
EIO-LCA	Economic Input Output LCA
ELU	Environmental Load Unit
EOL	End Of Life
EoLT	End of Life Treatment
ET	Eutrophication Terrestrial
ETFW	Ecotoxicity Freshwater
FTTH	Fibre To The Home
FWT	Fixed Wireless Terminal
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
HFC	Hydro Fluoro Carbons
HGW	Home Gateway
HLR	Home Location Record
HT	Human Toxicity
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
LED	Light Emitting Devices
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
LTE	Long Term Evolution
LU	Land Use
MGW	Media Gateway
MJ	Megajoule
MSC	Mobile Switching Center
OD	Ozone Depletion
ODP	Ozone Depletion Potential Indicator
OLT	Optical Line Terminal
ONU	Optical Network Unit
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Printed Circuit Boards
PCBA	Printed Circuit Board Assembly
PDA	Personal Digital Assistant
PDH	Plesiochronous Digital Hierarchy
PDP	Plasma Display Panel
PMMA	Polymethyl-Methacrylate
POF	Photochemical Ozone Formation
PWB	Printed Wiring Board
RAN	Radio Access Networks
RBS	Radio Base Station
RDMR	Resource Depletion Mineral Resources
RDW	Resource Depletion Water
RI/PM	Respiratory Inorganics/Particulate Matter
RMD	Natural Resources Depletion Indicator
RNC	Radio Network Controller
SAC	Sn/Ag/Cu alloys
SDH	Synchronous Digital Hierarchy
SGSN	Serving GPRS Support Node
SMS	Short Messaging Service
SMT	Surface Mounting Technology
STB	Set Top Box
STM	Synchronous Transport Module
SW	Software
TOE	Total Oil Equivalent
UE	User Equipment
UPS	Uninterruptible Power Supply
USD	United States Dollar
USGS	United States Geological Survey
WAN	Wide Area Network
WDM	Wavelength Division Multiplexer
WE	Water Eutrophication Indicator
WEEE	Waste Electrical and Electronic Equipment
WLAN	Wireless Local Area Network

4 General Description

This is a clause about compliance and comparisons. First it is recommended to study ISO 14040 [1], Section 4.1.

4.1 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*).

Recommendations and options are summarized in clause 8.

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, but not being able to fulfil all due to data gaps, lack of transparency in data bases and so forth.

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

It is acknowledged that full compliance to the present document may not be possible, especially for *Network* and *Service* level, where some data may be based on already published LCAs, which, especially initially, may not be in accordance with the present document.

The compliance statement contained in the report should disclose and explain the use of such data and why full set of data are not available.

4.2 Comparisons of results

It is important to realise 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 uses:

i) the present document;

ii) the same LCA tool; and

iii) 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 Equipment* LCAs the operational lifetime shall be set equal. Differences in lifetime could only be accepted if they reflect differences in actual characteristics.

5 Methodological framework

5.1 General requirements

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

5.1.1 Life cycle stages

The following life cycle stages (also shown in Figure 2) in the present document apply to *ICT Equipment, Networks* and *Services* and shall be assessed as applicable in LCAs based on the present document:

a) Equipment Raw material acquisition which is composed by:

- Raw material extraction.
- Raw material processing.

b) Production which is composed by:

- ICT Equipment production.
- Support Equipment production.

c) Use which is composed by:

- ICT Equipment Use.
- Support Equipment Use.
- Operator support activities.
- Service Provider support Activities.

d) Equipment End of Life Treatment:

- Re-use.
- ICT specific EoLT.
- Other EoLT.

Transports and energy supplies shall be included in all life cycle stages. It is important that all transports within and between life cycle stages are included in the assessment, especially transports of equipment between production and use stages shall be taken into account. The data collected shall be structured in such a way that transports could be reported transparently as far as possible.

NOTE: The assessment of raw materials acquisition is generally based on generic databases. At this stage such databases often do not report transports transparently.

It is optional to include the construction of plants in which ICT or Support Equipment is manufactured. The life cycle stages are further described in clause 5.2.2.

5.1.2 Handling of software

From the perspective of the present document software shall be considered as well as hardware.

Any *ICT Equipment* or *Network* or *Services* uses both hardware and software which both impacts, e.g. the production and use stages. For the production stage software development impacts the amount of persons involved in the development work and thus impacts the amount of energy used in offices and business travelling associated with the *ICT Equipment* or *Network*, in the same way as hardware development. For the use phase 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 phase but rather to focus on the impact from the *ICT Equipment* or *Network or Service* as such.

For specific software applications, such as a music distribution application, 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 included in the assessment.

This development is either within B1.3 or B1.1.11 depending on where the software is developed.

Due to the uncertainties of allocation it is optional for users of operating systems and other widely spread software (e.g. simulating tools) to consider the embedded impact.

5.1.3 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 equipment, i.e. ICT and Support *Equipment*. The lifetime of a *Network* cannot be defined as a *Network* cannot be defined with one start date and one end date, instead the *Network* is continuously built out, upgraded etc. and the associated lifetime is therefore the lifetimes of the individual nodes. The same is valid for *Services*.

Operating lifetime shall be based on information on actual product use if available (e.g. statistics for similar product systems or information on commercial lifetime) and should model real operating lifetime as closely as possible. If information on actual product system use 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 actual operating lifetime is not available and estimates are needed.

Storage time is not included in operating lifetime.

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

5.2 Goal and Scope definition

During the LCA scoping phase the building blocks of the *ICT Equipment*, *Networks* or *Services* shall be identified.

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:

- Equipment (ICT Equipment and Support Equipment).
- Network (ICT Network).
- Services (ICT Service).

All these product systems use *ICT Equipment* which follows the life cycle stages introduced in clause 5.1 and further described in this clause.

Equipment refers to the different physical products, with associated software, constituting the *Network*. ICT and Support *Equipment* 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 Equipment* 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 Equipment can be identified, e.g. *Network* nodes, End-user *Equipment*, and *Services* such as video conferencing.

5.2.1 Functional unit

5.2.1.1 General

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

An *ICT Equipment*, *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 quantification of the identified functions (performance characteristics) of the *ICT Equipment, Networks* and *Services.* The primary purpose of a functional unit is to provide a *reference* to which the inputs and outputs are related. This *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.

NOTE: 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.

5.2.1.2 ICT equipment

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 Equipment* 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 Equipment use or Total ICT Equipment use per lifetime of ICT Equipment.

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.

5.2.1.3 Networks

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

- 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).

5.2.1.4 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.

5.2.2 System boundaries

5.2.2.1 General

NOTE 1: Section 4.2.3.3 in ISO 14044 [2] applies as well.

The system boundaries define the life cycle stages and processes belonging to the analysed product system, i.e. are required for providing its function as defined by its functional unit.

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 2 shows the system boundary of an LCA of *ICT Equipment*, *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 2 denote generic processes that reoccur several times during these life cycle stages. These processes are further defined in Annex A.

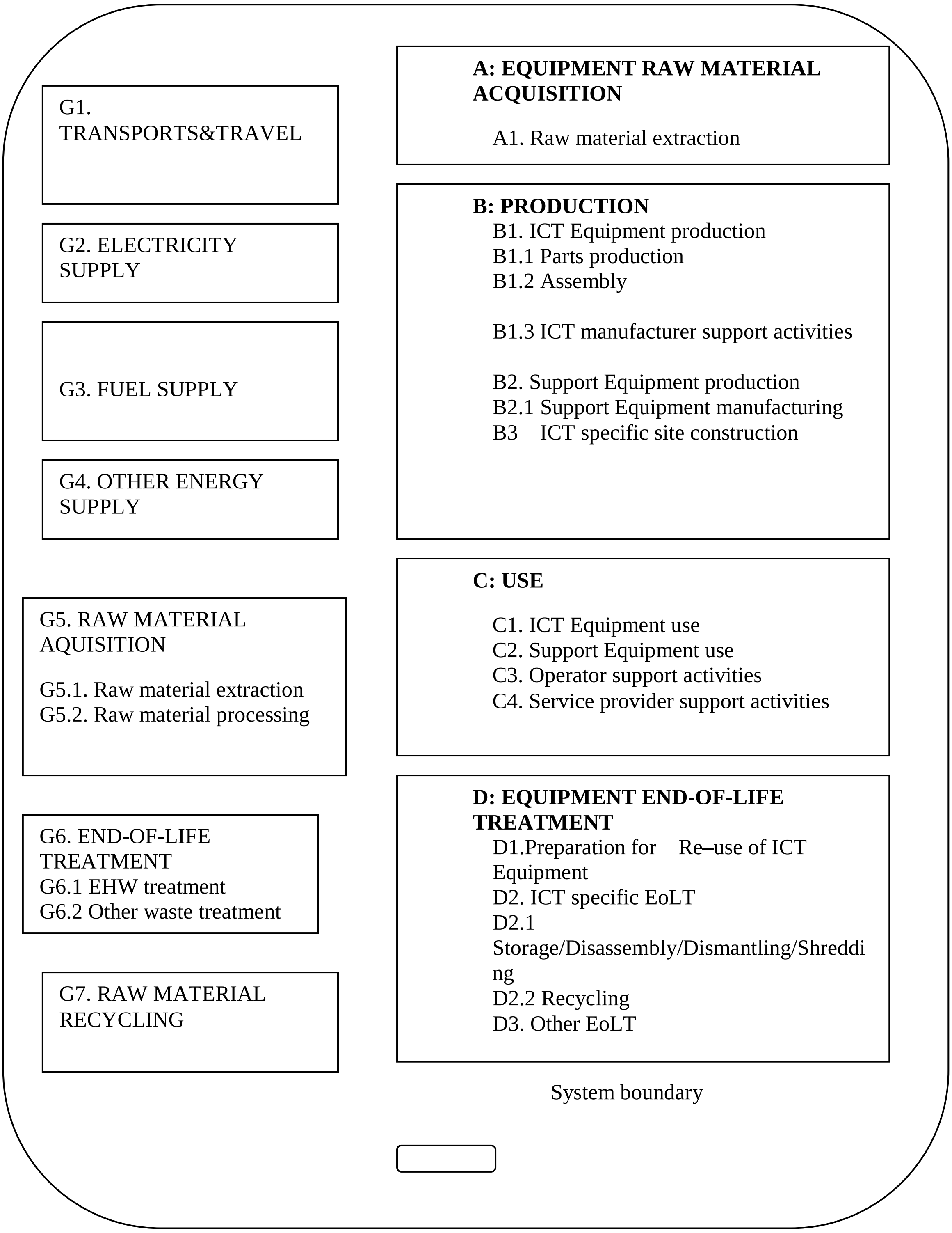


Figure 2: The system boundary of the product system for LCA of ICT Equipment, Networks or Services

Table 1 includes further details the life cycle stages to be included in LCAs of *ICT equipment*, *Networks,* and *Services*. The different life cycle stages are further described in clause 5.2.2.2.2 to 5.2.2.2.5. Mandatory in Table 1 means that the life cycle stage shall be included. However, this also means that even if, e.g. Parts production (B1.1) is mandatory not all Parts given in Annex B (Table B.1) are applicable to all studied *ICT Equipment* product systems. Mandatory life cycle stages or unit processes shall not be cut-off before considered for inclusion by using alternate data.

NOTE 2: Generic data such as EIO-LCA based data.

Table 1: Classification of life cycle stages/unit processes

Tag	Life cycle stage		Unit process	Class		
				ICT Equipment	Network	Service
A	Equipment Raw Material Acquisition					
A1		Raw material extraction		Mandatory	Mandatory	Mandatory
A2		Raw material processing		Mandatory	Mandatory	Mandatory
B	Production					
B1		ICT equipment production				
B1.1			Parts production (for further details refer to Annex F)	Mandatory	Mandatory	Mandatory
B1.2			Assembly (see note 2)	Mandatory	Mandatory	Mandatory
B1.3			ICT manufacturer support activities	Recommended	Recommended	Recommended
B2		Support equipment production				
B2.1			Support Equipment manufacturing	Mandatory if Support Equipment 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)	Recommended if Support Equipment is included in the studied product system	Recommended	Recommended
C	Use					
C1		ICT equipment use		Mandatory	Mandatory	Mandatory
C2		Support equipment use		Mandatory if Support Equipment 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
D	Equipment End of Life Treatment					
D1		Preparation of ICT Equipment for Re-use		Mandatory	Mandatory	Mandatory
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 Equipment and ICT Equipment.
NOTE 2: includes soldering of PCBAs.
NOTE 3: not applicable for End-user equipment.

In Table 1 "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 H.1), showing the detailed content and connection between all life cycle stages, is shown in Annex H. Guidance on how to interpret Table 1 for different stakeholders is given in clause 5.2.4.2.

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 buildings and travelling. For the ICT manufacturer, Operator and Service providers the support activities are indicated explicitly in Table 1 (B1.3, C.3, and C.4) and specified in clauses 5.2.2.2.3 to 4. For all other activities of Table 1 support activities are seen as an integrated part of the activity. It is recommended to include impact from support activities wherever possible. See Annex G.

NOTE 3: It has been proposed 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.

5.2.2.1.1 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 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.3] as a large part of the total work is related to research and development (including software), operation, maintenance, etc.

Any unit process can be modelled as shown in Figure 3. 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 B.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 shall be allocated to the targeted product system in a correct way. For allocation rules please refer to clause 5.3.3.1.3.

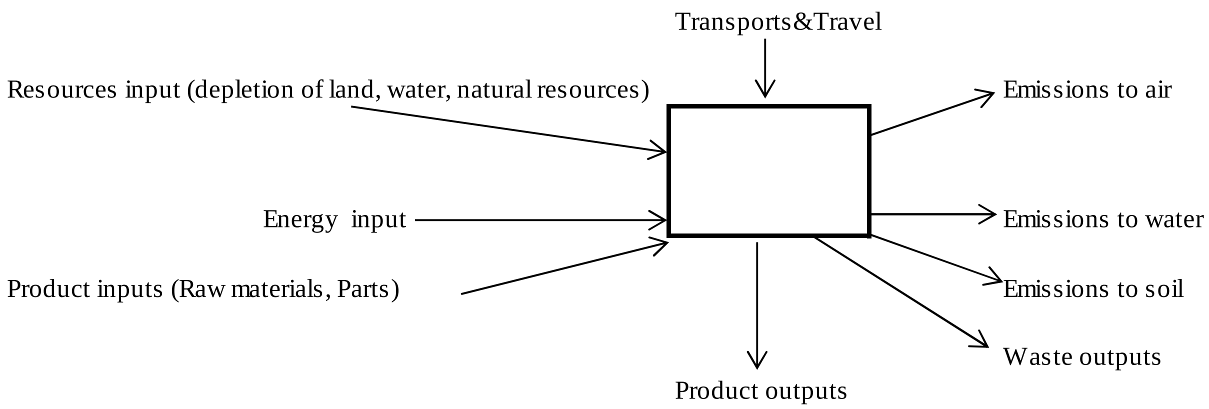


Figure 3: The generic unit process model

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, can involve transports which are then part of the input/output data connected to the unit process.

Emissions (elementary flows)

The following emissions shall be included for ICT:

- Emissions to air
- Emissions to water
- Emissions to ground

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 included for LCAs of ICT:

- Land use (or land depletion)
- Material resource use (or material depletion)
- Energy resource use (or energy resources depletion)
- Fresh water use (or fresh water depletion)

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) in LCAs of *ICT Equipment*, *Networks*, and *Services* can be found in Annex E (Table E.1).

Energy, product and services inputs

Further, the following inputs shall also be included for ICT:

- 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).

Product, water and waste output

Finally, the following flows shall also be included:

- 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 Equipment, Networks* and *Services* can be found in Annex A.

An informative list of typical *ICT Equipment, Support Equipment, and Network Equipment* can be found in clause I.3.

5.2.2.2 ICT equipment

5.2.2.2.1 General

5.2.2.2.2 Equipment Raw materials acquisition

Equipment 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.). *Equipment Raw Material Acquisition* is the life cycle stage for ICT Equipment as defined in Figure 2.

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

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

As shown in Figure 4, Raw Material Extraction and Raw Material Processing are within the system boundary of Raw Materials Acquisition.

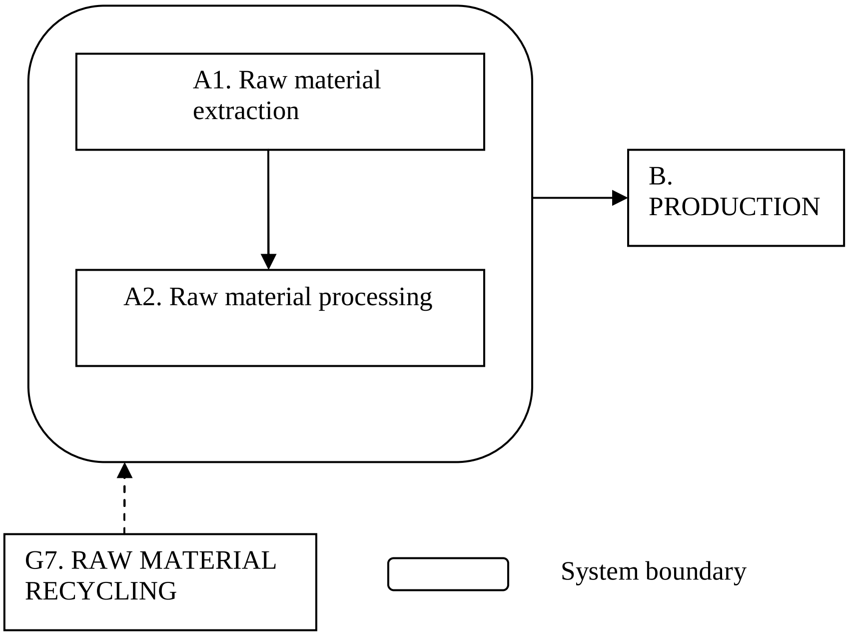


Figure 4: The system boundary of Equipment Raw material acquisition in LCA of ICT equipment

5.2.2.2.3 Production

The Production (B) **starts** with the Parts Production, and **ends** with the transport of ICT Equipment and Support Equipment to Use (C). The system boundary for Production, shown in Figure 5, includes ICT Equipment Production and Support Equipment Production.

NOTE 1: Detailed flow chart figure s of, e.g. transports are decided/provided in each unique LCA project.

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

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

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

As a starting point B2 and B3 are optional for *ICT Equipment* LCAs as the variance in solution is very large 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 equipment can have a significant impact on the use stage for an ICT solution.

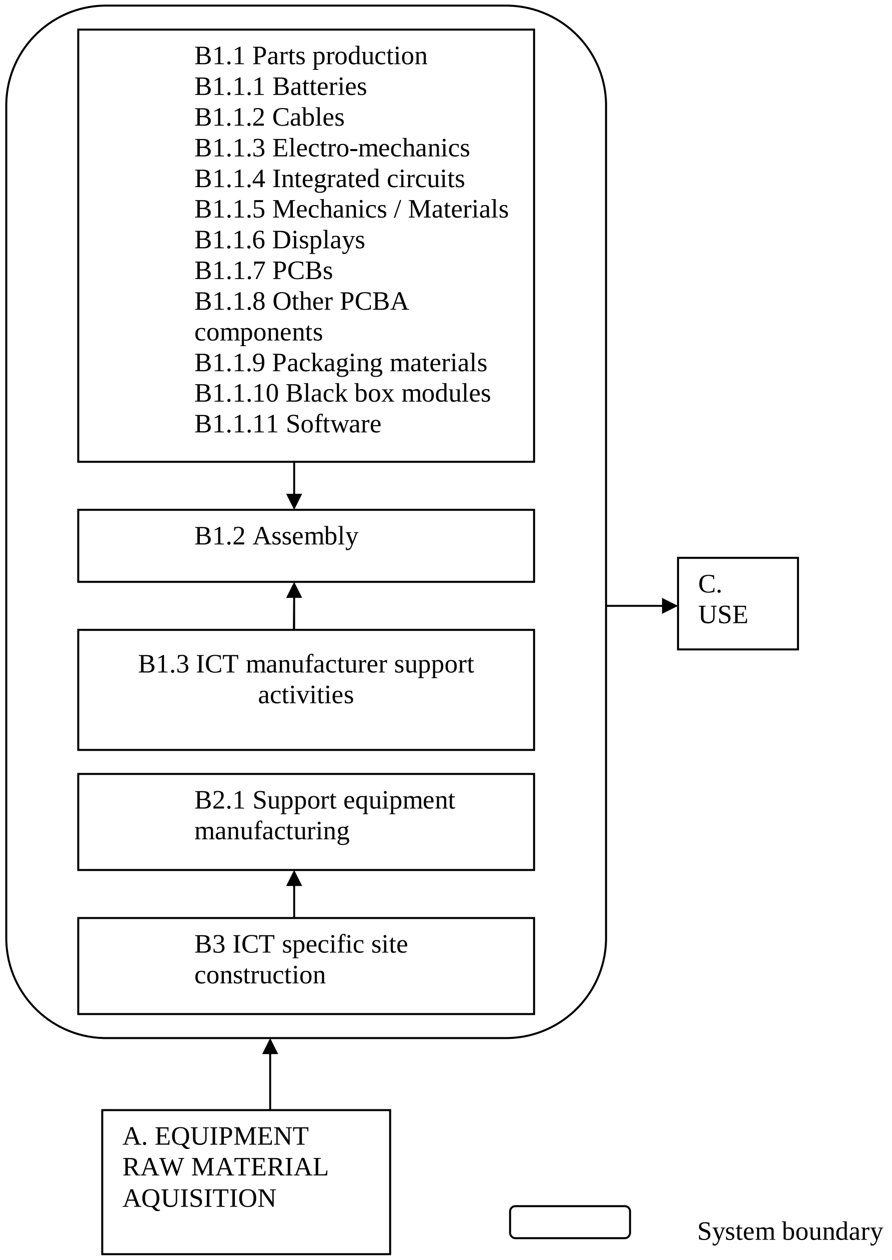


Figure 5: The system boundary of Production in LCA of ICT equipment

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

Annex B lists a mandatory set of **Parts** to be included where applicable to the studied ICT product system, when performing an LCA of ICT Equipment, 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 Equipment* 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 B, 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.

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

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

As stated in Table 1 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 5. Regarding other support activities for Support equipment production and Parts Production, please refer to the general principles in clause 5.2.2.1.

5.2.2.2.4 Use

The Use stage starts with the Installation of ICT Equipment and Support Equipment and ends with the de-installation just before the transport to EoLT. As shown in Figure 6, the use stage includes ICT Equipment Use (C1), Support Equipment Use (C2), Operator activities (C3), and Service provider activities (C4).

(C1) and (C2) consist of energy supply during the operating lifetime of the ICT Equipment.

Operator support activities (C3) which should at least be included are installation and de-installation of ICT Equipment and operation and maintenance of the ICT Equipment and Support Equipment, including associated transports and travel. The maintenance includes replacing, e.g. PCBAs. The Raw Material Acquisition and Production for the additional PCBAs used during the operational lifetime of the ICT Equipment are mandatory. The additional Raw Material Acquisition and Production impacts from spare parts are shown in Raw Material Acquisition and Production and EoLT results. The spare parts management is typically shared between ICT Equipment 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 G.

NOTE: An example of a Service provider support activity is the development of an "app" for smart phones. Another example is development of chairs used in video conference rooms.

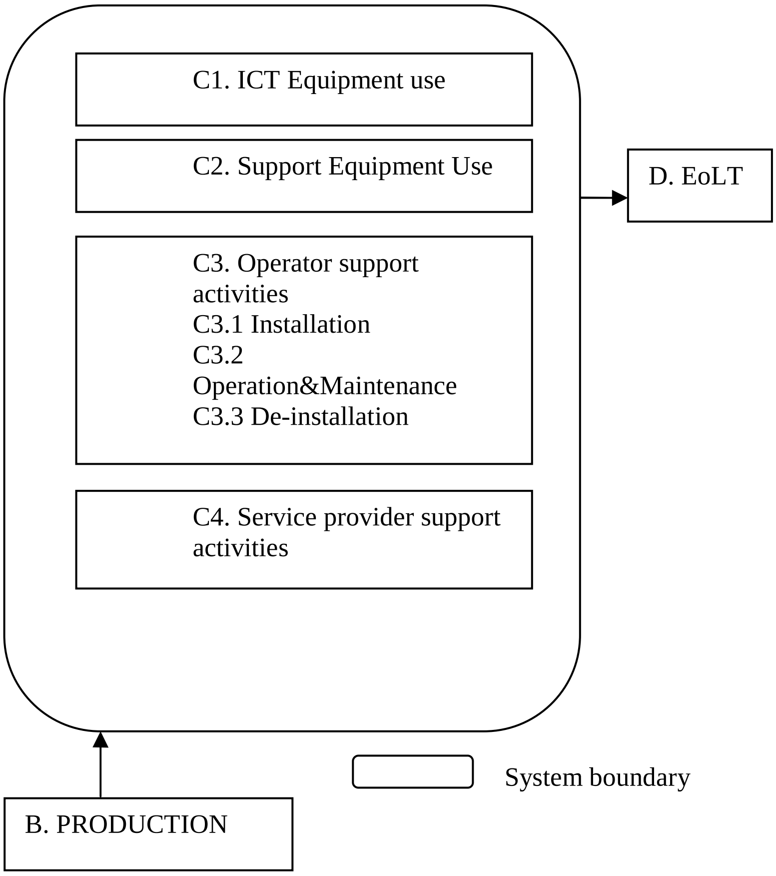


Figure 6: The system boundary of Use in LCA of ICT equipment

5.2.2.2.5 End-of-life treatment (EoLT)

EoLT **starts** with the transport of de-installed *ICT Equipment* and/or *Support Equipment* to Storage/Disassembly/Dismantling/Shredding facilities, and **ends** with the waste treatment of ICT Equipment and Support Equipment.

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

Raw Material Recycling (G7) starts *after* the EoLT.

As shown in Figure 7, *Preparation of ICT Equipment for Re-use of ICT Equipment (D1), ICT specific EoLT (D2) and Other EoLT (D3) are within the mandatory system boundary* for EoLT.

NOTE: Refurbishing and remanufacturing are applications of Re-use.

ICT specific EoLT is applicable to the *ICT Equipment* itself and also applies to ICT based *Support Equipment*.

Other EoLT mainly deals with non-ICT based *Support Equipment*.

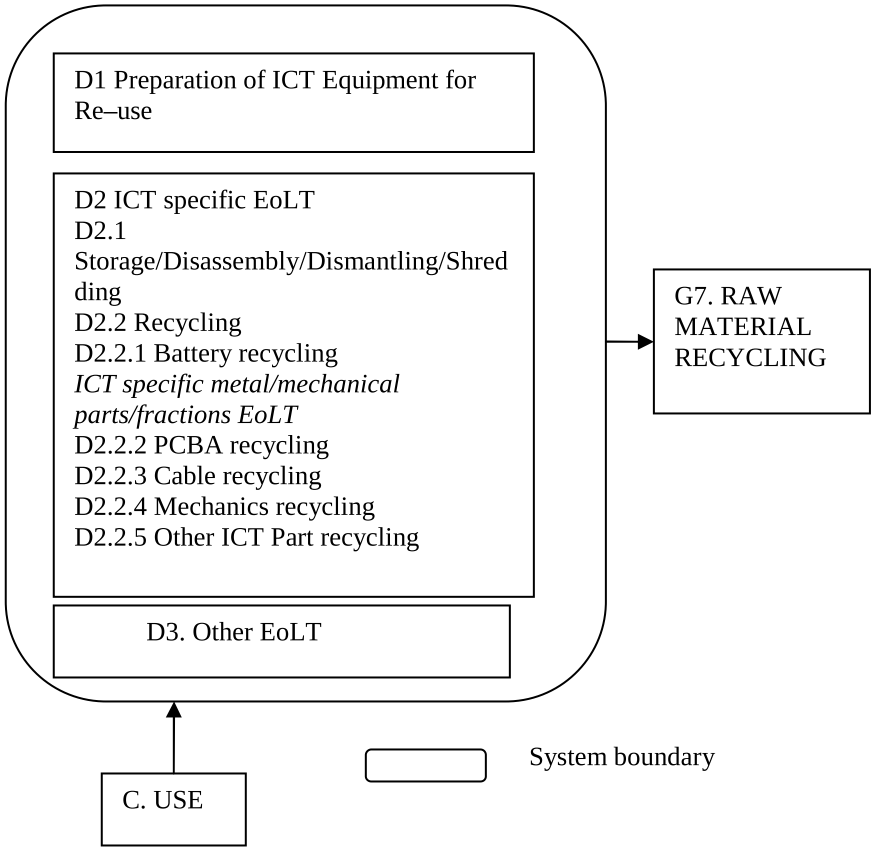


Figure 7: The system boundary of Equipment EoLT in LCA of ICT equipment

The ICT specific EoLT (D2) in LCA of ICT Equipment includes Transport from Use to Storage/Disassembly/Dismantling/Shredding processes (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.) apply to ICT Equipment and Support Equipment, respectively.

Annex C, Table C.1 lists a mandatory set of EoLT processes to be included where applicable when performing an LCA of ICT Equipment which includes the EoLT stage.

5.2.2.3 Networks

A 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 further on to the end-users (represented, e.g. by a telephone or PC). Ultimately the total Network may be studied, taking into account both wireline 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 Network under study applicable types of nodes and infrastructure, as well as amounts of these, shall be defined.

Thus the aggregated impact of a Network usually equals the sum of the impact from the different Equipment constituting the Network. When aggregating results the data for different nodes shall be based on equivalent assumptions/use scenarios, etc.

As the Network operation depends on the software program needed to run its basic function, as outlined in applicable standards, e.g. 3GPP for LTE, the impact from development of such software should be included.

The Network shall be defined in terms of ICT Equipment, Support Equipment 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 Equipment the rules defined for ICT Equipment 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 J shows typical ICT Equipment of which the Network consists.

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

For assessment of Networks, operator activities shall always be included.

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

For examples of Network Equipment refer to Annex J.

Depending on the studied product system and goal of the study, an LCA may cover an entire Network or a part of a Network, e.g. the access network.

5.2.2.4 Services

The operation of a Network could be described as the operation of several services working in parallel, among them the basic primary subscription service allowing transfer of voice and data, but also different applications. Thus, to calculate the impact of a Service, it is necessary to assess the Network, as outlined in previous paragraph and if necessary (i.e. in a multi-service situation) allocate an appropriate amount of this impact to the Service under study. For details on allocations refer to clause 5.3.3.4.

The system boundary requirements defined for Networks apply also to Services but with some additions listed here.

In addition to the use of ICT Equipment and Network, a Service may also have additional impacts associated with the application Software development, use of consumables, sales and logistics infrastructure, associated travels and transports (in addition to those already included for the ICT Equipment and Network) which should also be included. Often these activities are part of the overall service provider activities.

The data centres where the Service is operating shall be included whereas the support activities of the Service provider should be included. 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 number of servers, storage and Network Equipment 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 Equipment.

It is optional to include the data centre infrastructure Production, 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 give a correct level of impact of the Service. For further details refer to clause 5.6.

5.2.3 Cut-off rules

NOTE: Section 4.2.3.3.3 in ISO 14044 [2] applies as well.

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

The cut-off is strongly connected to clause 5.2.2 about System boundaries, as system boundary setting can be seen as a qualitative cut-off. LCA modelling of an ICT Equipment, Network or Service involves Mandatory, Recommended, and Optional life cycle stages/unit processes/activities. Obviously 100 % of the environmental impacts of any studied product system are never known *a priori*. However, the life cycle stages/unit processes/activities of Table 1 together constitute a significant share for typical product systems in ICT LCAs.

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. Moreover, for each criterion the accumulated impacts shall be considered.

The cut-off criteria used within a study shall be clearly understood and described.

The intention of the present document is to include all mandatory activities of Table 1. If these activities are not included such cut-offs shall be clearly motivated. All cut-offs shall be listed and motivated in the final report. See clause 6 for further details.

Activities/processes/flows that have been cut-off shall be included in the sensitivity analysis.

For practical examples on cut-off refer to Annex O.

5.2.4 Data Quality Requirements

5.2.4.1 General

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

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

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

For all data categories the data quality requirements from ISO 14040 [1] and ISO 14044 [2], section 4.2.3.6 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: The level of independence ranges from "verified data from independent source" to "unverified information from enterprise interested in the LCA.

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

5.2.4.2 Specific requirements on data and data sources

In general data age and technology are especially important in LCAs for ICT Equipment, 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, e.g. for allocation between *Services*, as data traffic grows considerably year by year. Older figures therefore tend to give overestimated results for energy use and related emissions per amount of data.

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 following requirements (Table 2) on data quality 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 practitioner needs not collect data from all suppliers but can focus on a representative number of suppliers whose data are extrapolated to represent all similar products.

Moreover, it is acknowledged that practitioners from different parts of the values 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 Equipment 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 Annex O.

Table 2: Applicable data types per life cycle stage/unit processes

Tag	Life cycle stage		Unit process	Type of data		
				Equipment	Network	Service
A	Equipment Raw Material Acquisition					
A1		Raw material extraction		Generic data	Generic data	Generic data
A2		Raw material processing		Generic data	Generic data	Generic data
B	Production					
B1		ICT equipment production				
B1.1			Parts production (for further details refer to Annex B	Specific data	Specific data	Specific data
B1.2			Assembly	Specific data	Specific data	Specific data
B1.3			ICT manufacturer support activities	Specific data	Specific data	Specific data
B2		Support equipment production				
B2.1			Support Equipment manufacturing	Specific data: Amounts, etc. Generic data: processes	Specific data: Amounts, etc. Generic data: processes	Specific data: Amounts, etc. Generic data: processes
B3	ICT specific site construction					
B3.1			ICT specific site construction	Specific data: Amounts, etc. Generic data: processes	Specific data: Amounts, etc. Generic data: processes	Specific data: Amounts, etc. Generic data: processes
C	Use					
C1		ICT equipment use		Specific data	Specific data	Specific data
C2		Support equipment use		Specific data	Specific data	Specific data
C3		Operator support activities		Specific data	Specific data	Specific data
C4		Service provider support activities		Not applicable	Specific data	Specific data
D	Equipment End of Life Treatment					
D1		FFF Preparation for Re–use of ICT Equipment		Specific data	Specific data	Specific data
D2		ICT specific EoLT		Specific data	Specific data	Specific data
D2.1			Storage/Disassembly/Dismantling/ Shredding	Specific data	Specific data	Specific data
D2.2			Recycling	Specific data	Specific data	Specific data
D3		Other EoLT		Generic data	Generic data	Generic data

5.3 Life Cycle Inventory (LCI)

NOTE: ISO 14044 [2], Section 4.3.1 applied as well.

5.3.1 Data collection

5.3.1.1 General

NOTE: ISO 14044 [2], Section 4.3.2 applies as well.

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 shall report for which processes transports/energy supplies have been added separately and for which they are "hidden".

Data shall be collected for all mandatory processes outlined in Table 1.

5.3.1.2 Energy consumption during use stage

The best way to determine the energy consumption is to measure a large number of products in real live operating environments over a long period of time (e.g. a year to capture all aspects of different use behaviour, climate etc.). Many network Equipment are installed in sites with energy meters.

If data from such measurements are not available the second best alternative would be to estimate energy consumption based on available ETSI standards for laboratory measurements of energy consumption, e.g. for Radio Base Stations, TS 102 706 [i.1] applies.

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/ measured energy consumption for certain user behaviour.

For many products (especially end-user equipment), periods of idling and power off are important to model the usage profile and shall be included if applicable.

The LCA practitioner shall use the applicable electricity mix to calculate the potential environmental impact from the use stage more exactly.

NOTE: The electricity mix ought to closely reflect the intended use place for the Equipment.

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

5.3.2 Data calculation

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

Several operational steps are needed for data calculation. These are described in ISO 14044 [2], sections 4.3.3.2 to 4.3.3.4 and 4.3.4 and ILCD Handbook [i.2], Section 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 procedure could be included in larger data sets, whereas other LCA tools/LCI databases provide each procedure separately.

NOTE 2: If possible to derive from the 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 may involve establishing, e.g. mass balances.

5.3.3 Allocation of data

5.3.3.1 General

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

5.3.3.1.1 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).

5.3.3.1.2 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 project/product system life cycle. If no detailed information on organization/operation is available the allocation shall be based on organizational/economic data.

5.3.3.1.3 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 × layer for printed circuit boards, good die area for ICs, weight for other components according to Table B.1). If information regarding physical parameters is insufficient economical allocation may be used.

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

For software design the "facility" is usually an office. In that case the allocation rules in clause 5.3.3.1.2 apply.

5.3.3.1.4 Allocation rules for transports

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

5.3.3.1.5 Allocation rules for recycling

The impacts of Raw Material Recycling (G7) shall 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 rest 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).
- The 100/0 allocation method shall be used for calculating primary Raw Material Acquisition impact.
- The 50/50 allocation method shall 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: US geological survey (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 N).

5.3.3.2 ICT equipment

See clause 5.3.3.1.

5.3.3.3 Network

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

End-user equipment (e.g. PCs, smart phones) which is accessing more than one *Network* (e.g. 3G, WLAN) shall be allocated to these *Networks* based on use time. The assumptions regarding use time for access to different *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 equipment, 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.

5.3.3.4 Services

The following allocation principle of *Network* data to a *Service* shall be used:

- Data for End-users equipment:
  - to be allocated based on active use time of the *Service*.
- 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. E.g. mobile access networks show a large dependency between data traffic and energy consumption and a traffic model that takes data traffic into account shall be used for allocation purposes. However, also in this case the load independent part of the energy consumption can be allocated based on active use time.
- Data for transport equipment:
  - to be allocated based on data traffic.
- Data for data centres and *Service provider* activities:
  - The data centre(s) where the *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.

Note that 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.

5.4 Life Cycle Impact Assessment (LCIA)

NOTE 1: ISO 14044 [2] Section 4.4 and ILCD Handbook [i.2], Sections 6.7 and 8) apply as well.

The Life Cycle Impact Assessment (LCIA) handles the translation of the environmental loadings of the life cycle inventory (LCI) to potential and real environmental impacts.

In the LCA it shall be ensured that the inventory elementary flows (see Annex E) are correctly linked with appropriate LCIA characterization factors (see note 2). The mid-point category Climate change is mandatory.

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

For climate change, the recent global warming characterization factors from the Intergovernmental Panel on Climate Change (IPCC) for each greenhouse gas shall be used as mid-point impact assessment category.

For other impact categories there is no methodological consensus in the LCA community, thus the 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 F.10) and justified.

Table 3 shows examples of impact assessment categories.

NOTE 2: Primary energy usage = Cumulative Energy Demand (CED) and Fresh water usage are to be reported as LCI results appropriately according to Table F.9.

Table 3: Examples of environmental impact categories and indicators (see note)

Mid-point Impact Assessment Categories	Mid-point Category indicator	End-point Impact Assessment Categories	End-point Category indicator	Reference
Climate Change(CC) (mandatory)	Infrared forcing as GWP100 and GWP500	Infectious diseases, Land loss	DALY, Extinction of species, Resource cost	IPCC for mid-point
Ozone Depletion(OD)	UV-B radiation as Ozone Depletion Potential	Plant damage, Skin cancer	Net Primary Production, DALY	ILCD [i.3]
Human Toxicity (HTC), Cancer effects	Concentration at human uptake level as Comparative Toxic Units for humans (CTUh)	Cancer	DALY	[i.3]
Human Toxicity (HTNC), non-cancer effects	Concentration at human uptake level as Comparative Toxic Units for humans (CTUh)	Memory loss	DALY	[i.3]
Respiratory inorganics/Particulate Matter (RI/PM)	Intake fraction for fine particles as ppm	Bronchitis, Asthma attacks	DALY	[i.3]
Ionizing Radiation (IRH), human health	Human exposure efficiency relative to U235 as %	Cancer	DALY	[i.3]
Ionizing Radiation (IRE), ecosystems				
Eutrophication (EA), aquatic	Fraction of nutrients reaching freshwater end compartment (Phosphorous) or marine end compartment (Nitrogen) as PO43-- equivalents	Fish population	Resource cost	[i.3]
Eutrophication (ET), terrestrial	Accumulated Exceedance in kiloequivalents nitrogen per year	Herbivore population	Resource cost, Extinction of species	[i.3]
Photochemical Ozone Formation (POF)	Tropospheric O3 concentration increase as C2H4-equivalents	Asthma, Plant damage	DALY, Net Primary Production	[i.3]

Mid-point Impact Assessment Categories	Mid-point Category indicator	End-point Impact Assessment Categories	End-point Category indicator	Reference
Acidification (A)	Acidification Potential as Accumulated Exceedance in kiloequivalent per year	Plant damage	Net Primary Production	[i.3]
Ecotoxicity (ETFW), freshwater	Concentration at aquatic ecosystem species uptake level as Comparative Toxic Units for ecosystems (CTUe)	Aquatic ecosystem population	Extinction of species	[i.3]
Land use (LU)	Soil Organic Matter as the amount and quality deficit of land occupied or transformed	Land loss	Extinction of species, Resource cost	[i.3]
Resource Depletion (RDW), Water	Water amount as Water use related to local scarcity of water	User cost	Resource cost	[i.3]
Resource Depletion (RDMR), mineral, fossil, and renewable	Resource amount as scarcity	User cost	Resource cost	[i.3]
NOTE: The mid-point impact assessment categories are suggested by the ILCD [i.3].				

5.5 Life Cycle Interpretation

NOTE: ISO 14044 [2], Section 4.5 applies as well.

5.5.1 General

In the life cycle interpretation, the results of the LCA are evaluated in order to answer questions raised in the goal definition (clause 5.2). 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 Equipment, 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.

5.5.2 Uncertainty

The uncertainty of the results of an LCA shall be assessed in accordance with ISO 14044 [2]: to the extent needed to understand the results.

Also the sources of uncertainty and methodological choices made shall be assessed and disclosed.

For more information regarding uncertainty categories and important uncertainty sources for the different life cycle phases of ICT products, networks and services, refer to Annex K.

For information regarding opportunities and limitations in the use of LCA for ICT products, networks and services refer to Annex L.

5.5.3 Sensitivity analysis

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], section 4.5.5.3.

5.6 Comparative LCA between ICT and reference product systems

To be able to quantify the net environmental impact when introducing an ICT based Service the environmental impact of both the Service itself and of the reference product system shall be assessed from a life cycle perspective. 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.

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.

To make sure that the comparative assessment is giving a reliable result the full life cycle of both systems shall always be included. Cut-off is only allowed if some processes are identical between the systems or are found negligible when applying the cut-off rules of the present document.

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 shall mimic each other as far as possible and the 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 phase 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.

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 report.

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.

A schematic illustration of a comparative assessment is shown in Figure 8. The figure indicates that the reference system and the ICT based system are assessed separately and then compared.

The assessment of the ICT based system shall be performed in accordance with the present document.

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.

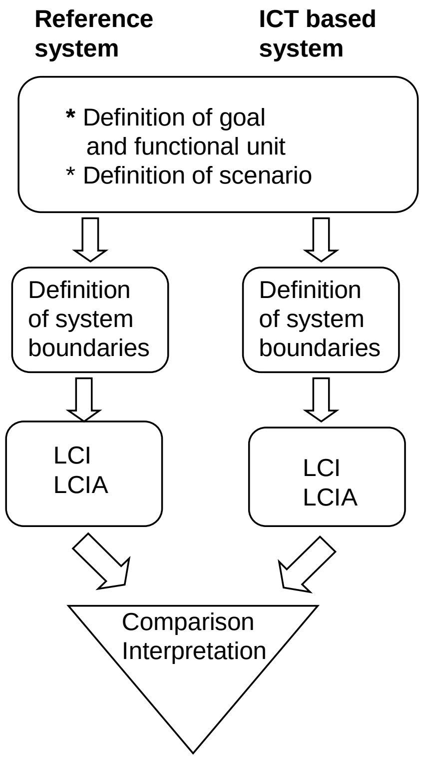


Figure 8: Calculation procedure for the comparative assessment

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.

6 Reporting

6.1 General

The reporting of ICT product systems shall fulfil the reporting rules as defined by ISO 14040 [1] and ISO 14044 [2].

In addition the rules outlined in this clause and what is stated in Annex F shall be followed for reporting of studies claiming compliance with the present document.

The report 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 exception of transparently listed and justified requirements (*partial compliance*).

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 report based on the scope and purpose of the LCA.

For each product system (including *ICT Equipment*, *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. specific/generic) shall be clearly stated, and deviations towards Table 2 shall be motivated.

For each product system (including *ICT Equipment*, *Network* and *Service*) an additional graph shall be presented whenever optional activities in Table 1 have been included. I.e. one graph is presented with the mandatory activities/processes and with the optional activities for transport reporting.

6.2 ICT equipment

6.2.1 Total result

For each impact category studied, diagrams *corresponding to* Figures 9a and 9b shall be reported for the corresponding category indicator result. It is allowed to present *Raw Material Acquisition*, *Production,* and *End-of-life treatment* together should there be LCA tools/LCI databases limitations preventing a split between these life cycle stages. Due to the importance of operating lifetime to results, information regarding this shall always be present in the graph, together with some other basic modelling statements including total result for the indicator, LCA study year operating lifetime, etc. as shown below. Figure9a shows the results corresponding to the Mandatory section of Table 1 whereas Figure 9b shows the results for the Mandatory/Recommended/Optional section of Table 1.

NOTE: Other kinds of diagrams allowed as long as identical content as Figures 9a and 9b.

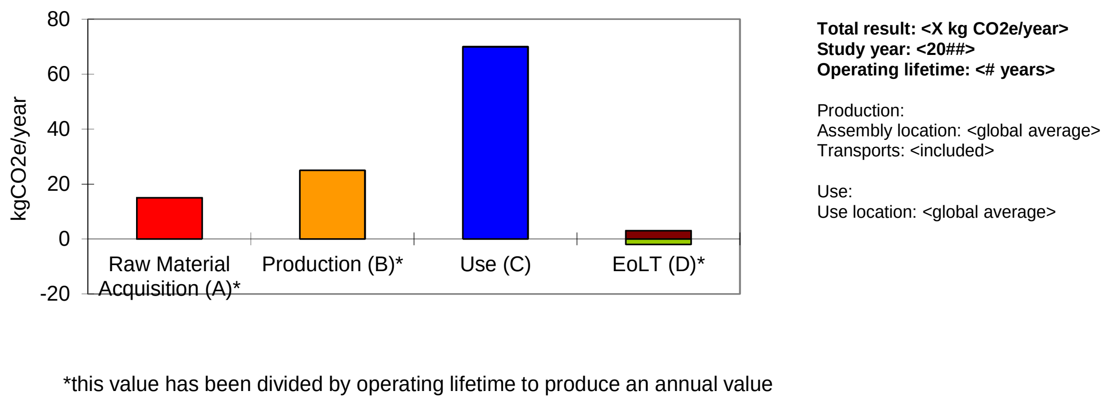


Figure 9a: Environmental impact category indicator result diagram example for Mandatory processes/activities (diagram for Global Warming Potential (GWP100) (CO2e)

Figure 9a 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.

Figure 9b shall be presented whenever optional activities/processes from Table 1 have been included in the studied product system.

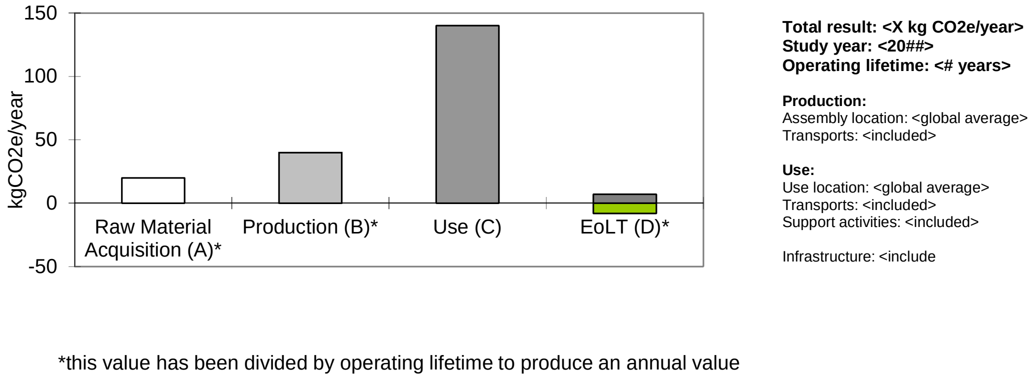


Figure 9b: Environmental impact category indicator result diagram example for Mandatory/Recommended/Optional processes/activities (diagram for Global Warming Potential (GWP100) (CO2e)

For transports, the total result including all transports throughout the life cycle (Annex F, Table F.4) shall be stated in the immediate proximity of the diagram (Figures 9a and 9b). If used data sets do not report transports separately any missing transport shall be listed and motivated.

Optionally, a graph showing transports between sub-unit processes within each life cycle stage should also be reported (Figure 10). Such transparency is encouraged.

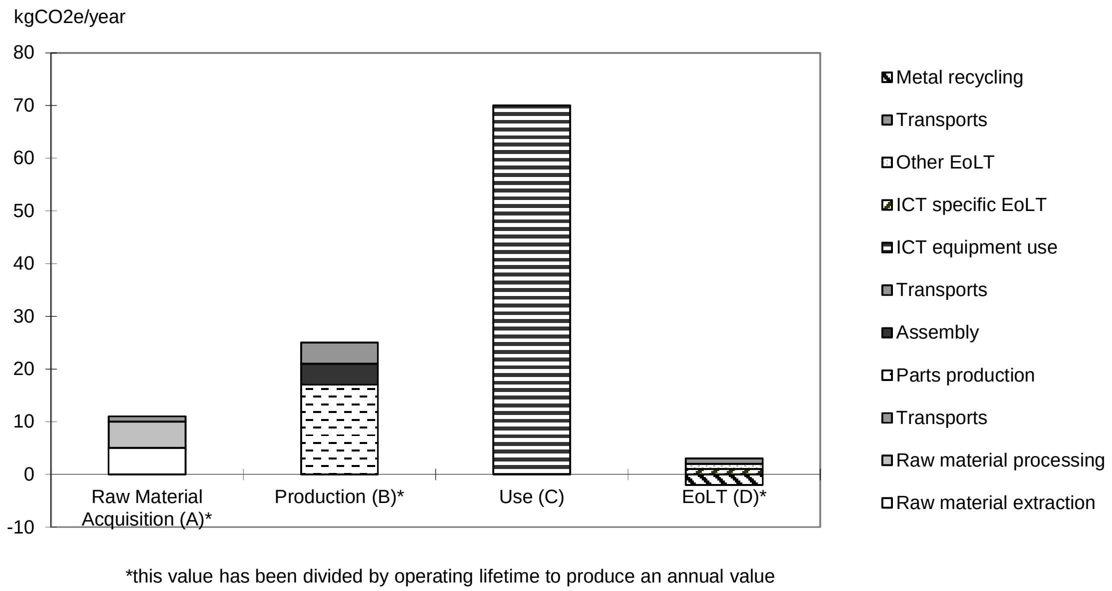


Figure 10: Environmental impact category indicator result: distribution between sub-unit processes within each life cycle stage

Figure 10 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.

Additionally a graph summarizing distribution of environmental impact category indicators between life cycle stages according to Figure 11 shall also be presented together with absolute figures as shown in the Annex F, Table F.10.

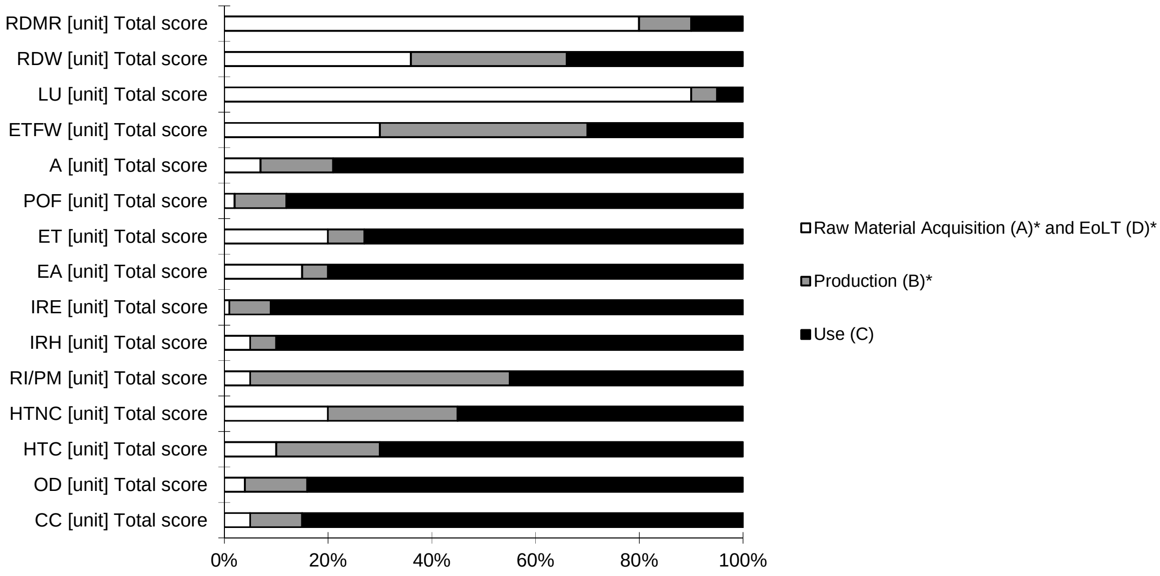


Figure 11: Environmental impact category indicators overview for ICT Equipment

Figure 11 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.

6.2.2 System boundaries

6.2.2.1 Life cycle stages, unit processes and generic processes

Any deviation to Table 1 and clause 5.2.2 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. Especially for transports, lack of transparent data are common for many unit processes, which shall be considered for the reporting.

Additionally, inclusion of generic processes shall be clearly stated in a flow diagram combined with the main life cycle stages/unit processes.

Generic processes deviations shall be reported according to Annex F, Table F.3. For appropriate reporting format refer to Annex A, Table A.1.

For reporting of transports and travel refer to Annex F, Table F.4. State if data are missing or is included in, e.g. support activity data but could not be reported separately.

6.2.2.3 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 included.

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

For appropriate reporting format refer to Annex F, Table F.5.

6.2.2.4 Production

Parts production

Compliance to Annex B, Table B.1 shall be reported according to below and any deviation shall be described and motivated.

For appropriate reporting format refer to Annex F, Table F.6.

6.2.2.5 Use

ICT equipment use

The basis for the energy consumption figures for the ICT equipment use stage shall be reported together with the annual value of the energy consumption.

For many products (especially end-user equipment), periods off idling and power off are important to model the usage profile. It is therefore mandatory to transparently report distribution over time for different usage modes including power off and idle and the basis for those.

For appropriate reporting format refer to Annex F, Table F.7.

Support equipment use

The basis for the energy consumption figures for the support equipment use shall be transparently described and motivated.

For appropriate reporting format refer to Annex F, Table F.7.

6.2.2.6 EoLT

If EoLT is included any deviations towards Annex C shall be transparently reported and motivated.

For appropriate reporting format refer to Annex F, Table F.8.

6.2.3 LCI results

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

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

Additionally, results for elementary flows according to Annex E, Table E.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 Annex F, Table F.9.

6.3 Network

6.3.1 Total result

For each environmental impact category studied, a diagram corresponding to Figure 12 shall be reported for the corresponding category indicator result. Operating lifetime is important also for *Networks*, but is associated with the lifetime of the different nodes, which shall be reported together in accordance with Annex F, Table F.11 which also describes the studied *Network*.

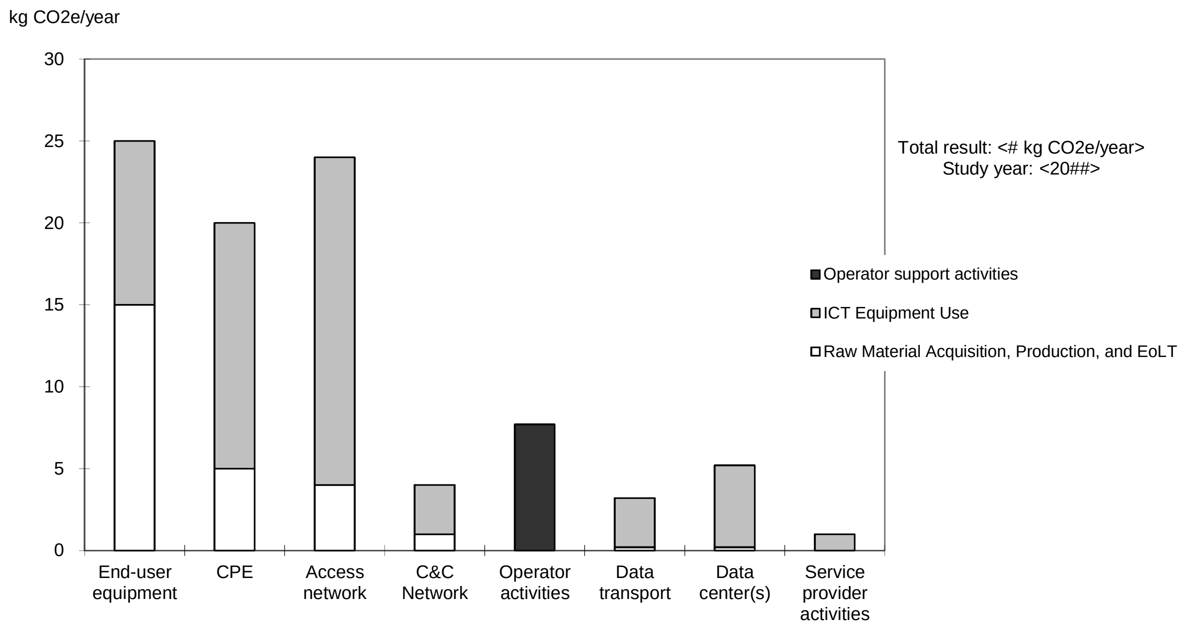


Figure 12: Environmental impact category indicator result diagram example for Network (diagram for Global Warming Potential (GWP100) (CO_2e)

Figure 12 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.

Figure 12 shows an example of Network LCA with a wide scope and it is not applicable to all studied product systems.

Optionally, a graph showing distribution between sub-activities within each life cycle stage could also be reported in the same way as for ICT equipment (see previous clause).

Additionally a graph summarizing distribution of environmental impact category indicators between life cycle stages according to Figure 13 shall also be presented together with absolute figures as shown in the Table F.10 in Annex F.

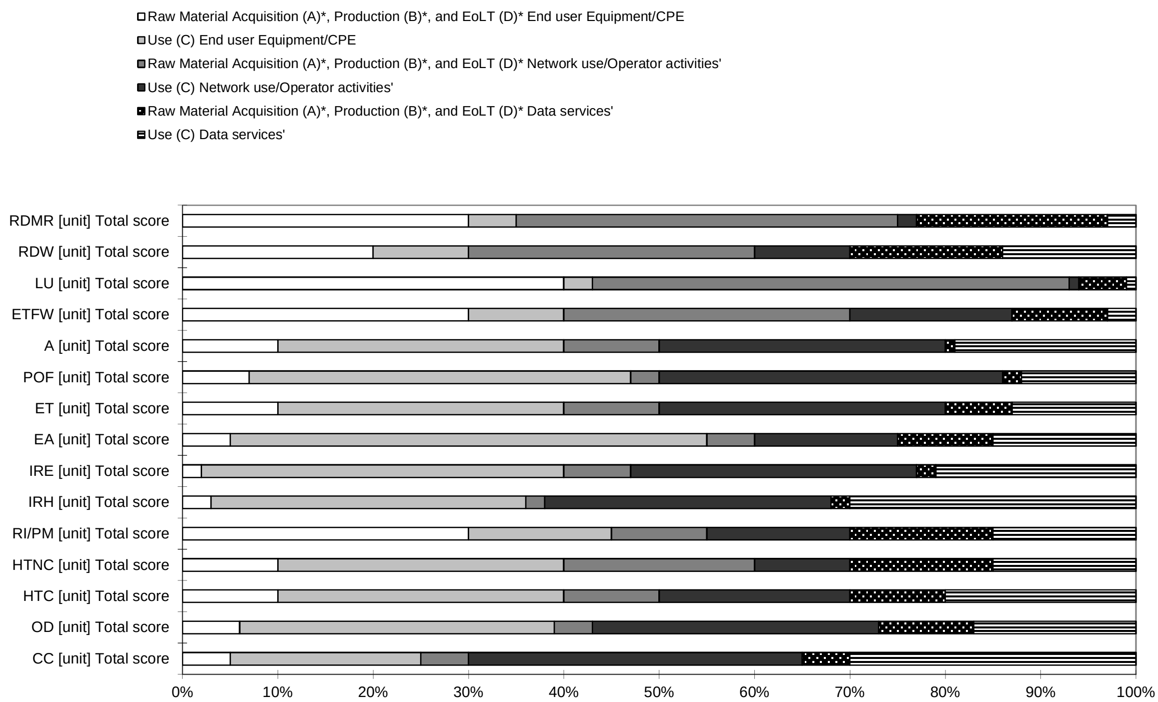


Figure 13: Environmental impact category indicators overview for Networks

Figure 13 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.

For reporting of Network energy consumption refers to Table F.12 in Annex F.

6.4 Services

6.4.1 Total result

For each impact category studied, a diagram corresponding to Figures 14a or 14b shall be reported for the corresponding category indicator result. Operating lifetime is important also for *Services*, but it is associated with the lifetime of the different nodes, which shall be reported together in accordance with Table F.11 in Annex F which also describes the studied Network(s).

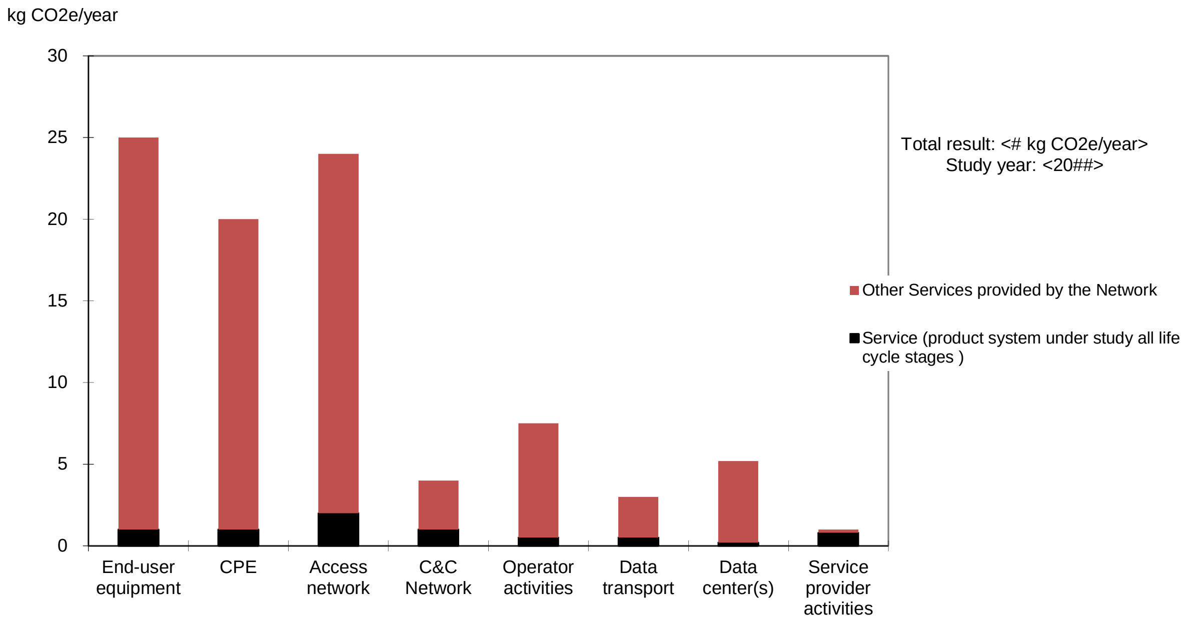


Figure 14a: Environmental impact category indicator result diagram example for Services (diagram for Global Warming Potential (GWP100) (CO2e)

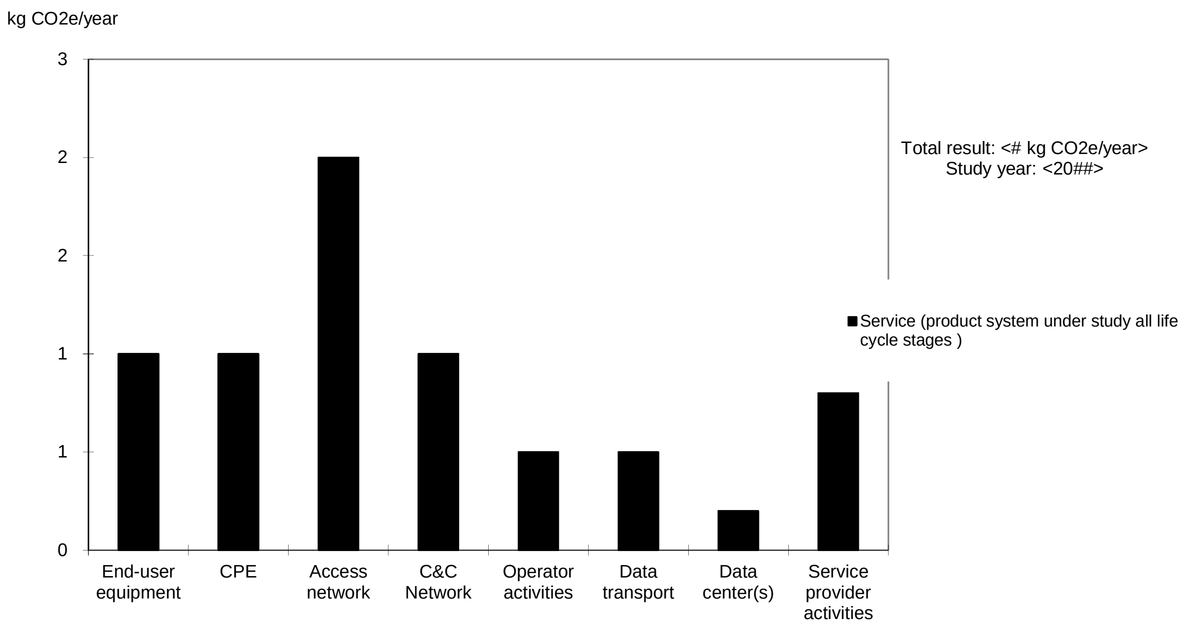


Figure 14b: Environmental impact category indicator result diagram example for Services (diagram for Global Warming Potential (GWP100) (CO2e)

Figures 14a and 14b should be used alternatively depending on the scope of the assessment, 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.

Allocation of *Network* data to the *Service* shall be reported according to Table F.13 in Annex F.

Additionally a graph summarizing distribution of impact category indicators between life cycle stages for the Service product system under study according to Figure 15 shall also be presented together with absolute figures as shown in the Table F.10 in Annex F.

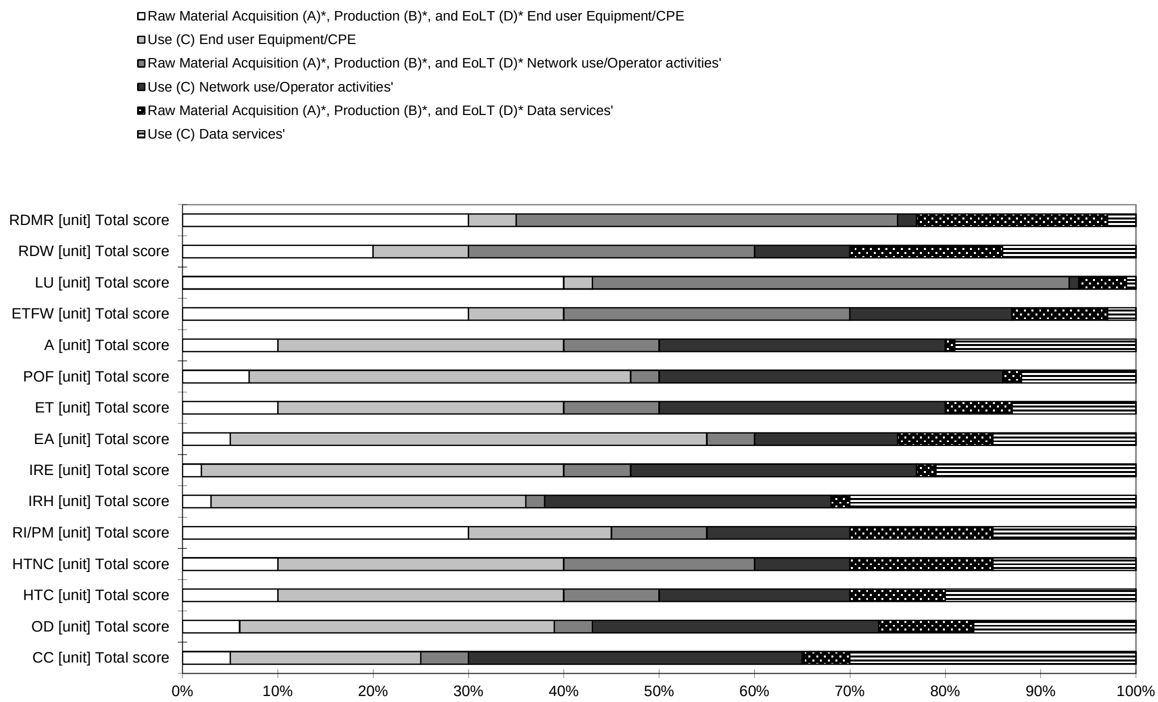


Figure 15: Environmental impact category indicators examples overview for Services

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.

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

7 Critical review

Any critical review shall be performed according to the requirements in ISO 14040 [1] and ISO 14044 [2] and in the present document.

Annex A (normative): Generic processes

Table A.1 defines the generic processes (G1 to G7) to be included if applicable in LCAs for *ICT Equipment*, *Networks*, and *Services*, as well as examples of categories and examples of unit processes to be included.

Table A.1: Generic processes for LCA of ICT equipment

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) Optional Vehicle production Infrastructure production	ton×km, kg×km, Cton×km	Chargeable weight = Cton×km (function that also considers volume or density)
G2. Electricity	National, regional and producer electricity mixes	Mandatory: Fuel supply chain(see note), Direct emissions (during electricity production) Optional: power plant production, dam production, the grid production, nuclear waste treatment	kWh	This is not applicable to local production of electricity
G3. Fuels	Oil Diesel Petrol Jet-fuel LPG LNG Coal Gas	Mandatory: Fuel supply chain (see note)	mass, volume, 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	Electricity is also a energy source or district heating/cooling production
G5. Raw material acquisition	See Annex D	Mandatory: Extraction Processing	mass, volume	
G6. End-of-life treatment	See Annex C			
G7. Raw material recycling	Metal recycling	Mandatory: Smelting Refining		Other material shall be considered
NOTE: Extraction and Production Distribution (transports).				

Annex B (normative): Part types and Assembly unit processes

Table B.1 lists parts and Assembly unit processes which shall be taken into account (if applicable to the LCA goal and scope and the studied product system) when performing an LCA of ICT equipment, as well as the corresponding categories and unit processes. The list is to be regarded as a mandatory list and more parts/part categories/unit processes may be included.

Table B.1: Mandatory set of parts and Assembly unit processes for LCA of ICT equipment

Part/Assembly	Part/Assembly categories	unit processes (for each Part/assembly category)	Product flow unit	Important issues which influence LCI data
B1.1.1 Batteries	Lead batteries Lithium batteries Nickel-Cadmium batteries	Raw Material Acquisition, Battery cell assembly (see note 1), Battery module (pack) assembly (see note 2)	Piece, energy content, mass	Size
B1.1.2 Cables	Coaxial cables Fibre cables Power cables Network/signal cables *Connectors*	Raw Material Acquisition, Cable final assembly	Piece, mass	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	Piece, mass	
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. Front-end: good die area [cm2], Back-end: piece package type (see note 3) Transistors and diodes: Piece, mass, or as for ICs for front-end and back-end	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	Piece, mass	
B1.1.6 Displays	PDP LCD (see note 4) LED	Raw Materials Acquisition Raw Materials Acquisition for special display panel materials, Display module assembly, Display panel assembly	Piece, mass, active area	Yield Business activities, Factory and machinery

Part/Assembly	Part/Assembly categories	unit processes (for each Part/assembly category)	Product flow unit	Important issues which influence LCI data
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	Piece, mass, $cm^2 \times layer$	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	Piece, mass	
B1.1.9 Packaging materials	Paper Cardboard Plastics Wood Steel	Raw Material Acquisition	Mass, volume (see note 5)	Lifetime, Re-use, energy recovery
B1.1.10 Black box modules	Modules bought by ICT equipment producer as complete products (e.g. cameras, modules, memories, printer cartridges)	"Cradle-to-gate" LCA from supplier (see note 6)	Piece, mass	Size, mass, technology
B1.1.11 Software module	Software	**Development**: e.g. daily way to work for programmer, business trips for programmer, electricity usage of ICT equipment 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: A BGA289 package. Good die area 0,166 cm^2. Environmental Load per BGA289 = ELU/good die area in cm^2 × 0,166 + ELU/piece BGA package type back-end process. Example 2: A "stacked chip" package. Total Good die area 12 cm^2. Environmental Load (ELU) per "stacked chip" package = ELU/good die area in cm^2 × 12 + ELU/piece "stacked chip" package type back-end process.

NOTE 4: Example: ELU for an LCD Display in a mobile phone, active area 33 cm^2 = ELU/active area display module in cm2 (mobile phone displays) × 33 cm2 + ELU/piece display panel (mobile phone display panels) × 1 piece.

NOTE 5: Relates to transport

NOTE 6: Operators, e.g. can use Black box module LCAs for ICT Equipment if the LCAs are compliant with the present document.

Annex C (normative): EoLT processes

Table C.1 defines the different generic and specific EoLT processes to be included (if applicable to the goal and scope and studied product system) in LCAs for ICT equipment as well as mandatory process categories and mandatory corresponding EoLT process unit processes. The list is to be regarded as a short 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.

Table C.1: EoLT processes for LCA of ICT equipment

	Process categories	EoLT process unit processes (for each category)	Product flow unit	Important issues
G6. End of Life Treatment				
G6.1 EHW treatment	EHW (destruction and energy recovery) Special EHW landfill	In general: Recovery/treatment	mass, (energy content)	
G6.2 Other Waste treatment	Diverse recycling Energy recovery (e.g. incineration, see note) Landfill	In general: Recycling/recovery/treatment	mass, (energy content)	
D. EoLT	D1. Preparation for Re-use of ICT Equipment 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	
NOTE: Energy recovery of incineration processes is optional				

Annex D (normative): List of Raw materials

Table D.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 Equipment, if applicable to the studied ICT product system.

Table D.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 add additives. Therefore each material name in Table D.1 refers to a *group* of Raw Materials and not specific CAS (Chemical Abstracts Service) code materials.

These Raw Materials *groups* are either part of the material content of the ICT Equipment/Support Equipment or used as ancillary materials throughout the life cycle.

Table D.1: cradle-to-gate groups of raw material to be included in LCA of ICT Equipment

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	Gold
H2O2	Lead
HydroCloric Acid (HCl)	Lithium
FeCl3	Magnesium
IsoPropyleneAlcohol	Mercury
Ethylene glycol	Nickel
HydroFluoric acid	Palladium
H3PO4	Platinum
HNO3	Silicon
NaOH	Silver
…	Solder - SAC (tin silver copper)
…	Solder - Sn/Pb
Fuels	Solder - SnZn
Heating oil	Steel - Cr3+ plated
Bunker oil / ship diesel	Steel - powder coated
Diesel	Steel - zinc plated
Petrol	Steel - stainless steel
Jet fuel	Tin
LPG	Zinc
LNG	Hard metal (W-Co)
"Biofuels"	
…	
…	
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	
Styrene acrylonitrile (SAN)	**Additives and others**
PA (Nylone)	Paper additives
PTFE (Teflone)	Plastic additives
PMMA	High purity grades of materials/chemicals and gases
…	Cooling media, fire extinguisher media (High GWPs/ODPs)

Annex E (normative): List of elementary flows in LCA of ICT

Table E.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 E.1 shall be used in the report.

The unit is mass (unless stated otherwise): g, kg, and ton.

Table E.1: Elementary flows in LCAs of ICT

Inventory		
Substance	**Measure unit**	**Contribution to Mid-point Impact Assessment Category(ies) (Table 3, clause 5.4)**
Aluminium (resource)	kg	*RDMR, LU*
Ammonia (to air)	kg	*A*
As (to air)	kg	*HTC, ETFW*
As (to water)	kg	*HTC, ETFW*
As (to ground)	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 ground)	kg	*HTC, ETFW*
Cr (to water)	kg	*HTC, ETFW*
Cr (to ground)	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*
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*

Inventory		
Substance	**Measure unit**	**Contribution to Mid-point Impact Assessment Category(ies) (Table 3, clause 5.4)**
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 ground)	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 ground)	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 ground)	kg	*HTNC, HTC, ETFW*
Mineral (waste)	kg	*LU*
Mo (to water)	kg	*HTNC, ETFW*
Mo (to ground)	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 ground)	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 ground)	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 ground)	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 ground)	kg	*HTNC, ETFW*
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*

Inventory		
Substance	**Measure unit**	**Contribution to Mid-point Impact Assessment Category(ies) (Table 3, clause 5.4)**
TCDDe ("Dioxin" equivalents) (to air)	kg	*HTC*
Tin (resource)	kg	*RDMR*
Titanium (to water)	kg	*HTNC, ETFW*
Titanium (to ground)	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)	m3	*RDW*
Water, well, in ground (resource)	m3	*RDW*
Water, unspecified, natural origin (resource)	m3	*RDW*
Zinc (to water)	kg	*HTNC, ETFW*
Zinc (resource)	kg	*RDMR*
Zinc (to ground)	kg	*HTNC, ETFW*
Zinc (to air)	kg	*HTNC, ETFW*

Annex F (normative): Reporting formats

This annex contains tables that shall be used to report the result of the assessment.

Table F.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 TS103199			*<put version of the specification>*
Software 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			
Define system boundary			
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 for environmental footprint			
Data quality			
Handling multi functionality			
Data gap			
Environmental impact assessment			
Assessment results			
Normalization			
Weighting			
Interpretation			
Identify hot spot			
Conclusion			

Table F.2: Reporting format for included life cycle stages, activities and generic processes

Tag	Life cycle stage	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	Equipment Raw Material Acquisition							
A1	Raw material extraction							
A2	Raw material processing							
B	Production							
B1	ICT equipment production							
B1.1		Parts production (for further details refer to Annex B)						
B1.2		Assembly						
B1.3		ICT manufacturer support activities						
B2	Support equipment production							
B2.1		Support Equipment manufacturing*						
B3	ICT specific Site construction							
C	Use							
C1	ICT equipment use							
C2	Support equipment use							
C3	Operator activities							
C4	Service provider activities							
D	Equipment End of Life Treatment							
D1	Preparation of ICT Equipment for Re-use							
D2	ICT specific EoLT							
D2.1		Storage/Disassembly/Dismantling/ Shredding						
D2.2		Recycling						
D3	Other EoLT							

Table F.3: Reporting format for Generic processes for LCA of ICT equipment

Generic process	Generic process categories included	Unit processes included (for each generic process category)	Important issues
G1. Transports and Travel			
G2. Electricity			
G3. Fuels			
G4. Other energy			
G5. Raw material acquisition			
G6. End-of-life treatment			
G7. Raw material recycling			

Table F.4: Reporting format for transports/travel

Mode	**CO_2 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 travels**	
		Transport work (see note 2) {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton*km}	GWP 100 {kg CO_2e}	Transport work {ton×km}	GWP 100 {kg CO_2e}	Transport distance (see note 3) {km}	GWP100 {kg CO_2e}
Air													
Other													

NOTE 1: The final transport of ICT Equipment 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 weight, etc.
NOTE 3: Average in terms of distance, transport mode, load factor, chargeable weight, etc.
NOTE 4: This includes direct fuel consumption and also fuel supply chain.

Table F.5: Reporting format for raw materials

	Total input (g, kg, ton)	Content in product (%) (see note 1)	Recycled raw material used (see note 2) (%)	Recycling of total input (see note3) (%)	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.					

For a full list of materials that could optionally be reported in Table F.5, refer to Annex D.

Table F.6: Reporting format for parts production

	Part categories included	Part Unit processes included	Handling of special issues
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			

Table F.7: Reporting format for use stage energy consumption

	Energy consumption {kWh/year}	Source {long term average/standardized measurement/ modelled	Motivation/ comment
ICT equipment			
Support equipment			

Table F.8: Reporting format for EoLT

	Process categories included	Process Unit processes included	Handling of special issues
EHW treatment			
Other Waste treatment			

Table F.9: Reporting format for LCI results

	TOTAL	Raw materials acquisition	Production	Use	EoLT
Primary energy use (see note)					
Total electricity use					
Land use					
Fresh water use					
LCI data 1(optional)					
LCI data …(optional)					
LCI data n (optional)					
NOTE: Primary energy usage is appropriate to express as Cumulative Energy Demand.					

Table F.10: Impact category indicators

Mid-point category indicator	Impact category indicator value	LCIA methodology reference
Global warming potential	# kg CO_2e	IPCC
Etc.		

Table F.11: Reporting format for Network description

	List of Included ICT Equipment	List of Included infrastructure	Quantity [unit] (see note)	Operating Lifetime [year]
End-user equipment and CPE				
End-user equipment			# [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 analyzed.				

Table F.12: Reporting format for Network Energy consumption

	ICT equipment energy consumption	Support equipment energy consumption	Source {long term average/ standardized measurement/ modelled}
End-user equipment and CPE			
End-user equipment			
CPE			
Operator Network and activities			
Access network			
Control and core network			
Operator activities			
Data Services			
Data transport			
Data centre(s)			
Service provider(s) activities			

Table F.13: Reporting format for Service hardware allocation

End-user equipment and CPE	Allocation method	Allocation of use stage [%]	Allocation of all non–use stages [%]
End-user equipment and CPE			
End–user equipment			
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 G (normative): Support activities

All activities during the life cycle of an ICT equipment, 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 equipment 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 Figures 2, 5 and 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 H (informative): Life cycle stages overview

An overview figure showing the contents and connections between all life cycle stages are shown below in Figure H.1.

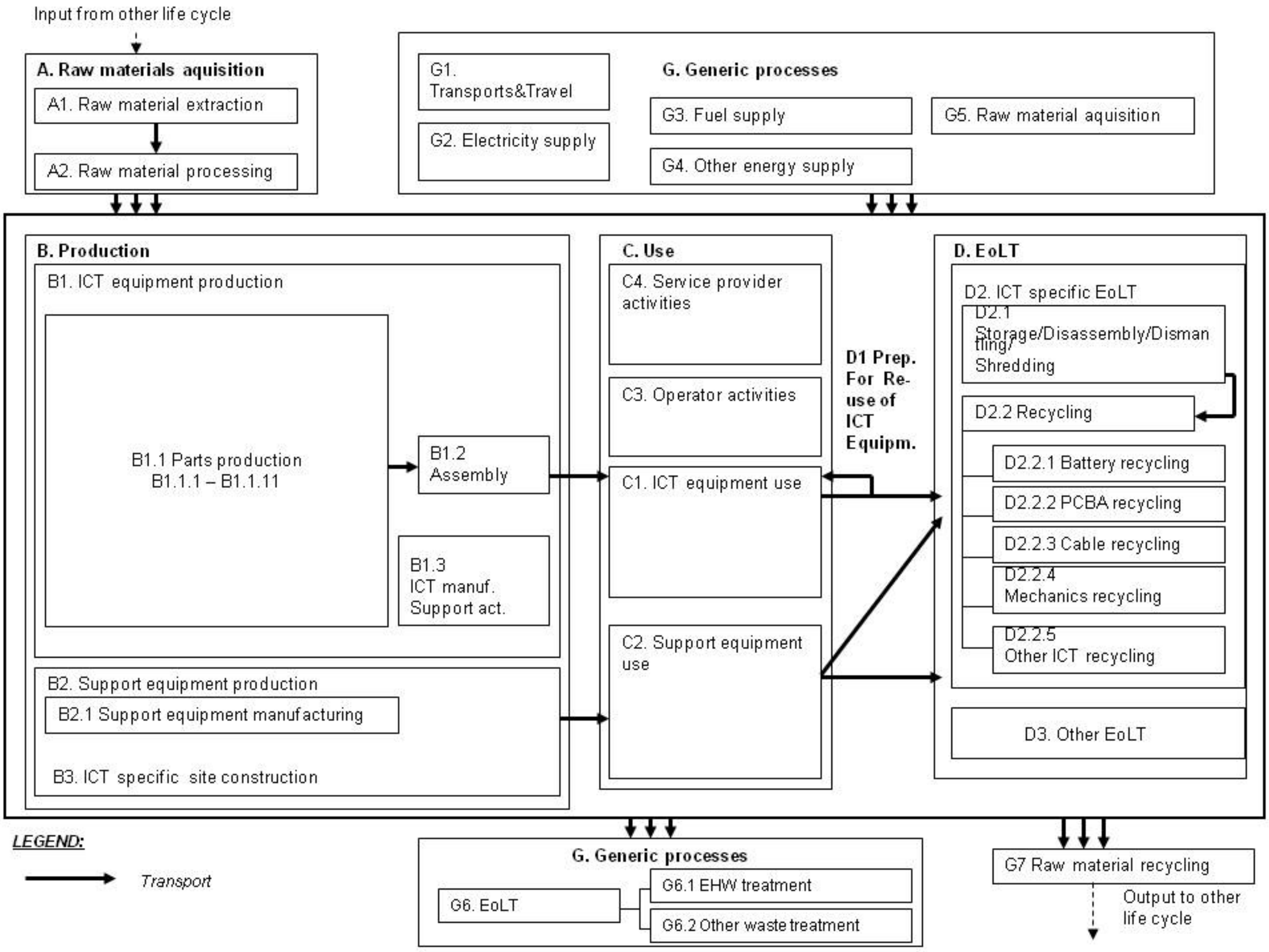


Figure H.1: Connection between all life cycle stages

Annex I (informative): Examples of Equipment and black box modules

This list summarizes entities frequently used in LCAs of ICT. The list is not a complete set of ICT Equipment but is rather an example to indicate the broad range of applicable ICT Equipment and Support Equipment to be considered.

Each Equipment type may be further divided into more specific Equipment types.

I.1 End-user Equipment

- 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.

I.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.

I.3 Network site Equipment (from base station sites to data centres)

- Base station equipment.
- Transmission equipment (e.g. STM-1, radio link).
- RAN control and core equipment (BSC, RNC, SGSN, GGSN, HLR, MSC, etc.).
- Fixed access node (FAN) equipment (POTS, xDSL, FTTx/OLT).
- Telecom switches and telecom servers (services).
- Edge/Metro routers/switches.

- Core routers/switches.
- Optical high capacity transport equipment (WDM).
- Servers.
- Data switches.
- Storage array network equipment.

I.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.

I.5 Site support Equipment

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 J (informative): Examples of Networks and Network Equipment

Table J.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 equipment ("switches and routers") Cooling, power and back-up power equipment
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). NOTE2: 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 equipment 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 J.2: Examples of Network Equipment

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 equipment 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 broadbandnetwork		Coax cable network	Fibre nodes

Annex K (informative): Uncertainties of Life Cycle Assessments for ICT Equipment, networks and services

K.1 General

The uncertainty of LCA can be divided into three categories:

- parameter uncertainty;
- scenario uncertainty;
- model uncertainty.

Parameter uncertainty 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 potentials. 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 (CO2) and other Green House Gases (GHGs) into carbon dioxide equivalents (CO2e).

Scenario uncertainty represents 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 and vehicle use to the product system studied and also use of old data to represent current activities.

NOTE 1: Often based on economical data.

NOTE 2: Emission data for a site is typically measured at the site level and not for individual processes and products.

Model uncertainty arises from insufficient knowledge of the studied product system, leading to omission of data or incorrect assumptions. Model uncertainties are difficult to quantify. The influence of aviation emissions such as NO_X and soot on CC and the effect of, e.g. as land use on CC and biodiversity are examples of emissions/effects usually left out because of lack of knowledge. One source of model uncertainty much discussed is the possible inclusion of emissions from infrastructure and supply chain for travel and transportation activities.

NOTE 3: Decisions regarding which activities to include in the life cycle is part of the system boundary setting of a study.

K.2 Some important uncertainty sources for different life

Table K.1 summarizes some important uncertainty sources associated with different life cycle phases.

Table K.1: Important uncertainty sources of the different life cycle phases

Life cycle phase	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 control of ICT.
Production	ICT Equipment production Support Equipment 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 Equipment use Support Equipment 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 challenging to collect all product system specific data for the whole upstream supply chain. **Raw material acquisition** depends on long supply chains related to world market variations beyond control of the ICT sector and the Part 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. 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 1: A magnitude of thousand facilities could be associated with the supply chain of a major ICT company.

NOTE 2: An LCA study can involve hundreds of LCI data sets (unit processes) using thousands of parameters.

For the **Use stage** estimated operational lifetimes for the Equipment (s) featuring in the studied product system can generate essential scenario uncertainties. A twofold increase of the studied product system's operational lifetime will result in a twofold increase of emissions from studied product system operation if operational lifetime results are presented. Model uncertainties related to studied product system operation also include assumptions regarding the electricity production and amount of traffic.

End-of-Life Treatment (EoLT) and transports typically include model uncertainties related to 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 L (informative): Opportunities and limitations in the use of LCA for ICT Equipment, Networks and Services

Life Cycle Assessment (LCA) is a powerful, systematic methodology which gives an understanding of the relative importance of the different life cycle stages/activities. LCA assists companies in determining where to put their efforts to improve life cycle environmental performance and also how 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 the real and potential environmental impacts, and that the actual impacts of a certain Equipment, Network, Service or organization is beyond reach. This is true for all kinds of product systems in LCA, but especially so for the complex product systems of the ICT sector.

LCA addresses **potential environmental impact**; LCA **does not predict absolute, actual, or precise environmental impacts** 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 impacts, and the fact that some possible environmental impacts are clearly future impacts (source: 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 any studied 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 initial calculation value without uncertainty 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 ten (1 000 %). 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 LCA

LCA should primarily be used for the following purposes:

- Identification of opportunities to improve environmental performance of goods, networks, services and organizations.
- Information to decisions-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.

On the contrary LCA is less suitable for:

- Quantitative benchmarking between studies.
- Aggregation of results between studies.
- Product system performance legislation (measurable parameters more appropriate).
- Labelling of ICT goods, networks and services.

NOTE: with sufficient accuracy.

Annex M (informative): Example of data quality indicators

Table M.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. 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 M.1.

Table M.1: Matrix for data quality assessment

Data Quality Indicator	Applicable section	Comment				
Methodological appropriateness and consistency	Entire specification	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	5.2.3	Indication of the % of applicable LCI flows in Table E.1 which are included in the LCI. Also degree of coverage of an LCIA indicator in Table F.10.				
Uncertainty	5.5	Indication of the variability of the data elements used in the LCA.				
Acquisition method	5.2.4	Indication of how the data used have been obtained. The range is roughly from directly measured to nonqualified estimations.				
Supplier independence	5.2.4	Indication of the verifiability of the data. The range is roughly from verified data from independent source to unverified information.				
Data representativeness	5.2.4	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	5.2.4	< 3 years	< 6 years	< 10 years	< 15 years	Age unknown
Geographical correlation	5.2.4	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	5.2.4	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)	5.2.3	Indication of how homogeneously and transparently the cut-off criteria have been applied.				

Annex N (informative): Examples of Allocation Procedures

N.1 Examples for Allocation Procedures for Recycling of Materials

The examples in Figures N.1 and N.2 use the same values, here expressed as Environmental Load Units (ELU) representing environmental impact: *Raw material acquisition*: **80 ELU/kg**, *Raw Material recycling*: **10 ELU/kg.** It is also assumed that the ***total*** **Raw Material input** (both Equipment Raw Material Acquisition and Generic Raw Material Acquisition) **is 1 kg** and Production waste is not shown separately.

The ratio between Raw Material Recycling ELU and primary Raw Material Acquisition ELU is 1:8 which means that Raw Material Recycling is very favourable.

N.1.1 Example of the 100/0 and 0/100 methods

An example of *Raw Material Acquisition* with the 100/0 method and *Raw Material Recycling* with the 0/100 method is given below in Figure N.1. Simultaneous application of these methods overestimates or overallocates emissions to the studied product/material life cycle, i.e. causes double accounting.

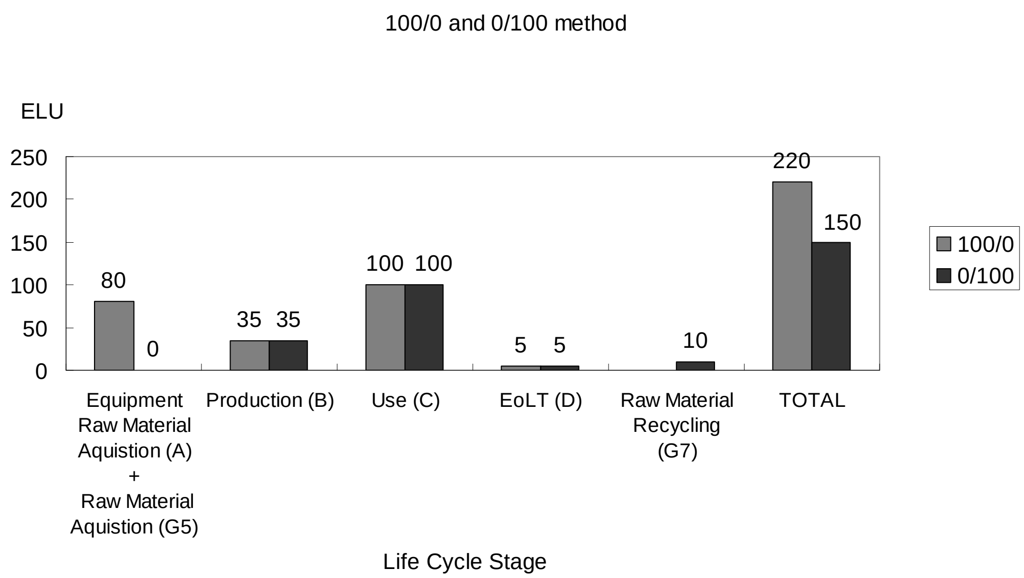


Figure N.1: Example showing the 100/0 method and the 0/100 method

N.1.2 Example of the 50/50 method and combination of 100/0 and 50/50

An example of *Raw Material Acquisition* and *Raw Material Recycling* with the 50/50 method is given below in Figure N.2. Figure N.2 shows the 50/50 method and a *combination* of the 100/0 and 50/50 method, of which the latter is believed to give the best total information.

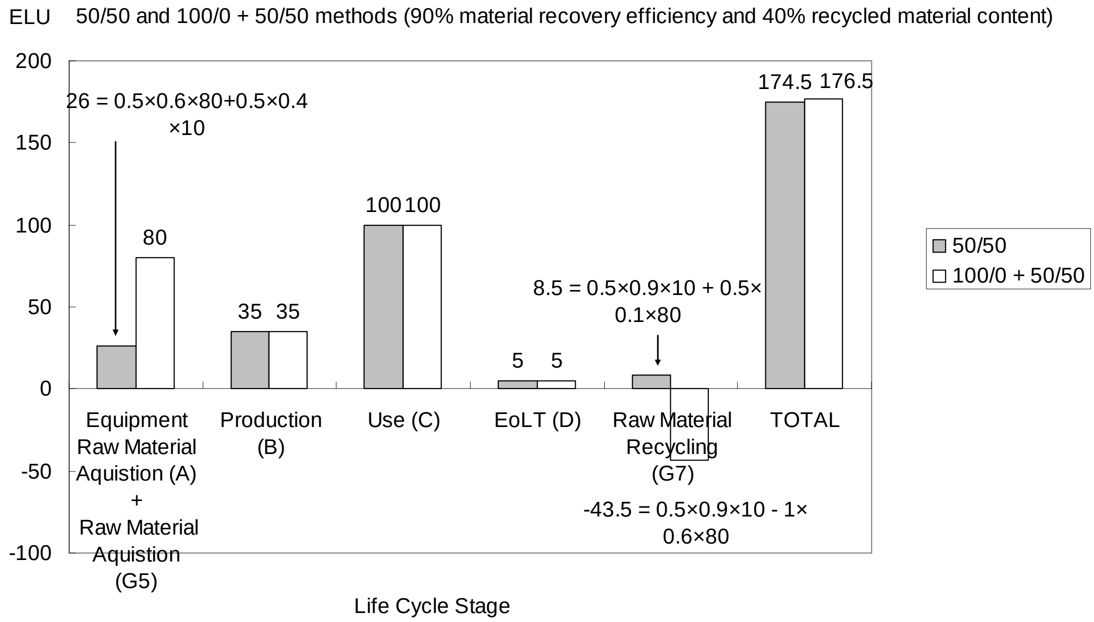


Figure N.2: Example of the 50/50 method and a combination of the 100/0 and the 50/50 method

Recycling of input material (50/50 split with a *prior* life cycle) is a small part of total *Raw Material Acquisition* in Figure N.2, **2 of 26 ELU**. However, *Raw Material Acquisition* (from primary ore, 50/50 split with a *future* life cycle) is a substantial part of *Raw Material Recycling* in Figure N.2, **4 of 8,5 ELU**. It is also possible to present results with these two parts changed so that *Raw Material Acquisition* and *Raw Material Recycling* are presented together (100/0+50/50 in Figure N.2).

In Figure N.2, for the 100/0+50/50 method, by subtracting the *Raw Material Recycling* from the *Raw Material Acquisition*, the same total results as for 50/50 method are obtained. However, the importance of *Raw Material Recycling* is more visible for the 100/0+50/50 method than for the 50/50 method.

Table N.1 gives an example of the 50/50 method with USGS average numbers applied to recycled contents and 90 % material recovery efficiency of the Raw Material in the studied product.

NOTE: The applicability of USGS average numbers varies case by case.

Table N.1: Example of ELU related to Raw Material Acquisition and Raw Material Recycling of 1 kg material

	Raw Material Acquisition [ELU/kg]	Raw Material Recycling (Reprocessing / Remelting) [ELU/kg]	USGS average recycling [%]	Results with 90 % recovery efficiency in Raw Material Recycling and 50/50 method [ELU]
Steel	2,5	0,5 to 1	50	1,1 to 1,45 (see note)
Copper	7	1,5 to 2	30	3,7 to 4
Aluminium	12	1,5	35	5,44 to 5,75
NOTE: [0,5×0,5×2,5+0,5×0,5×0,5] (Raw Material Acquisition) + [0,5×0,9×0,5 + 0,5×0,1×2,5] (End-of-life treatment) = 1,1 ELU.				

Annex O (informative): Examples of application of the present document

O.1 General

This annex reports some example of application of the present document to some system. The examples are not a complete description of application to a real case, but just illustrating some important concepts of the standard application; figure are not related to any real system and not so be used for real application.

O.2 Radio Base Station

This example shows an LCA of *Equipment* performed by an *ICT manufacturer* which gives guidance on how to be fully compliant with the present document as described in clause 4.1.

Goal definition:

The goal of the study is to estimate indicators for Climate Change (CC), Ozone Depletion (OD), Resource Depletion (RDMR), and Human Toxicity (HTC and HTNC) mid-point impact categories of a *Radio Base Station (RBS) during its lifetime.*

The purpose of the study was to find a base for internal prioritization.

Scope definition:

The studied product system is one *RBS* of S444 GSM type covering three cells each with a 1 km diameter, supporting GPRS and 2 500 subscribers. Except the operation system software program, it physically consists of general building blocks such as:

- Cabinets, Panels, Transceiver Units, Dual Duplexer Units, PCBAs, Cable Sets, Grounding Units, Dust Covers, Install kits and Combiner Dividers.

These building blocks can in turn be categorised according to Parts defined in Table B.1.

Installation Guides and Labels are also part of the studied product system.

The **operating lifetime** is estimated to be 10 years based on the studied type of RBS. Preparation for re-use is considered.

The **applicable functional unit** is one year of use.

System boundaries

Table 1 specifies the mandatory and optional life cycle stages/unit processes for ICT Equipment. Listed below are the life cycle stages included in this LCA.

A1
A2
B1.1
B1.2
B1.3
C1
D1
D2.2
D3

The activities B2.1 and B.3 were left out as not part of the studied product system.

Support activities except B1.3 are not considered for any unit processes because of lack of data and models.

The geographical and temporal coordinates vary dynamically for the *Raw Material Acquisition* and *Production* of the ICT Equipment. The presented results for *Raw Material Acquisition* and *Production* will therefore represent a global average for the *RBS.*

Underlined Processes in Figure O.1 were included in the studied product system.

Processes below in *italic* style were not included as they are optional or not part of the studied product system scope.

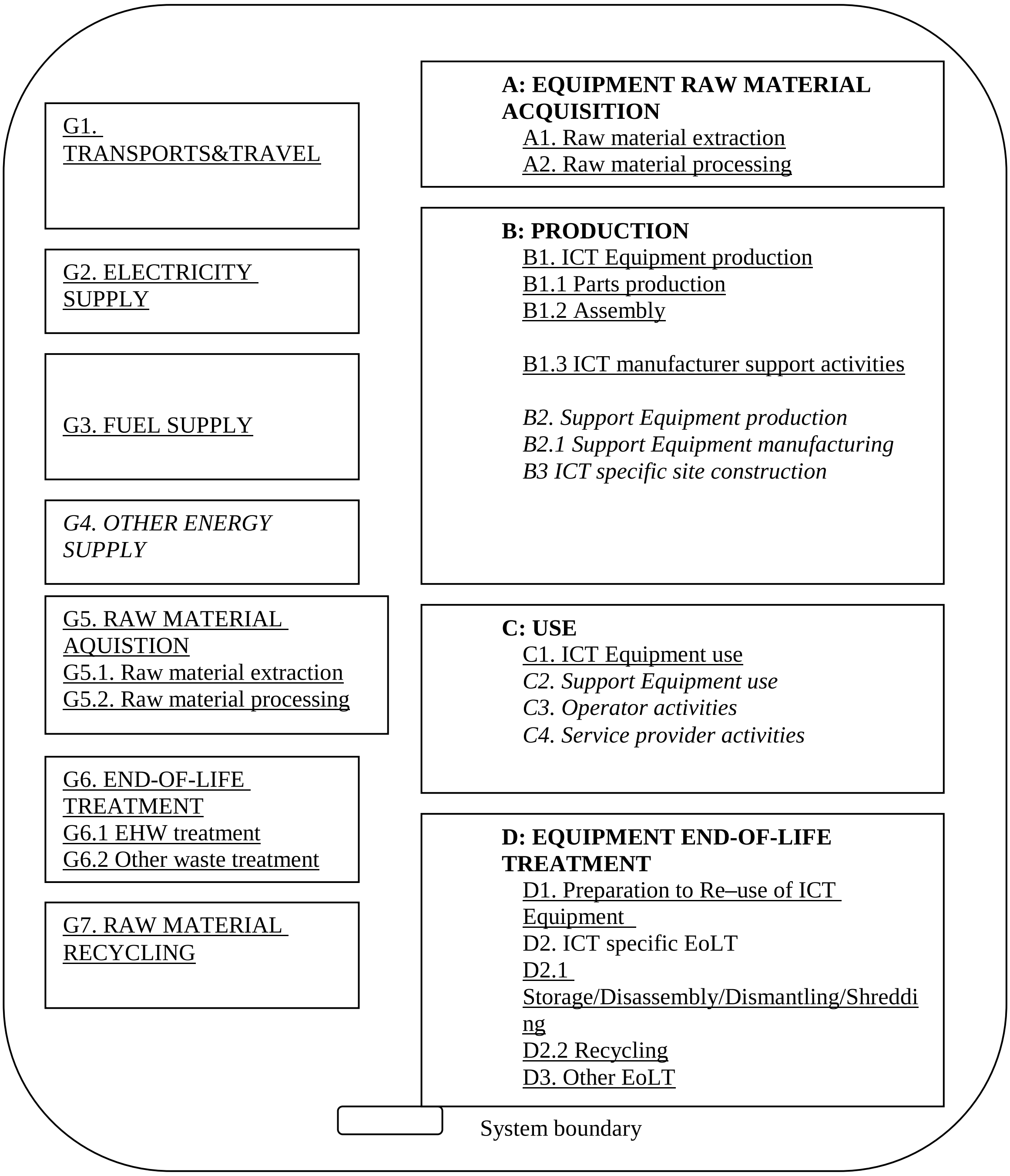


Figure O.1: The system boundary of the product system for LCA of the RBS

Figure O.2 shows a product system flowchart showing where the generic re-occurring processes are used. Boxes in which the text is marked underlined and bold type style are modelled whereas boxes marked with *italic* style are cut-off. These *italic* processes are *within* the studied product system but are cut-off.

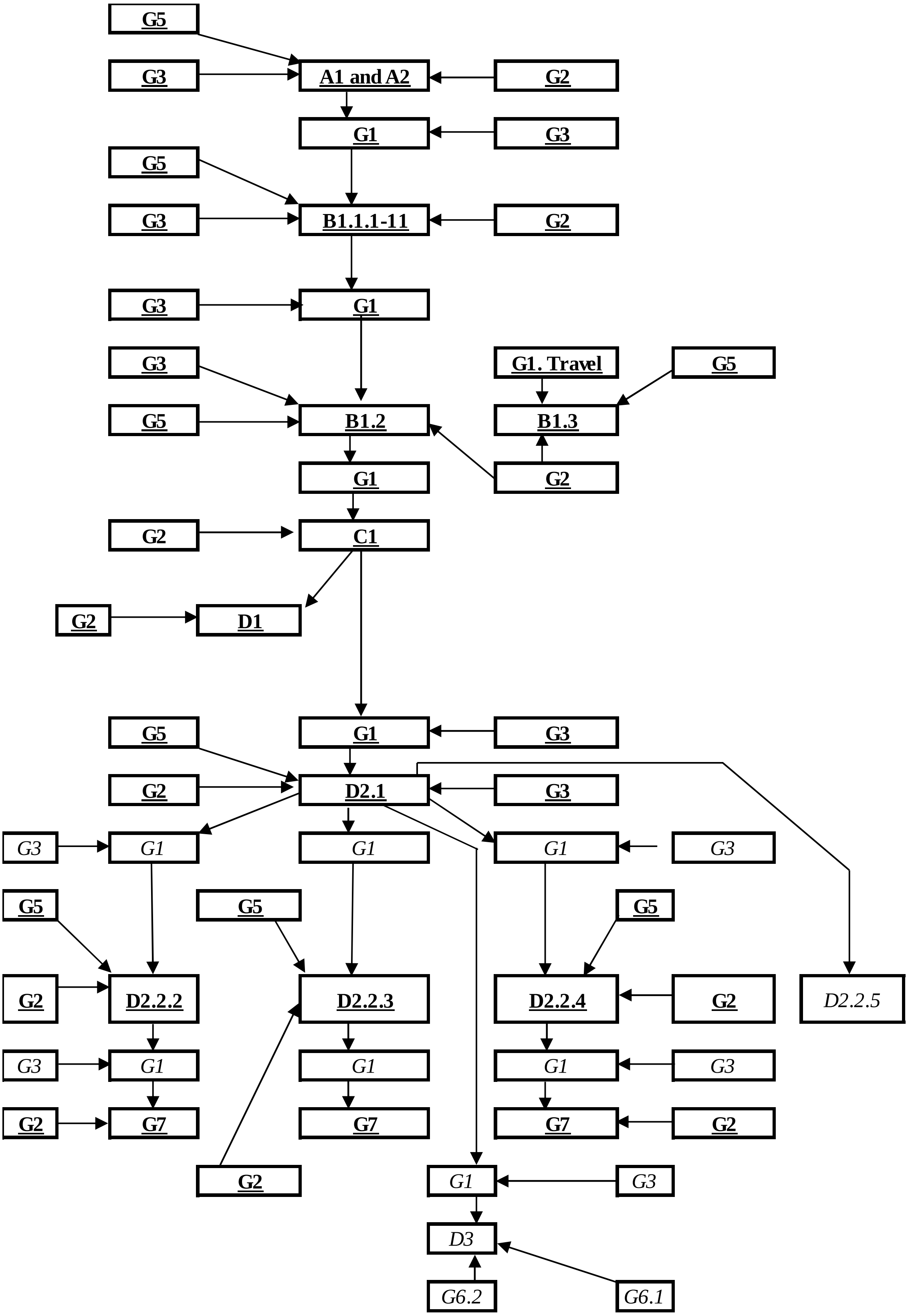


Figure O.2: The system boundary of the product system for LCA of the RBS showing connections with generic processes

Data collection

Equipment Raw material acquisition

For raw material extraction and raw material processing databases contained within the LCA tool/LCI databases were used.

Production

For unit processes within B1.1 data were mainly collected from literature reflecting a global average supply chain but also samples from own suppliers of ICs and PCBs.

For B1.2 data were collected as annual consumption figures from the RBS assembly plant.

For data collection from suppliers clause 5.2.2.1.1 was considered as well as the Annexes A to G.

For manufacturing process share (e.g. electricity used per Part unit processes) of the impact of applicable Parts B1.1.1-10 data were reused from a previous study.

B1.1.10 Black box modules were modelled per piece based on estimation of mass/pieces of sub-Parts inside the black boxes.

B1.1.11 was based on annual data collected internally.

For material content share of the impact, primary data was collected. E.g. amount of steel for a certain part.

For B1.3 data were collected as annual data for offices.

Use

Use phase energy consumption (electricity) was measurements by the operator as the annual average consumption.

Global average energy mixes (electricity) were applied as the product was operating on a Global market and the purpose of the study was to find design improvements.

Equipment End of Life Treatment

For end-of-life data was based on assumptions and literature on global average ICT specific EoLT for Storage/Disassembly/Dismantling/Shredding and Recycling.

Generic processes

For data collection for generic processes the databases which came with the LCA tool/LCI database were used.

Other information

For *Raw Material Acquisition* no transparent data on transports was available, thus impacts from these transports are embedded (if included) and could not be reported separately.

Transport of *RBS* to Use stage was modelled based on assumptions of share of *Rail*, *Air*, *Truck* and *Ship* Transports. See example below in Data calculation.

Data calculation

Below follows examples of data calculations.

B1.1.4 ICs:

The package type (e.g. FBGA-676) for each IC, transistor and diode inside the *RBS* was identified.

The *mass* of each package type was estimated. One package type based LCI data set (e.g. BGA packages) was designed and applied to the *mass* of each IC, transistor, and diode.

The good die area inside each IC, transistor and diode was identified. One Si area based LCI data set was applied to good die area for each IC.

B1.1.7 PCBs:

The [area × layer] value for each PCB piece was identified. An LCI data set expressed per area (produced multilayer PCBs) was used for each PCB. The factory for the PCB had allocated the environmental loadings per area multilayer PCB output.

B1.1.8 Other PCBA Components:

The process environmental data per mass was estimated from databases. Mass based LCI modules were created for a set of Parts in this group. The mass and material content of each Part was identified. The mass based LCI modules were applied to appropriate Parts.

B1.1.11 Software:

The number of programmers involved in software development per year, the number of hours annual work per programmer, salary in USD per programmer per hour, the output of CO_2 per USD estimated by an EIO-LCA, and the number of *RBSs* supported by the annually produced software → CO_2 , water, energy, land use for B1.1.11 software per *RBS*.

B1.2 examples for solder and electricity per PCBA:

The amount of solder paste used per day for an assembly line was measured and divided by a certain number of PCBAs produced daily by an assembly line producing. This gives the **solder used per PCBA.**

For the above assembly line was measured and monitored:

- the power usage was for a number of Assembly steps;
- the number of boards produced per day;
- the hours of usage.

By the above data the **electricity per PCBA** could be calculated.

G1. Example for CO2e emissions of Transports between B1.2 and C1:

- A = % of ICT Equipment manufacturer transports from B1.2 to C1 location by Air.
- B = Average air distance from near B1.2 Airport to near C1 location Airport [km].
- C = Average emission factor for air freight [kg CO2e/tonkm].
- D = Average Distance B1.2 to near B1.2 Airport [km].
- E = Average emission factor for lorry in B1.2 Nation [kg CO2e/tonkm].
- F = Average Distance C1 location Airport to C1 location warehouse [km].
- G = Average emission factor for lorry in C1 location Nation [kg CO2e/tonkm].
- H = Average Distance C1 location warehouse to C1 use location site [km].
- I = Average emission factor for van in C1 location Nation [kg CO2e/tonkm].
- J = % of ICT Equipment manufacturer transports from B1.2 to C1 location by Rail.
- K = Average railway distance from B1.2 to C1 [km].
- L = Average emission factor for rail freight [kg CO2e/tonkm].
- M = Average Distance B1.2 by lorry to B1.2 location railway station [km].
- N = Average Distance C1 location railway station to C1 location warehouse [km].
- O = Average Distance C1 location warehouse to C1 use location [km].
- P = % of ICT Equipment manufacturer transports from B1.2 to C1 location by Sea.

- Q = Average sea distance from B1.2 to near C1 location docks [km].
- R = Average emission factor for sea freight [kg CO2e/tonkm].
- S = Average Distance B1.2 by lorry to near B1.2 docks [km].
- T = Average Distance B1.2 docks to C1 location warehouse [km].
- U = Distance C1 location warehouse to C1 location [km].
- V= % of ICT Equipment manufacturer logistics from B1.2 to C1 location by Road.
- W = Average Distance B1.2 by lorry to C1 location warehouse [km].
- Z = Average Distance C1 location warehouse to C1 use location [km].

Then the CO2e [kg] per transported ton from B1.2 to C1 is:

$A\times(B\times C+D\times E+F\times G+H\times I)+$

$J\times(K\times L+M\times E+N\times G+O\times I)+$

$P\times(Q\times R+S\times E+T\times G+U\times I)+$

$V\times(W\times E+Z\times I)$

G1. for Travelling by ICT Manufacturer, support activity:

The travelling pattern for one person (engineer) per month and the person × months per number of RBS developed per year was monitored. By these data the travelling impact *per RBS per year could be calculated.*

B1.3 for Office Activity (ICT Manufacturer support activity):

By monitoring the number of personnel (engineers) in office area and the Consumption (of water, paper, computer usage, other electricity per month) for the office area in combination with person×months per number of RBS developed per year the Office Activity for Engineers *per RBS per year could be calculated.*

Allocation of data

Equipment raw material acquisition

The allocations performed for the database data used were not transparently reported by the database.

Production

For the Part Production Facility data used it could be confirmed that data had been allocated by the practitioner based on the relative proportion of relevant physical characteristics (such as weight and layer × area) compared to totally produced amount, as preferred by the present document.

B1.1.1 Batteries and B1.1.6. Displays were not applicable to the *RBS* LCA studied product system.

For B1.1.5 Mechanics. Database modules were used and allocated per mass/area/volume of each piece.

For B1.1.7 PCBs. The factory for the PCB had allocated the environmental loadings per area multilayer PCB output.

Use

No allocation was done. The operator reported the annual average electricity consumption for the studied *RBS*. This simplification was judged to be enough for the internal purpose.

Equipment End of Life Treatment

The 100/0 method was applied for Raw Material Production and Raw Material Recycling applied to Iron/Steel alloys, Aluminium alloys, Copper alloys, Silver, and Gold.

After ten years use, 10 % of the RBSs are assumed prepared for re-use (D1). 90 % go for average PCBA (D2.2.2), Cable (D2.2.3) and Mechanics (D2.2.4) Recycling and then to Raw Material Recycling (G7).

Generic processes

The transports were allocated based on mass.

Support activities

Support activities only included partly for B1.3. Operation project accounting information was used to estimate the number of persons involved in the ICT manufacturer support activities needed for R&D. These resources were then associated with a proportional amount of the organizational resource need.

Cut-off

One cut-off criterion was set: 5 % addition to the first iteration LCA score for CC, OD, RDMR and HTC/HTNC. That is, if the excluded activities/processes did not increase the total CC, OD, RDMR and HTC/HTNC scores with more than 5 %, respectively, the cut-off criterion was justified.

Based on this criterion several cut-offs were done from the studied product system: B1.1.11, transports within EoLT, Raw Material consumptions, Electricity, and Fuel consumptions within EoLT, EoLT activities (D3) G6.1-2.

During the data collection it was hard to get hold of data for the specific EoLT transport distances so they were cut-off.

Moreover D3 is mandatory according to Table 1 and applicable to the studied product system, but no appropriate data could be collected so it was cut-off.

From a total environmental impact point of view these excluded processes were not assessed to be associated with any specific concerns, thus the cut-off was made.

Data quality

- Methodological appropriateness and consistency

The applied LCI methods and methodological choices are in line with the goal and scope of the data. The methods have been applied consistently across all data.

- Completeness (total LCA level)

95 % of applicable LCI flows in Table E.1 are included in the LCI. The degree of coverage of the RDMR LCIA indicator in Table F.10 is 90 % based on mass.

- Uncertainty

The variability of the data elements used in the LCA is low enough.

- Data representativeness
- Data age (timeliness)
- Acquisition method

Some of the data used have been directly measured such as the number of Parts. None of the data used are nonqualified estimations.

- Supplier independence

Most of the data used are Independent source but based on unverified Information. Verified data from independent source to No unverified information has been used.

- Geographical correlation

"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.

- Technological correlation

"Data from process studied of the exact company" is used for Assembly and Use stage electricity. "Data from process studied of company with similar technology" is used for Battery production.

- Cut-off rules (rules of inclusion/exclusion)

The cut-off criterion was homogeneously and transparently applied.

LCIA

The following impact categories were included: CC, OD, RDMR, HTC, HTNC.

The impact assessment methods applied were "Climate change", "Ozone depletion", "Metal depletion", and "Human toxicity" from ReCiPe Midpoint (H) V1.05. HTC and HTNC could not be assessed separately due to lack of data.

Life cycle interpretation

Initial Conclusions

The LCA showed that the most significant activity for CC, OD, and HT categories is the *Use Stage* driven by the amount of electricity used by the RBS. For RDMR the *Raw Material Acquisition stage* is most important. As far as transports are concerned the impact is limited from a life cycle perspective for all impact categories. The assessment also indicates that *Mechanics/Materials* dominate both *Raw Material Acquisition* and *Production* stages. Included *support activities* were not important. The Re-use scenario used for this RBS LCA increase the use stage driven scores for impact categories but decrease the *Raw Material Acquisition and Production stages* which totally leads to an increase for all impact categories.

Uncertainty estimation

Uncertainty Calculation was done according to the Monte Carlo procedure provided by the LCA tool. The uncertainty range for total CC was around +/- 15 %. For OD, RDMR and HTC/HTNC the uncertainty range could not be assessed due to lack of uncertainty data. The uncertainty range for *Raw Material Acquisition* and *Production* stages are higher than for the *Use* stage. Uncertainty of LCIA characterization factors was not possible to estimate. The following steps were taken to reduce the uncertainties: verification of the reasonableness of the electricity usage of the RBS.

Sensitivity analyses

By contribution analysis the most contributing elementary LCI flows and unit processes were identified for each impact category. Subsequently models applied and the data used were assessed with respect to accuracy and a list of candidates bound for sensitivity analysis was identified, e.g.:

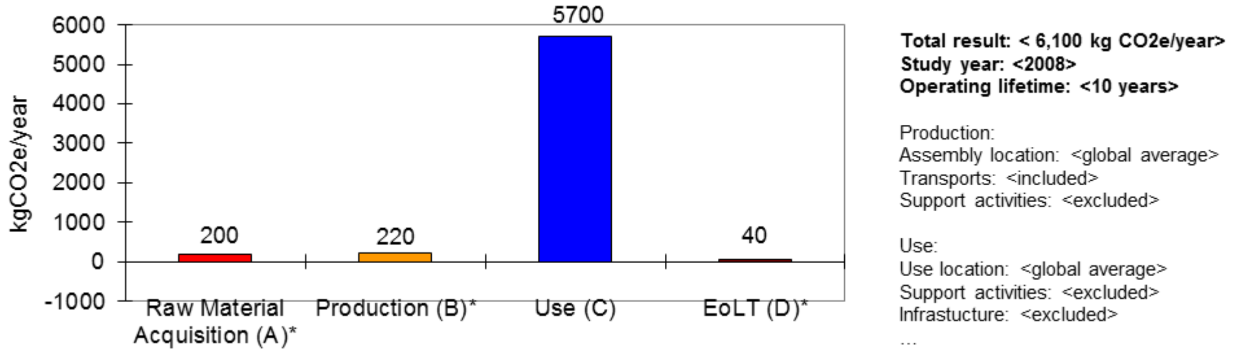
- operating life time;
- transport distances between final assembly and customer;
- production region;
- change to Global electricity mix for Raw Material Acquisition instead of original database electricity mix.

Moreover, the sensitivity of the cut-off B1.1.11, transports within EoLT, Raw Material consumptions, Electricity, and Fuel consumptions within EoLT, EoLT activities (D3) G6.1-2 was tested by inserting a range of electricity consumptions for D3 and Road transport distances. B1.1.11 was assumed similar to the software development impacts of B1.3 and therefore a proxy for B1.1.11 could be used based on B1.3.

These sensitivity analyses revealed that the conclusions were stable.

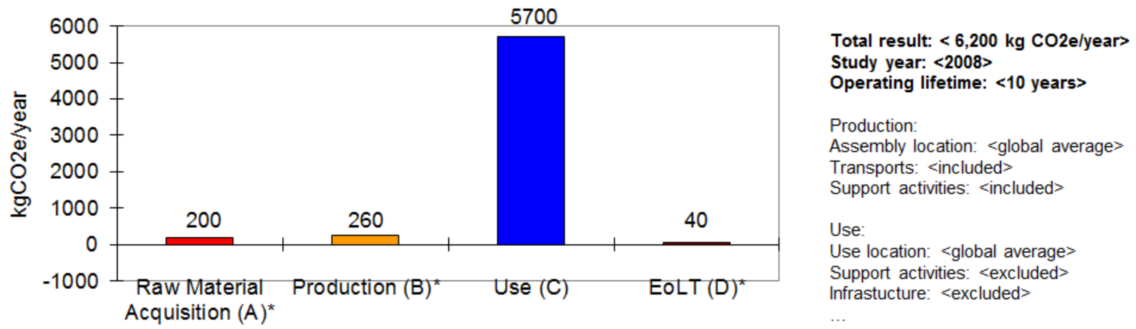
Reporting

All omissions and deviations towards the present document were transparently reported and the reporting formats of the standards were followed in detail. Furthermore the reporting formats of the present document were used in the final report.



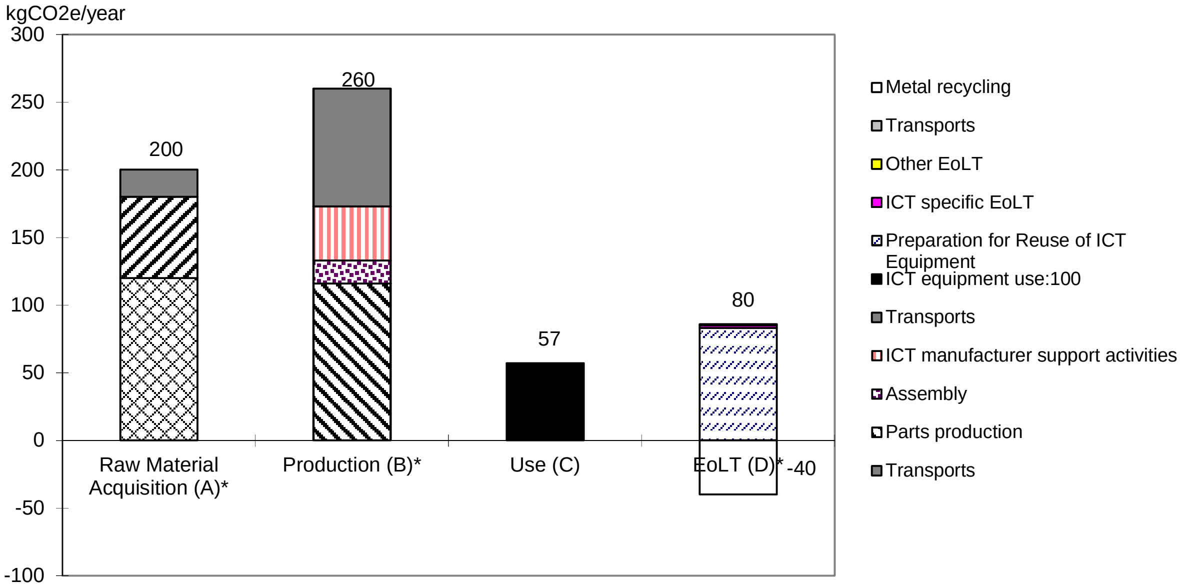
*this value has been divided by operating lifetime to produce an annual value

Figure O.3: GWP100 result diagram example for RBS for Mandatory processes/activities (diagram for Global Warming Potential (GWP100) (CO2e)



*this value has been divided by operating lifetime to produce an annual value

Figure O.4: GWP100 result diagram example for RBS for Mandatory/Recommended/Optional processes/activities (diagram for Global Warming Potential (GWP100) (CO2e)



*this value has been divided by lifetime to produce annual value

Figure O.5: GWP100 result for Mandatory/Recommended/Optional processes/activities: distribution between sub-unit processes within each life cycle stage

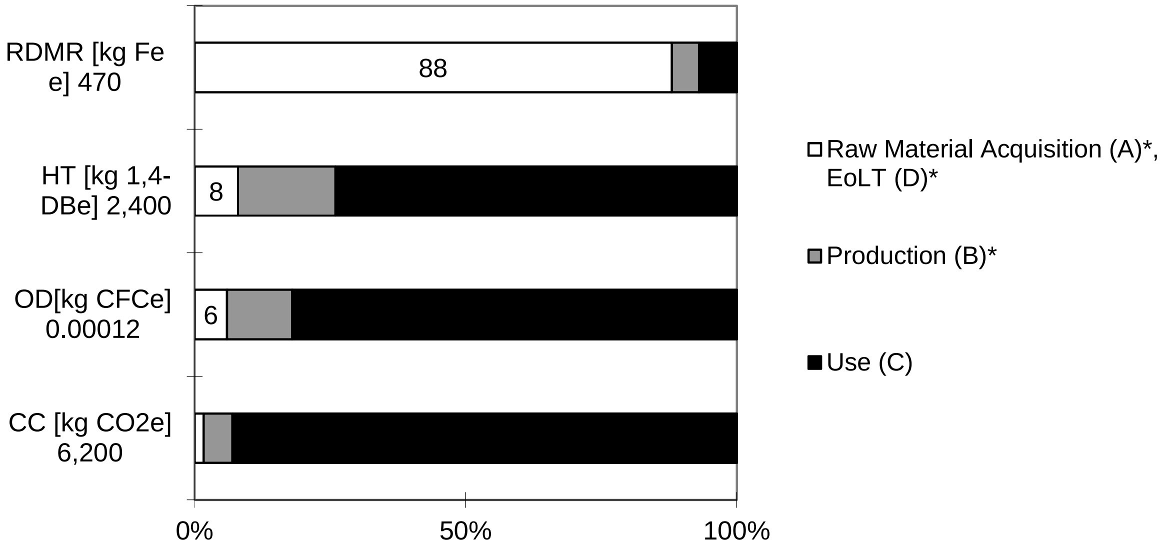


Figure O.6: Environmental impact category indicators overview per functional unit for RBS for Mandatory/Recommended/Optional activities/processes

Table O.1: (life cycle stages, activities and generic processes

Tag	Life cycle stage	**Unit process**	**Included (Yes/No)**	**Electricity mix (specific/ country/ world average**	**Support activities included (Yes/No)**	**Transport activities included (Yes/No)**	**Other generic activities included (Yes/No)**	**Motivation/ Comment**
A	Equipment Raw Material Acquisition							
A1	Raw material extraction		Yes	Specific	No	Yes	Yes	Specific electricity mix might deviate from world average
A2	Raw material processing		Yes	Specific	No	Yes	Yes	Specific electricity mix might deviate from world average
B	Production							
B1	ICT equipment production							
B1.1		Parts production	Yes	World	No	Yes	Yes	B1.1.11 cut-off
B1.2		Assembly	Yes	World	No	Yes	Yes	
B1.3		ICT manufacturer support activities	Yes	World	Yes	Yes	Yes	
B2	Support equipment production							
B2.1		*Support Equipment manufacturing**	*No*					
B3		*ICT specific Site construction*	*No*					
C	Use							
C1	ICT equipment use		Yes	World	No	No	No	
C2	*Support equipment use*		*No*					
C3	*Operator activities*		*No*					
C4	*Service provider activities*		*No*					
D	Equipment End of Life Treatment							
D1	Re-use of ICT Equipment		Yes	World	No	Yes	No	10 % of RBSs prepared for Re-use. 90 % to Recycling D2.2.2-4
D2	ICT specific EoLT							
D2.1		Storage/Disassembly /Dismantling/ Shredding	Yes	World	No	Yes	Yes	

Tag	Life cycle stage	Unit process	Included (Yes/No)	Electricity mix (specific/ country/ world average	Support activities included (Yes/No)	Transport activities included (Yes/No)	Other generic activities included (Yes/No)	Motivation/ Comment
D2.2		Recycling	Yes	World	No	Yes	Yes	PCBA, Cables, and Mechanics recycling included. D2.2.5 cut-off.
D3	Other EoLT		Yes	World	No	Yes	Yes	Cut-off. Tested in sensitivity analysis.
NOTE: The electricity mixes used in the LCI databases were specific and not world average.								

Table O.2: Generic processes per functional unit

Generic process	Generic process categories included	Unit processes included (for each generic process category)	Important issues
G1. Transports & Travel	Road Air Ship Train	Direct (during transport) emissions Fuel supply chain	
G2. Electricity	World electricity mixes	Fuel supply chain, Direct emissions (during electricity production)	
G3. Fuels	Oil Diesel Petrol Jet-fuel Coal Gas	Fuel supply chain:	
G4. Other energy			
G5. Raw material acquisition	See Annex 4	Extraction Processing	
G6. End-of-life treatment	Landfill Incineration	One "site model" for landfill	Cut-off
G7. Raw material recycling	Metal recycling	Smelting Refining	

Table O.3: Transports/travel per functional unit

Mode	CO_2 emission factor	Raw material acquisition transports		Production stage transports excluding final transport		Final transport (Production to use stage))		Use stage transports		EoLT transports		Total travels	
		Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton*km}	GWP 100 {kg CO_2e}	Transport work {ton×km}	GWP 100 {kg CO_2e}	Transport distance {km})	GWP100 {kg CO_2e}
Air	1,1 kg CO_2e/ [ton × km]					120	130					0,15 kgCO_2/ [person × km]	7)
Other	Road: Lorry (16 tons) 0,25 kg CO_2e/ [ton × km], Van 1,5 kg CO_2e/ [ton × km], Rail 0,01 kg CO_2e// [ton × km], Ship 0,009 kg CO_2e// [ton × km]					Road: *Lorry* 80, *Van* 10 Rail: 70 Ship: 260	Road: 40 Rail: 1, Ship: 2					Car 0,2 kg CO_2e/ [person × km]	0,4

Table O.4: Raw materials per functional unit

	Total input (g,kg, ton)	Content in product (%)	Recycled input (%)	Recycling of total input (see note) (%)	Reference
Iron/Steel alloys	23 kg	0	50	0	Assumption for recycled input according to USGS
Aluminium alloys	3 kg	0	35	0	Assumption for recycled input according to USGS
Copper alloys	2 kg	0	30	0	Assumption for recycled input according to USGS
Silver	0,02 kg	0	20	0	Assumption for recycled input according to USGS
Gold	0,0009 kg	0	15	0	Assumption for recycled input according to USGS
NOTE: Total recycling of all input materials, i.e. recycling of manufacturing waste, and recycling of total content in final product.					

Table O.5: Parts production

	Part categories included	Part Unit processes included	Handling of special issues
B1.1.1 Batteries	N.A.	N.A.	N.A.
B1.1.2 Cables	Coaxial cables Fibre cables Power cables Network/signal cables	Raw Material Acquisition, Cable final assembly	
B1.1.3 Electro-mechanics	Connectors	Raw Material Acquisition, Part final assembly	
B1.1.4 Integrated circuits (ICs)	Processors, DSPs ASICs Memories Microprocessors Transistors and diodes	Front-end: Special IC materials production, Wafer production, Chip production ("the wafer fab") Back-end: IC encapsulation	Package type for each Part and Good die area for each Part → Load Per B1.1.4
B1.1.5 Mechanics / materials	Fronts Frames Racks Cabinets Solder Nuts, bolts	Raw Material Acquisition, Part final assembly	
B1.1.6 Displays	N.A	N.A.	N.A.
B1.1.7 Printed circuit boards (PCBs)	Plastic	Raw materials Acquisition for special PCB materials, Raw materials Acquisition for PCB semi-produced composite materials, PCB final assembly	
B1.1.8 Other PBA components	Resistors Capacitors Inductors Relays LEDs Potentiometers Quartz crystal oscillator	Raw Material Acquisition, Part final assembly	
B1.1.9 Packaging materials	Paper Cardboard Plastics Wood Steel		
B1.1.10 Black box modules		"Cradle-to-gate" LCA from supplier	
B1.1.11 Software	Software developed in B1.3	Development: Daily way to work for programmer, Business trips for programmer, Electricity usage of ICT Equipment used by programmer, Office lighting.	Cut-off: Manuals production, Data medium production.

Table O.6: Use stage energy consumption per function unit for the RBS

	Energy consumption {kWh/year}	Source {long term average/standardized measurement/ modelled	Motivation/ comment
ICT equipment	8,760	Measured/Modelled by Operator	Simplified purpose of LCA study
Support equipment	*Not included*		

Table O.7: EoLT

	Process categories included	Process Unit processes included	Handling of special issues
EHW treatment	EHW (destruction and energy recovery) Special EHW landfill	In general: Recovery/treatment (one unit process or "site LCI model" for the entire EHW category)	Handled as Cut-off
Other Waste treatment	Diverse recycling Energy recovery (e.g. incineration) Landfill	In general: Recycling/recovery/treatment (one unit process or "site LCI model" for each material/ waste category)	Handled as Cut-off

Table O.8: LCI results per functional unit

	TOTAL	Raw materials acquisition *and* EoLT	Production	Use
Primary energy use	120,000 MJ	2,200	3,000 MJ	110,000 MJ
Total electricity use	9,300 kWh	200 kWh	300 kWh	8,760 kWh
Land use (see Note 1)	16 m^2	1 m^2	1 m^2	14 m^2
Fresh water use (see Note 2)	44 m^3	2 m^3	2 m^3	40 m^3
NOTE 1: According to ReCiPe MidPoint (H) V.1.05 Land occupation and transformation impact categories. NOTE 2: According to ReCiPe MidPoint (H)V.1.05 Water Depletion impact category.				

Table O.9: Impact category indicators per functional unit for Mandatory/Recommended/Optional activities/unit processes for the RBS

Mid-point Impact Assessment Categories included	Impact category indicator value	LCIA methodology reference
CC	6 200 kg CO_2e	Mid-point Category indicator: Infrared forcing as GWP100, IPCC as used by ReCiPe MidPoint (H) V1.05
OD	0,00012 kg CFC-11 e	ReCiPe MidPoint (H) V1.05
HTC, HTNC	2 400 kg 1,4-DB e	ReCiPe MidPoint (H) V1.05
RDMR	470 kg Fe e	ReCiPe MidPoint (H) V1.05

Table O.10: Matrix for data quality assessment applied to RBS LCA

Data Quality Indicator	Applicable section	Comment
Methodological appropriateness and consistency	Entire specification	The applied LCI methods and methodological choices are in line with the goal and scope of the data. The methods have been applied consistently across all data.
Completeness	5.2.3	95 % of applicable LCI flows in Table E.1 are included in the LCI. The degree of coverage of the RDMR LCIA indicator in Table F.10 is 90 % based on mass.
Uncertainty	5.5	The variability of the data elements used in the LCA is low enough.
Acquisition method	5.2.4	Some of the data used has been directly measured such as the number of Parts. None of the data used are nonqualified estimations.
Supplier independence	5.2.4	Most of the data used are Independent source but based on unverified Information. Verified data from independent source to No unverified information has been used.
Data representativeness	5.2.4	"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.
Data age/timeliness	5.2.4	Most data used are <6 years old No data has been used for which the age were unknown.
Geographical correlation	5.2.4	"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.
Technological correlation	5.2.4	"Data from process studied of the exact company" is used for Assembly and Use stage electricity. "Data from process studied of company with similar technology" is used for Battery production.
Rule of inclusion/exclusion (Elements/Flows/Unit process)	5.2.3	The cut-off criteria were homogeneously and transparently applied

O.3 Mobile phone

This example shows an LCA of Mobile phone *Equipment* performed by an *ICT manufacturer*.

For compliance with the present document all body text and annexes need to be considered when performing an LCA, i.e. the example as such is fully compliant with the present document as described in clause 1.1.

NOTE: The LCA report resulting from a compliant LCA will have to be more extensive.

Goal definition:

The goal of this example LCA study is to clarify and understand the environmental impact of a mobile phone during all stages of the lifecycle by estimate Climate Change (CC) mid-point impact category indicator of a *Mobile Phone during its lifetime.*

The purpose of the LCA study is for internal use in order to develop the product and processes to be environmentally sound.

Scope definition:

The studied product system is one *Mobile Phone* of *3G* type with typical functionality for entry-level models such as voice, SMS, and internet browsing. Except the operation system software program, it physically consists of general building blocks such as: battery, mechanics, electro-mechanics, and electrical components. These building blocks can in turn be categorised according to Parts defined in Table B.1. Table B.1 also includes Software as a Part. In this case of an entry-level mobile phone the main software component is operating system which according to clause5.1.2 can be considered optional due to allocation difficulties.

The **operating lifetime** is estimated to be 3 years based on the studied type of Mobile Phone and on consumer studies. No extended operating lifetime or other lifetimes are considered.

The **applicable functional unit** is *Total ICT equipment use per lifetime*

Other related equipment, like accessories and charging equipment are outside of scope as those vary case by case. Also sales packages, which vary, are excluded.

The packaging material related with parts production and assembly is included.

ICT manufacturer Bill of Materials (BOM) primary data were used to identify the Parts and Raw material contents of the Mobile Phone.

The assessment scope is also focused on direct operations and therefore infrastructure capacity buildings (like factories, roads, vehicles and telecommunications) are excluded. Also capital goods, like production machinery are excluded. Human resources, corporate overhead and travels are also excluded.

ICT Manufacturers facilities energy consumption is included.

Typical first owner and first use lifetime is considered and included in the scope.

The assessed mobile phone is a globally marketed product. However, the geographical and temporal coordinates vary dynamically for the Raw Material Acquisition and Production of the ICT Equipment. The presented results for *Raw Material Acquisition* and *Production* will therefore represent a global average for the Mobile Phone.

System boundaries

Table 1 specifies the mandatory, recommended and optional life cycle stages/unit processes for ICT Equipment. Listed below are the life cycle stages included in this LCA:

A1
A2
B1.1
B1.2
C1
D2.1
D2.2
D3

The optional activities B2.1 3 were left out as Support Equipment such as Chargers was not part of the studied product system and B3, ICT specific site, is not applicable.

Moreover, C3 and C4 are not applicable to the studied product system.

In EoLT D2.1, D2.2.1, D2.2.2, D2.2.4, and D2.2.5 processes are included.

Support activities are not considered for any unit processes.

Underlined Processes in Figure O.7 were included in the studied product system.

Processes below in *italic* style were not included as they are optional or not part of the studied product system scope.

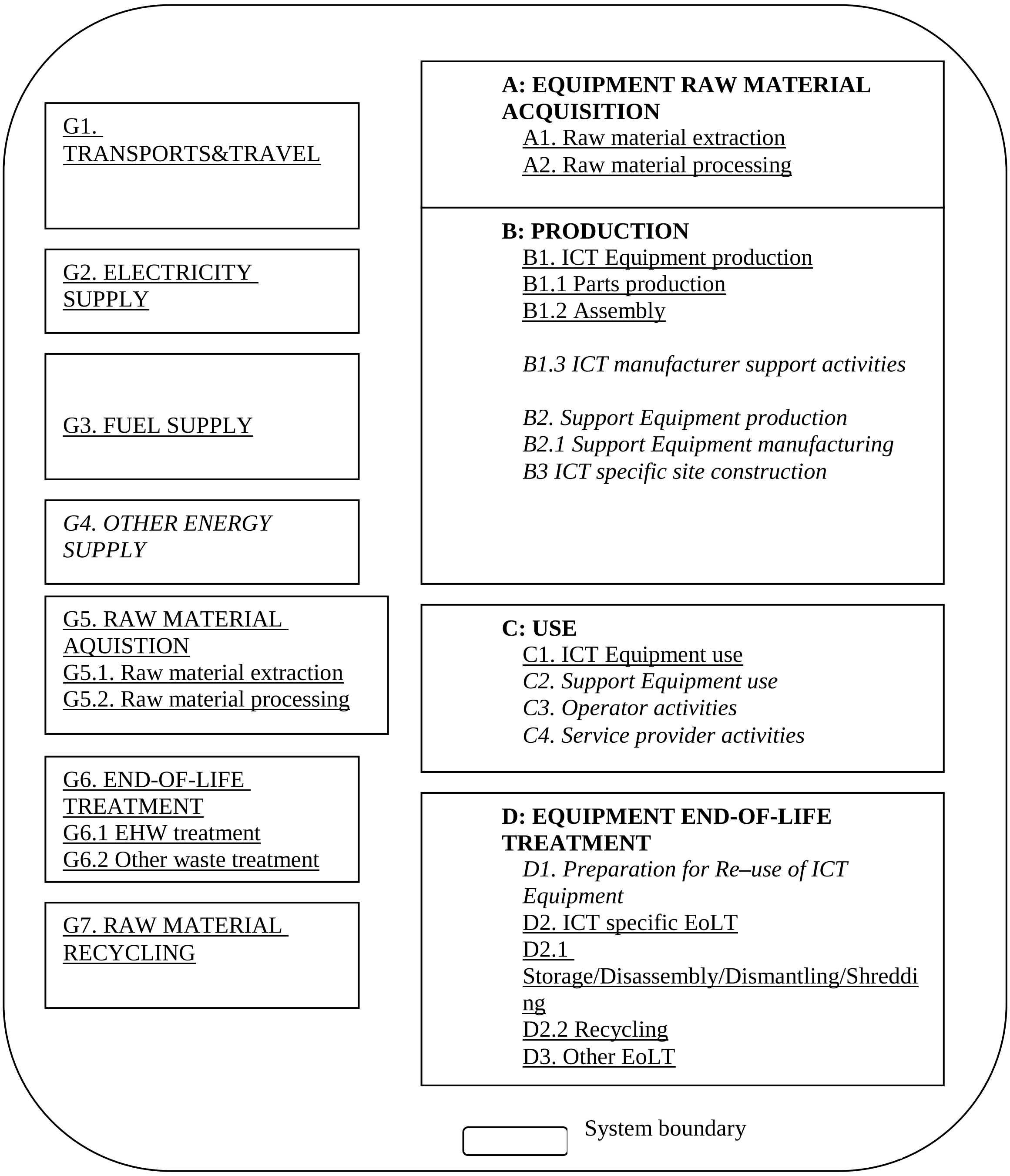


Figure O.7:The system boundary of the product system for LCA of the Mobile Phone

Figure O.8 shows a product system flowchart showing where the generic re-occurring processes are used. Boxes in which the text is marked underlined and bold type style are modelled whereas boxes marked with *italic* style are cut-off. These *italic* processes are *within* the studied product system but are cut-off.

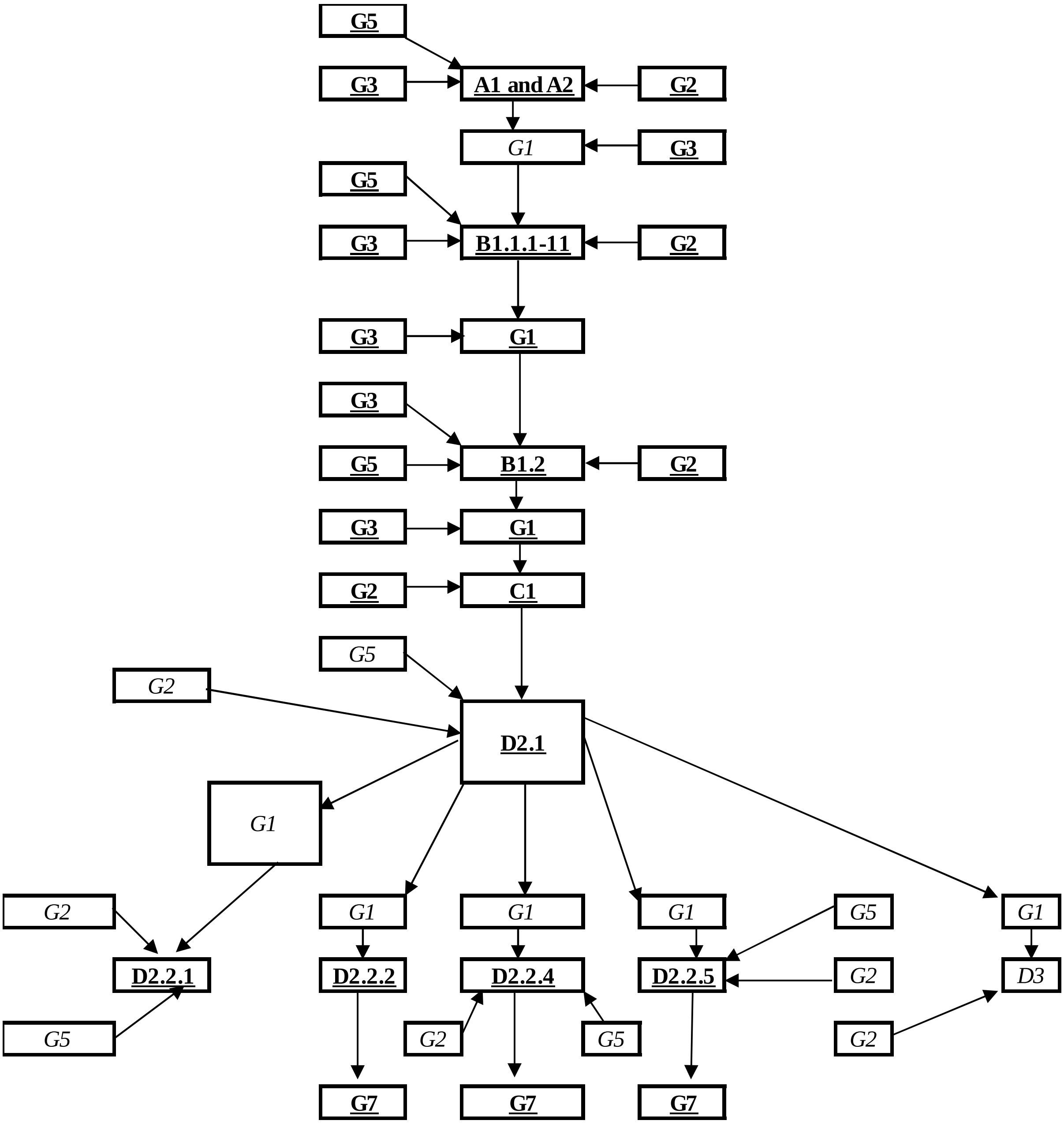


Figure O.8:The system boundary of the product system for LCA of the Mobile Phone showing connections with generic processes

Data collection

Equipment Raw material acquisition

Selected external data bases are used for raw material extraction and raw material processing data.

Production

Primary data is collected for inbound and outbound logistics and own production (assembly, B1.2) operations. Parts (B1.1.1-11) production and Raw materials acquisition data are collected from external databases and case by case from suppliers.

Use

Energy consumption during mobile phone use phase is estimated based on third alternative in clause 5.3.1.2.1 (with certain user profile / product category) including typical use of all functionalities of the multifunctional ICT equipment. Phone charging energy efficiency is based on ICT manufacturer's own charger relevant for the study. Assumption is that the charger is not unplugged and therefore no-load consumption has been taken into account (worst case scenario). World average energy mixes are used as the product is intended for global market.

Equipment End of Life Treatment

For end-of-life data are based on average data from literature (e.g. regarding amount of electricity used per piece or mass of mobile phone for Storage/Disassembly/Dismantling/Shredding (D2.1) and Recycling (D2.2.1, D2.2.2, D2.2.4, and D2.2.5).

Generic processes

For transports (G1) distances and own facilities consumption of (G2, 3, 5 and 7) primary data is used. Relevant local and global energy mixes are used from data bases.

Other information

For raw material acquisition no transparent data on transports (G1) were available (in databases or otherwise), thus impact from these transports cannot be reported separately.

Data calculation

Below follows some examples of data calculations.

B1.1.1 Battery:

The battery capacity (mAh) and the nominal cell voltage (V) were determined and thereafter the energy content of the battery used in the mobile phone was calculated. Then an LCI module for Lithium batteries expressing the impacts per energy content was applied according to Table B.1.

B1.1.4 ICs:

The package type (e.g. PLCC-28) for each IC inside the *Mobile Phone* was identified.

The *mass* of each package type was estimated. One package type based LCI module (e.g. BGA packages) was designed and applied to the *mass* of each IC.

The good die area inside each IC was identified. One Si area based LCI data set was applied to good die area for each IC.

The mass of transistors and diodes were identified. LCI data set expressed per mass transistor and diode were applied.

B1.1.6 Display:

The mass of the display unit and the active area of the display were determined. A mass based LCI model for display unit final assembly was used for the "Display panel assembly" by using the mass of the display unit. An LCI data set expressed per active area was used for "Display module assembly". The sum of these two multiplications represents the LCI model for the display.

B1.1.7 PCBs:

The [area×layer] value for each PCB piece was identified. An LCI data set expressed per area (produced multilayer PCBs) was used for each PCB. The factory for the PCB had allocated the environmental loadings per area multilayer PCB output.

Allocation of data

Equipment raw material acquisition

The allocation performed for the database data used was not transparently reported by the database.

Production

Own assembly facility data (energy consumption) has been allocated by dividing with relevant unit volume.

Use

There was no need for allocations in use stage in this study.

Equipment End of Life Treatment

100 % of the Mobile Phones are assumed to go for average ICT specific EoLT and WEEE Recycling.

Generic processes

See Raw material acquisition and Production.

Support activities:

No support activities have been included.

Cut-off

One cut-off criteria was set: 5 % addition to the first iteration LCA score for CC and CED. That is, if the excluded activities/processes did not increase the total CC score with more than 5 % the cut-off criteria was justified.

Based on these criteria several cut-offs were done from the studied product system: Some transports in Production, some transports, Raw Material consumptions and Electricity consumptions within EoLT, EoLT activities (D3). Additionally B1.1.11 is excluded as the software is an operating system and is optional according to clause 5.1.2.

Data quality

- Methodological appropriateness and consistency.

The applied LCI methods and methodological choices are in line with the goal and scope of the data. The methods have been applied consistently across all data.

- Completeness (total LCA level).

90 % of applicable LCI flows in Table E.1 are included in the LCI. The degree of coverage of the CC LCIA indicator in Table F.10 is 98 % based on mass.

- Uncertainty.

The variability of the data elements used in the LCA is low enough.

- Data representativeness.
- Data age (timeliness).
- Acquisition method.
- Some of the data used have been directly measured such as the number of Parts. None of the data used are nonqualified estimations.
- Supplier independence.

Most of the data used are Independent source but based on unverified Information. Verified data from independent source to No unverified information has been used.

- Geographical correlation.

"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.

- Technological correlation.

"Data from process studied of the exact company" is used for Assembly and Use stage electricity. "Data from process studied of company with similar technology" is used for Battery production.

- Cut-off rules (rules of inclusion/exclusion).

The cut-off criteria were homogeneously and transparently applied.

LCIA

The following impact categories were included: Climate Change (CC).

The impact assessment method applied was: IPCC 2007 GWP100a.

Cumulative Energy Demand was used for Primary energy consumption.

Life cycle interpretation

Conclusions

The results indicate that in the entire life cycle (cradle-to-grave) for CC and primary energy consumption, the *Raw Material Acquisition+Production* is the biggest contributor. *Transport from Assembly Location to Use Location of the Mobile Phone is in*cluded in the Production stage contribution according to clause 5.2.2.2.3. B1.2 assembly accounts for less than 5 % of the total impact for CC. The *Use stage* contributes to around 20 % of the total CC and the percentage is dependent on the usage scenario and charger used.

Uncertainty

The uncertainty range for the *Use stage* CC score is around +/-5 % whereas the *Raw Material Acquisition and Production* stages together show approximately a +/-40 % uncertainty range.

Sensitivity analyses

By contribution analysis the most contributing elementary LCI flows and unit processes were identified for each impact category. Subsequently models applied and the data used were assessed with respect to accuracy and candidates bound for sensitivity analysis were identified, e.g.:

- Good die area of ICs.
- Transport distance by Air from Assembly Location to Use Location.
- Other transports than Air for the above distance.

Moreover, the sensitivity of the cut-off of B1.1.11, some transports in Production, some transports, Raw Material consumptions and Electricity consumptions within EoLT, EoLT activities (D3) was tested by inserting a range of approximations from literature and previous studies for B1.1.11, material consumptions and electricity consumptions for D2.1, D2.2.2.1, D2.2.2,4-5, and Road transport distances for the transports.

These sensitivity analyses revealed that the conclusions were stable and the absolute values for CC and CED did not increase by more than 5 %.

Reporting

All omissions and deviations towards the present document are transparently reported. As the aim is to assess the mobile phone as such the selected reporting is based on the lifetime. Per year calculations can be made if needed. Furthermore the reporting formats of the present document are used in the final report. Due to LCA tool/LCI database limitations the *Raw Material Acquisition*, *Production* (including Transport from Assembly Location to Use Location) is reported together.

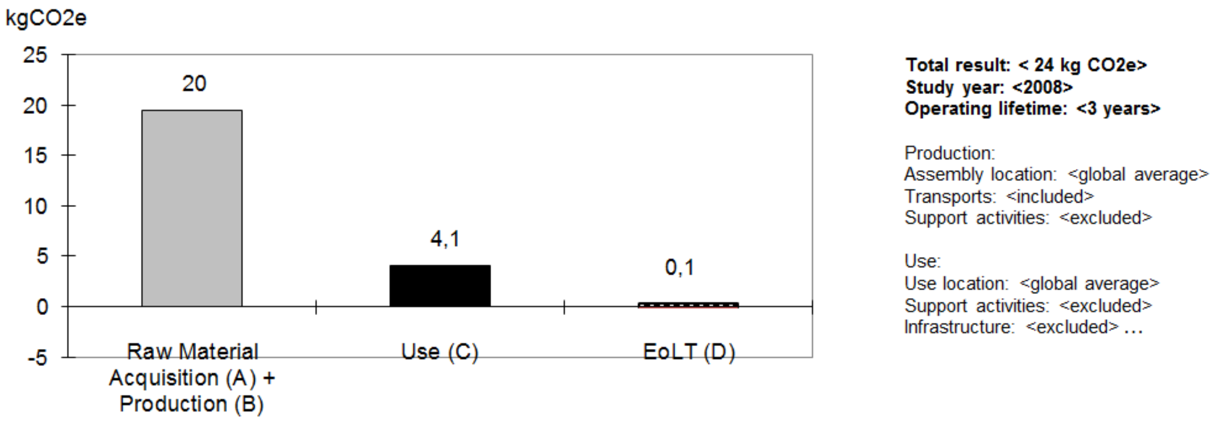


Figure O.9:GWP100 result diagram example for Mobile Phone for Mandatory activities/processes (diagram for Global Warming Potential (GWP100) (CO2e)

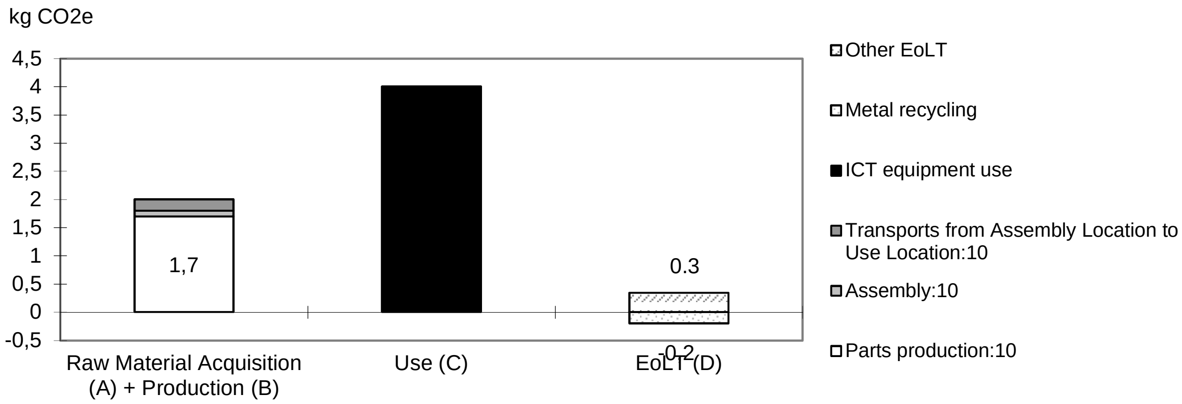


Figure O.10: GWP100 result: distribution between sub-unit processes within each life cycle stage per functional unit for Mobile Phone

Table O.11: Life cycle stages, activities and generic processes for Mobile Phone

Tag	Life cycle stage	Unit process	Included (Yes/No)	Electricity mix (specific/country/world average	Support activities included (Yes/No)	Transport activities included (Yes/No)	Other generic activities included (Yes/No)	Motivation/Comment
A	Equipment Raw Material Acquisition							
A1	Raw material extraction		Yes	Specific electricity mixes were defined by LCI database.	No	No	Yes	Transports and energy mixes are transparent from LCI databases used for Iron/Steel, Aluminium, Copper, Gold and Silver and all other applicable Raw Material Groups from Table D.1
A2	Raw material processing		Yes	Specific electricity mixes were defined by LCI database.	No	No	Yes	Transports and energy mixes are transparent from LCI databases used for Iron/Steel, Aluminium, Copper, Gold and Silver and all other applicable Raw Material Groups from Table D.1
B	Production							
B1	ICT equipment production							
B1.1		Parts production	Yes	World	No	Yes	Yes	B1.1.11 is cut-off. Tested in sensitivity analysis. As all Parts are considered as global averages no separate Part reporting is made here.
B1.2		Assembly	Yes	World	No	Yes	Yes	Transport to Use Location is included
B1.3		*ICT manufacturer support activities*	*No*	*World*	*No*	*No*	*No*	
B2	Support equipment production							
B2.1		Support Equipment manufacturing*	*No*					
B3		ICT specific site construction	*No*					

Tag	Life cycle stage	Unit process	Included (Yes/No)	Electricity mix (specific/country/world average	Support activities included (Yes/No)	Transport activities included (Yes/No)	Other generic activities included (Yes/No)	Motivation/Comment
C	Use							
C1	ICT equipment use		Yes	World	No	No	No	
C2	*Support equipment use*		*No*					
C3	*Operator activities*		*No*					
C4	*Service provider activities*		*No*					
D	Equipment End of Life Treatment							
D1	Re-use of ICT Equipment		*No*					
D2	ICT specific EoLT							
D2.1		Storage/Disassembly/Dismantling/ Shredding	Yes	World	No	Yes	Yes	G1, G2, G5 Cut-off. Tested in sensitivity analysis.
D2.2		Recycling	Yes	World	No	Yes	Yes	G1, G2 and G5 Cut-off for D2.2.2, D2.2.4-5. Tested in sensitivity analysis.
D3	Other EoLT		Yes	World	No	Yes	Yes	Cut-off. Tested in sensitivity analysis.

Table O.12: Generic processes per functional unit for Mobile Phone

Generic process	Generic process categories included	Unit processes included (for each generic process category)	Important issues
G1. Transports & Travel	Road Air	Direct (during transport) emissions Fuel supply chain (the Raw Material Acquisition, Production and Transport of the Fuel)	No travel included
G2. Electricity	World electricity mixes	Fuel supply chain, Direct emissions (during electricity production)	
G3. Fuels	Oil Diesel Petrol Jet-fuel Coal Gas	Fuel supply chain: Extraction and Production	
G4. Other energy			
G5. Raw material acquisition	See Table D.1 Annex D	Extraction Processing	e.g. Nitrogen gas (N_2) used in B1.1.4, solder paste used in B1.2. Paper additives and plastic additives are data gaps.
G6. End-of-life treatment	Landfill	One "site LCI model" for landfill site	Cut-off.
G7. Raw material recycling	Metal recycling	Smelting Refining	

Raw Materials marked Bold and underlined are included A1-A2 or G5 Raw Materials. Raw Materials marked with *Italic* style are not applicable to the studied product system.

Table O.13: Raw material acquisition processes to be included in LCA of ICT Equipment if applicable to the studied ICT product system

Chemicals
<u>Nitrogen gas (N2)</u>
<u>Oxygen gas (O2)</u>
<u>Hydrogen gas (H2)</u>
<u>Argon gas (Ar)</u>
Acetone
CaO
H2SO4
<u>H2O2</u>
HydroCloric Acid (HCl)
FeCl3
<u>IsoPropyleneAlcohol</u>
<u>Ethylene glycol</u>
HydroFluoric acid
<u>H3PO4</u>
HNO3
<u>NaOH</u>
...
...
Fuels
Heating oil
Bunker oil / ship diesel
<u>Diesel</u>
<u>Petrol</u>
<u>Jet fuel</u>
LPG
LNG
"Biofuels"
...
...

Metals and alloys
Aluminium
Brass
Bronze
Cadmium
Chromium
Copper
Gold
Lead
Lithium
Magnesium
Mercury
Nickel
Palladium
Platinum
Silicon
Silver
Solder - SAC
Solder - Sn/Pb
Solder - SnZn
Steel - Cr3+ plated
Steel - powder coated
Steel - zinc plated
Steel - stainless steel
Tin
Zinc
Hard metal (W-Co)
....
....
Others
Concrete
Packaging materials
Ceramics
Paper
Cardboard
Wood
Wood board
Glass
Glassfibre
...
....
Plastics
Acrylonitrile butadiene styrene (ABS)
Epoxy
Polycarbonate (PC)
Polyethylene (PE) - HD
Polyethylene (PE) - LD
Polypropylene (PP)
Polystyrene (PS)
Polyurethane (PUR)
Polyester (e.g. PET)
PVC
Silicone rubber
Styrene acrylonitrile (SAN)
PA (Nylone)
PTFE (Teflone)
PMMA
…
…
Additives and others
Brominated flame retardants (e.g. TBBP-A)
Sb2O3
Be in alloys ...and similar
Paper additives

Plastic additives
High purity grades of materials/chemicals and gases
Cooling media, fire extinguisher media (High GWPs/ODPs)
…

Table O.14: Transports/travel per functional unit

Mode	CO_2 emission factor	Raw material acquisition transports		Production stage transports excluding final transport		Final transport (Production to use stage)		Use stage transports		EoLT transports		Total travels	
		Transport work{ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	Transport distance {km}	Transport distance {km}	GWP 100 {kg CO_2e}	Transport work {ton×km}	GWP 100 {kg CO_2e}	Transport distance {km}	GWP100 {kg CO_2e}
Air	1 kg CO_2e/ [ton×km]					2	N.A.	N.A.				N.A.	N.A.
Other	Cut-off						N.A.	N.A.				N.A.	N.A.

Table O.15: Parts production

	Part categories included	Part Unit processes included	Handling of special issues
B1.1.1 Batteries	Lithium batteries	Raw Material Acquisition, Battery cell assembly, Battery module assembly	The LCI model was based on energy content according to Table B.1
B1.1.2 Cables	N.A.	N.A	
B1.1.3 Electro-mechanics	Connectors	Raw Material Acquisition, Part final assembly	
B1.1.4 Integrated circuits (ICs)	Processors, DSPs ASICs Memories Microprocessors Transistors and diodes	Front-end: Special IC materials production, Wafer production, Chip production ("the wafer fab") Back-end: IC encapsulation	Package type for each Part and Good die area for each Part → Load Per B1.1.4
B1.1.5 Mechanics / materials	Fronts Frames Solder Nuts, bolts	Raw Material Acquisition, Part final assembly	
B1.1.6 Displays	LCD	Raw Materials Acquisition Raw Materials Acquisition for special display panel materials, Display module assembly, Display panel assembly,	
B1.1.7 Printed circuit boards (PCBs)	Plastic, FR4 type	Raw materials Acquisition for special PCB materials, Raw materials Acquisition for PCB semi-produced composite materials, PCB final assembly	
B1.1.8 Other PBA components			
B1.1.9 Packaging materials	Paper, Cardboard , Plastic	Raw Material Acquisition for Paper, Cardboard, Polyurethane (PUR)	
B1.1.10 Black box modules	Camera	"Cradle-to-gate" LCI data set from ICT manufacturer	
B1.1.11 Software			Cut-off

Table O.16: Use stage energy consumption per functional unit

	Energy consumption {kWh}	**Source {long term average/standardized measurement/ modelled**	**Motivation/ comment**
ICT equipment	5.3	Measured/Modelled by ICT manufacturer	Simplified purpose of LCA study
Support equipment	*Not included*		

Table O.17: EoLT per functional unit

	Process categories included	Process Unit processes included	Handling of special issues
EHW treatment	EHW (destruction and energy "recovery") Special EHW landfill	In general: "Recovery"/"treatment" (one unit process or "site LCI model" for the entire EHW category)	Handled as Cut-off
Other Waste treatment	Diverse "recycling" Energy "recovery" (e.g. incineration) Landfill	In general: "Recycling"/"recovery"/"treatment" (one unit process or "site LCI model" for each material/ waste category)	Handled as Cut-off

Table O.18: LCI results per functional unit

	TOTAL	Raw materials acquisition ***and*** EoLT ***and*** Production	Use
Primary energy use	330 MJ	280 MJ	50 MJ
Total electricity use	33 kWh	28 kWh (obtained by relation proxy between Primary energy and global average electricity, 2,76:1)	5,3 kWh
Land use	0,11 m^2 ×years	0,088 m^2×years	0,022 m^2×years
Fresh water use	0,18 m^3	0,15 m^3	0,03 m^3

Table O.19: Impact category indicators per functional unit

Mid-point Impact Assessment Categories included	Impact category indicator value	LCIA methodology reference
CC	24 kg CO_2e	Mid-point Category indicator: Infrared forcing as GWP100, IPCC as used by ReCiPe MidPoint (H) V1.05

Table O.20: Matrix for data quality assessment applied to Mobile Phone LCA

Data Quality Indicator	Applicable section	Comment
Methodological appropriateness and consistency	Entire specification	The applied LCI methods and methodological choices are in line with the goal and scope of the data. The methods have been applied consistently across all data.
Completeness	5.2.3	95 % of applicable LCI flows in Table E.1 are included in the LCI. The degree of coverage of the RDMR LCIA indicator in Table F.10 is 90 % based on mass.
Uncertainty	5.5	The variability of the data elements used in the LCA is low enough.
Acquisition method	5.2.4	Some of the data used have been directly measured such as the number of Parts. None of the data used are nonqualified estimations.
Supplier independence	5.2.4	Most of the data used are Independent source but based on unverified Information. Verified data from independent source to No unverified information has been used.
Data representativeness	5.2.4	"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.
Data age/timeliness	5.2.4	Most data used are <6 years old No data has been used for which the age were unknown.
Geographical correlation	5.2.4	"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.
Technological correlation	5.2.4	"Data from process studied of the exact company" is used for Assembly and Use stage electricity. "Data from process studied of company with similar technology" is used for Battery production.
Rule of inclusion/exclusion (Elements/Flows/Unit process)	5.2.3	The cut-off criteria were homogeneously and transparently applied.

O.4 Networks

O.4.1 Fibre To The Home

This example shows an LCA of a *Network* performed by an *Operator.*

Goal definition:

The goal of this example LCA study is to clarify and understand the environmental impact of a FTTH *Network* during all stages of the lifecycle by estimate Climate Change (CC) and Acidification (A) mid-point impact category indicators for a FTTH Network *during its lifetime.*

The purpose of the LCA study is for external use in order to promote the *Network* and have a basis for further improvements.

Scope definition:

The studied product system is one *Network* of *FTTH type* providing typically 100 MB/s for 10 000 homes. Except the operation system software programs, it physically consists of building blocks such as: Cables, OLT, HGW, and, pipes.

Other related equipment, which are not part of the studied product system are: LAN switches, routers, optical splitters, and end-user equipment PC or TVs.

The **applicable functional unit** is *Annual Network use.*

The packaging material related with parts production and assembly is included.

OLT and HGW details needed for the LCA are based on primary data from ICT manufacturers.

The assessment scope is also focused on direct operations and therefore infrastructure capacity buildings (like factories, roads, vehicles and telecommunications) are excluded. Also capital goods, like production machinery are excluded.

The assessed FTTH is deployed in Italy. The geographical and temporal coordinates vary dynamically for the Raw Material Acquisition and Production of the *ICT Equipment* featuring in the FTTH. The presented results for Raw Material Acquisition and Production will therefore represent a global average but deployment and use in Italy.

System boundaries

Table 1 specifies the mandatory and optional life cycle stages/unit processes for *Networks.* Below is listed the life cycle stages included in this LCA.

A1
A2
B1.1
B1.2
B2.1
B3
C1
C2
C3
D2.1
D2.2
D3
D1 and C4 are not applicable to the studied product system.

Support activities except C3 are not considered for any unit processes because of lack of data and models.

Underlined Processes below in Figure O.11 were included in the studied product system.

Processes below in *italic* style were not included as they are optional or not part of the studied product system scope.

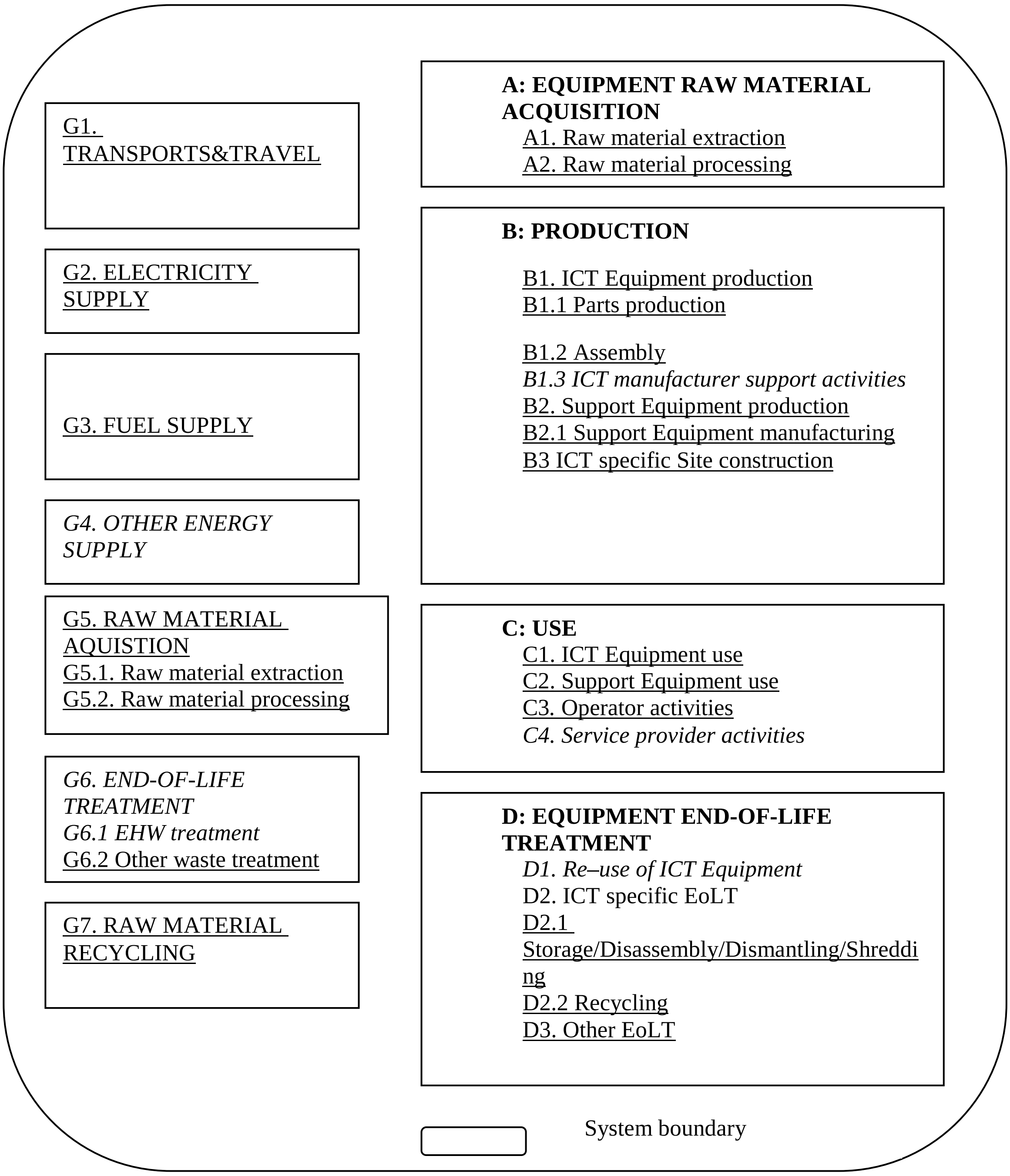


Figure O.11: The system boundary of the product system for LCA of the FTTH Network

Figure O.12 shows a product system flowchart showing where the generic re-occurring processes are used. Boxes in which the text is marked underlined and bold type style are modelled whereas boxes marked with *italic* style are cut-off. These *italic* processes are *within* the studied product system but are cut-off.

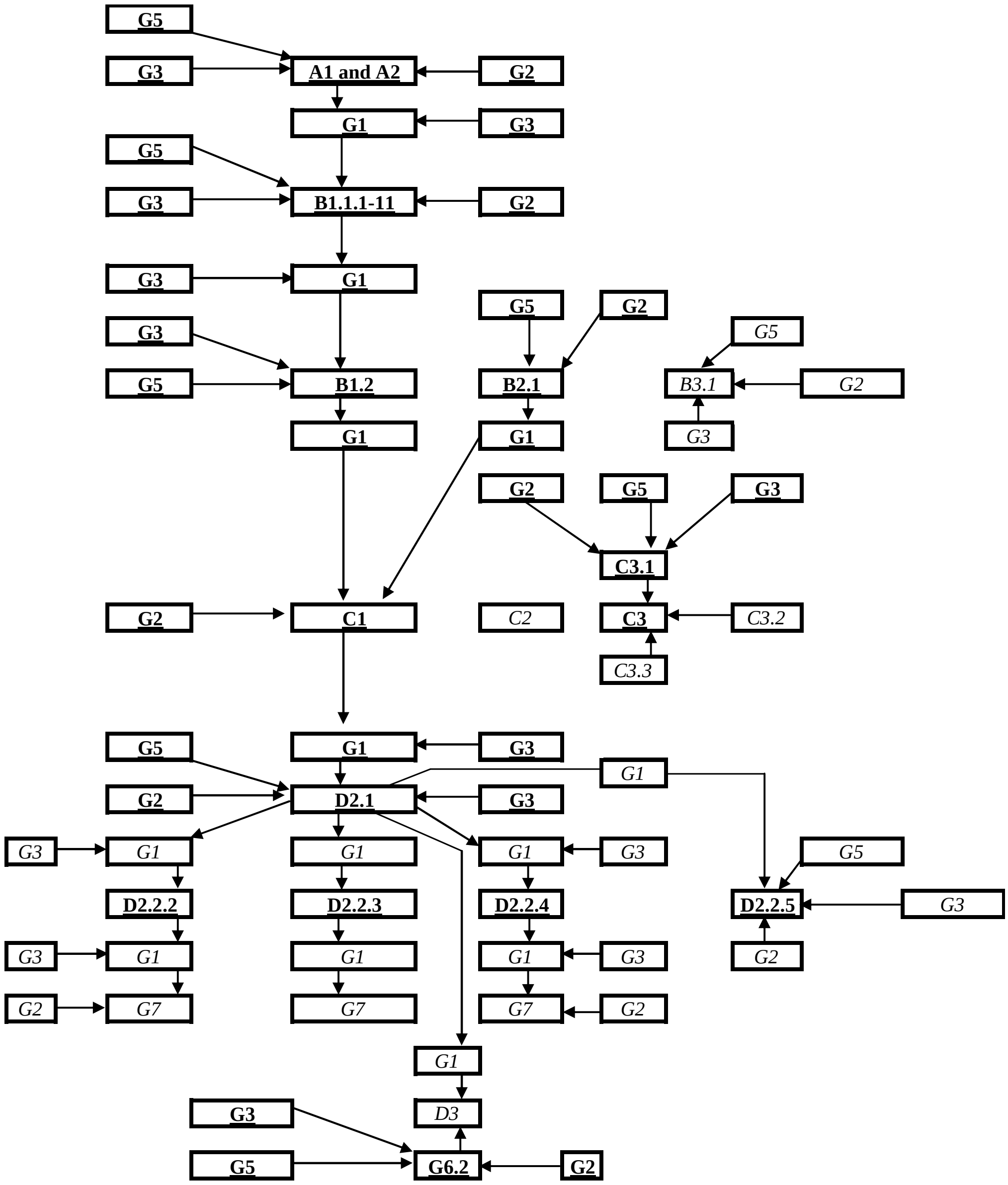


Figure O.12: The system boundary of the product system for LCA of the FTTH Network | showing connections with generic processes

Data collection

Equipment Raw material acquisition

Selected external data bases were used for raw material extraction and raw material processing data for activities under the financial or operational control of the Operator.

Production

Primary data were collected from suppliers for Raw Material Acquisition and Production of ICT Equipment.

Use

Energy consumption for FTTH Network use phase was measured in laboratories for OLT and HGW annually based on the second alternative in clause 5.3.1.2.1 (with certain user profile / product category) including typical use of all functionalities of the multifunctional *ICT equipment.* Energy efficiency metrics were based on relevant ETSI standards. Italy average energy mixes were used as the FTTH is intended for Italian market.

Equipment End of Life Treatment

For end-of-life (D2.2.2-5) data are based on assumptions and external data bases.

Generic processes

For transports (G1) distances and own facilities consumption (amounts) of (G2-3) primary data is used. Relevant energy mixes were used from data bases.

Other information

For raw material acquisition no transparent data on transports (G1) were available (in databases or otherwise), thus impact from these transports cannot be reported separately.

Data calculation

Here follows two examples of data calculation procedures.

B2.1 Support Equipment

In this LCA *Fibre Cables* is a *Support Equipment.* Here follows a calculation on the distance of *fibber cables* needed for 10 000 homes:

- G = number of GPONs needed for acceptable bandwidth.
- DP = primary distance optic fibre [km].
- DS = secondary distance optic fibre [km].
- L = number of links.
- RP = "Average Reduction coefficient" for primary network, is between 0.5 (best) and 1 (worst), share of links which are included under the same digging.
- RS = Average Reduction coefficient for secondary network.
- D = Digging distance deployment needed [km].
- D = G×(DP×RP+DS×L×RS).
- D for 10 000 homes.
- D = 125×(1,3×1+0,5×4×1) = 413 km.
- *C3.1 Installation.*

Here follows a calculation procedure for expressing the environmental impact of mini-trench deployment technique *per user (per home):*

- First the impact (Z) ELU per km mini-trench is calculated by quantifying the amount of concrete, plastic, bitumen (G5), fuel (G3) used per km and applying LCI databases.
- Then the amount of fibber cable/home for different types of deployment areas is established.

Table O.21: Amount of fibber cable/home for different types of deployment areas

Total distance of outdoor cable in the FTTH network (in km) per user	
	km
urban dense area	A
urban wide area	B
rural area	C

Then the shares of different deployment technologies are outlined.

Table O.22: Repartition of deployment technologies

Repartition of deployment technologies			
	urban dense area	*urban wide area*	*rural area*
Existing	A1	B1	C1
Poles	A2	B2	C2
Facade	A3	B3	C3
Traditional civil works	A4	B4	C4
Mini-trench	A5	B5	C5
	100 %	**100 %**	**100 %**

Then the shares of topologies for the deployment are outlined.

Table O.23: Deployment topology scenarios FTTH

These results are for a deployment scenario made of A6 % in urban dense areas, B6 % in urban wide areas and C6 % in rural areas.	
urban dense area	A6 %
urban wide area	B6 %
rural area	C6 %

Mini-trench distance per user [km]: A6×A5×A+B6×B5×B+C6×C5×C.

Mini-trench impact per user: Mini-trench distance per user [km] × Z.

Mini-trench distance per user for some scenario [km]: 0,6×0,2×0,014 + 0,3×0,3×0,083 + 0,1×0,24×0,28 = 0,016 km.

Mini-trench impact per user: 0,016 [km] × 18 000 ELU/km = 290 ELU/user.

Allocation of data

Raw material acquisition

The allocation performed for the database data used was not transparently reported by the database. For Equipment Raw material acquisition the ICT manufacturer LCI were used.

Production

ICT manufacturer LCIs were used and these were compliant with the present document. As the "internet backbone" was not part of the studied product system, no allocations had to be done of, e.g. transmission equipment, core nodes and data centers, to the studied FTTH Network.

Use

There is no allocation need in use stage in this study.

Equipment End of Life Treatment

Fibre Cables: For D3 is G6.2 considered. Landfill 50 %, Incineration 50 %.

HGW: D2.1 and D2.2.2 are included. The Storage/Disassembly/Dismantling/Shredding and Recycling facility allocation was done per mass.

OLT: D2.1, D2.2.2-5 are considered. The facility allocation was done per mass.

Generic processes

See Raw material acquisition and Production.

Support activities:

No support activities have been included except C3.1 (Installation, i.e. Deployment of the FTTH Network). The allocation as done per meter deployed fibber cable.

Cut-off

Two cut-off criteria were set: 1 % based on mass of the total input Product (Raw Materials + ICT Equipment + Support Equipment) mass flow, and 5 % addition to the first iteration LCA score for CC and A. That is, if the excluded activities/processes did not increase the total CC and A scores with more than 5 % the cut-off criteria was justified. Cumulative effect also was considered and complies with the criteria.

Based on these criteria several cut-offs were done from the studied product system: B1.1.9-11, B2.1 (air conditioners for OLT), B3 (ICT specific Site construction for OLT facility), C2 (Air conditioner use), C3.2 (Maintenance of the Network), C3.3 (De-installation), EoLT transports, EoLT activities, G7 (Raw Material Recycling), D3 for Concrete and Plastics.

Data quality

- Methodological appropriateness and consistency.

The applied LCI methods and methodological choices are in line with the goal and scope of the data. The methods have been applied consistently across all data.

- Completeness (total LCA level).

93 % of applicable LCI flows in Table E.1 are included in the LCI. The degree of coverage of the (A) LCIA indicator in Table F.10 is 99 % based on mass.

- Uncertainty.

The variability of the data elements used in the LCA is low enough.

- Data representativeness.

- Data age (timeliness).

- Acquisition method.

Some of the data used have been directly measured such as the number of Parts. None of the data used are nonqualified estimations.

- Supplier independence.

Most of the data used are Independent source but based on unverified Information. Verified data from independent source to No unverified information has been used.

- Geographical correlation.

"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.

- Technological correlation.

"Data from process studied of the exact company" is used for Assembly and Use stage electricity. "Data from process studied of company with similar technology" is used for Battery production.

- Cut-off rules (rules of inclusion/exclusion).

The cut-off criteria were homogeneously and transparently applied.

LCIA

The following impact categories were included: CC, A.

The impact assessment methods applied were: "ReCiPe Midpoint (E) V1.05' "Climate Change" for CC and "Terrestrial acidification" for A.

Cumulative Energy Demand was used for Primary energy consumption.

Life cycle interpretation

Conclusions

The results indicate that in the entire life cycle (cradle-to-grave) for CC and (A) the *Use stage* and *Installation* are the biggest contributors. C3.1 Installation accounts for 37 % of the total impact for CC and 50 % of (A). The End-user Equipment *Use stage* contributes to around 54 % of the total CC and 34 % of (A).

The percentages are mostly dependent on the usage scenario (full power vs. low power) and distance fibre cables installed (deployed) per day.

Uncertainty

The uncertainty for the Use stage and Installation is relatively low whereas the Raw Material Acquisition and Production stages have relatively large inherent uncertainty.

Sensitivity analyses

By contribution analysis the most contributing elementary LCI flows and unit processes were identified for each impact category. Subsequently models applied and the data used were assessed with respect to accuracy and candidates bound for sensitivity analysis were identified, e.g.:

- Distance installed cable per day.
- HGW Use stage power usage.

Below is shown a figure for these candidates for sensitivity analyses.

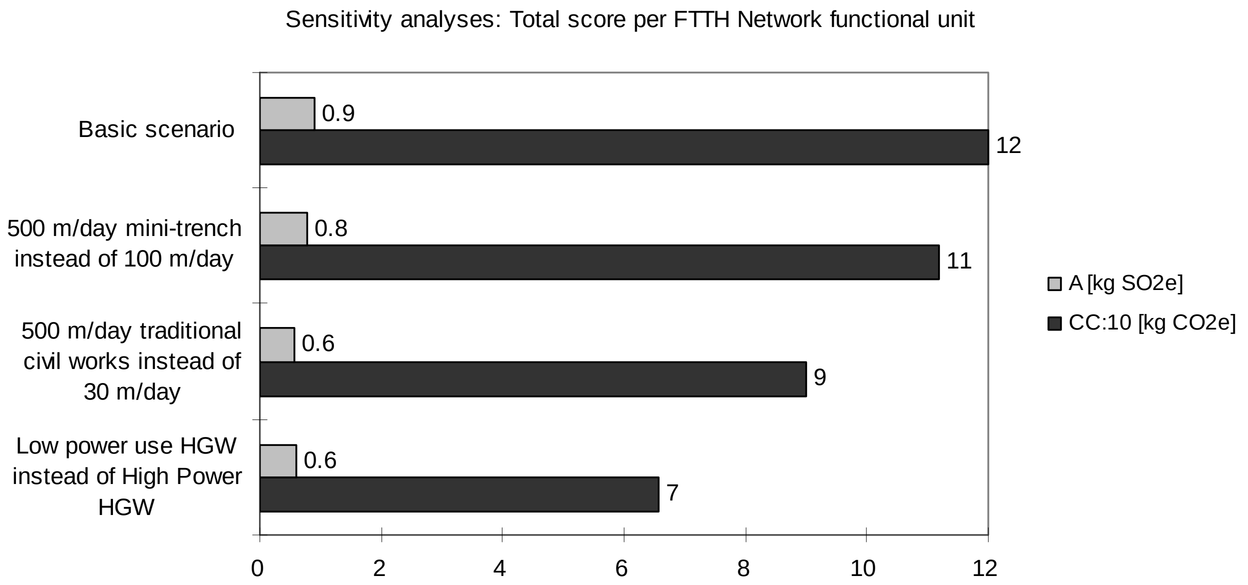


Figure O.13: Sensitivity analyses for FTTH Network LCA

Moreover, the sensitivity of the cut-off of:

- B2.1 (air conditioners for OLT);
- B3 (ICT specific Site construction for OLT facility);
- C2 (Air conditioner use);
- C3.2 (Maintenance of the Network);
- C3.3 (De-installation);
- some EoLT transports;

- G7 (Raw Material Recycling);
- D3 for Concrete and Plastics.

These sensitivity analyses revealed that the conclusions were stable. The Use stage will be more dominant if C2 was included and C3.1 less important if a longer distance fibber cable would be installed per day.

Reporting

All omissions and deviations towards the present document are transparently reported.

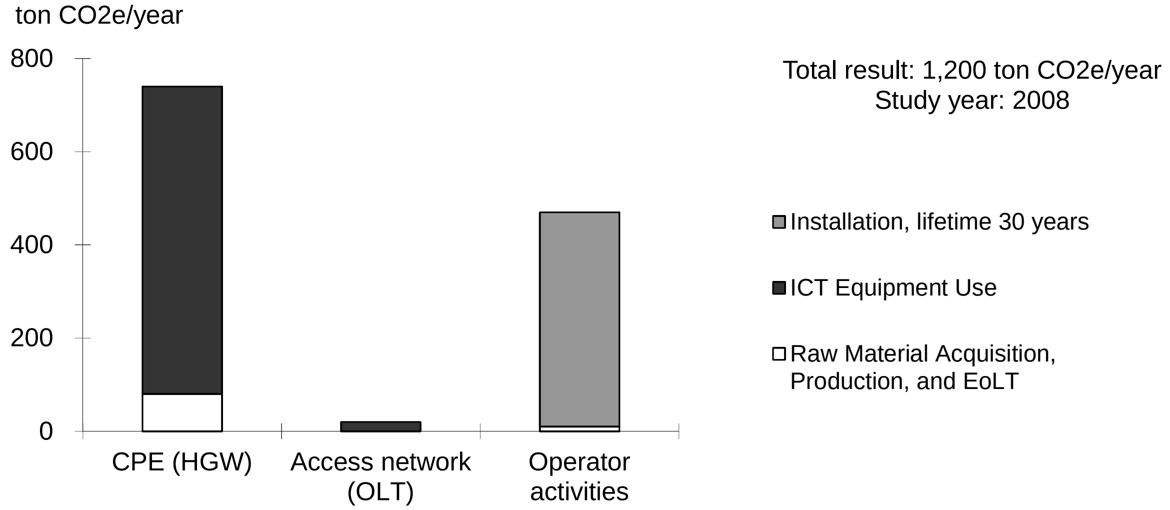


Figure O.14: Environmental impact category indicator result diagram example for FTTH Network (diagram for Global Warming Potential (GWP100) (CO_2e)

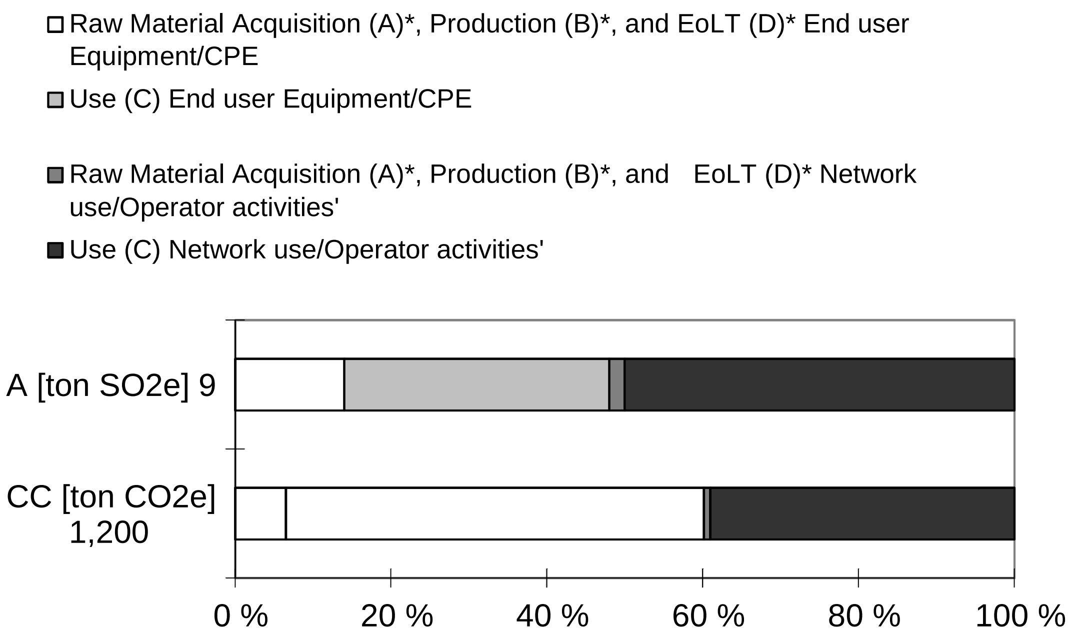


Figure O.15: Environmental impact category indicators overview for Networks

Table O.24: Life cycle stages, activities and generic processes for FTTH Network

Tag	Life cycle stage	Unit process	Included (Yes/No)	Electricity mix (specific/country/world average	Support activities included (Yes/No)	Transport activities included (Yes/No)	Other generic activities included (Yes/No)	Motivation/Comment
A	Equipment Raw Material Acquisition							
A1	Raw material extraction		Yes	Specific	No	No	No	Transports are not transparent from LCI databases used
A2	Raw material processing		Yes	Specific	No	No	No	Transports are not transparent from LCI databases used
B	Production							
B1	ICT equipment production							
B1.1		Parts production	Yes	World	No	No	No	Provided by ICT manufacturer
B1.2		Assembly	Yes	World	No	Yes	No	Provided by ICT manufacturer
B1.3		*ICT manufacturer support activities*	*No*	*World*	*No*	*No*	*No*	
B2	Support equipment production							
B2.1		Support Equipment manufacturing	Yes	World	No	Yes	Yes	Air conditioners for OLT cut-off
B3		ICT specific Site construction	Yes	Italy	No	Yes	Yes	Facility for OLT cut-off

Tag	Life cycle stage	Unit process	Included (Yes/No)	Electricity mix (specific/country/world average	Support activities included (Yes/No)	Transport activities included (Yes/No)	Other generic activities included (Yes/No)	Motivation/Comment
C	Use							
C1	ICT equipment use		Yes	Italy	No	No	No	HGW and OLT electricity usage included
C2	Support equipment use		Yes	Italy	No	No	No	Air conditioners for OLT cut-off. Tested in sensitivity analysis
C3	Operator activities		Yes	Italy	Yes	Yes	No	Maintenance and De-installation Cut-off. Tested in sensitivity analysis
C4	*Service provider activities*		*No*					
D	Equipment End of Life Treatment							
D1	Re-use of ICT Equipment		*No*		*No*	*No*	*No*	
D2	ICT specific EoLT		Yes					
D2.1		Storage/Disassembly/Dismantling/ Shredding	Yes					.
D2.2		Recycling	Yes					G7 Cut-off. Tested in sensitivity analysis
D2.2.2		PCBA Recycling	Yes		No	Yes	Yes	G1-G3,G5 cut-off
D2.2.3		Cable Recycling	Yes		No	Yes	Yes	G1-G3,G5 cut-off
D2.2.4		Mechanics Recycling	Yes		No	Yes	Yes	G1-G3,G5 cut-off
D2.2.5		Other ICT Recycling	Yes		No	Yes	Yes	Used for OLT. G1-G3,G5 cut-off
D3	Other EoLT							
G6.1			No					G6.1 not part of studied product system
G6.2			Yes		No	Yes	Yes	G6.2 Landfill included

Table O.25: Generic processes per functional unit

Generic process	Generic process categories included	Unit processes included (for each generic process category)	Important issues
G1. Transports & Travel	Road Air	Direct (during transport) emissions Fuel supply chain	No travel included in the studied product system
G2. Electricity	World electricity mixes, Italy electricity mixes	Fuel supply chain, Direct emissions (during electricity production)	
G3. Fuels	Oil Diesel Petrol Jet-fuel Coal Gas	Fuel supply chain: Extraction and Production	
G4. Other energy			Not in included in the studied product system
G5. Raw material acquisition	See Annex 4	Extraction Processing	e.g. Concrete used in B3.1
G6. End-of-life treatment	Landfill	One "site LCI model" for landfill site	Incineration cut-off
G7. Raw material recycling	Metal recycling	Smelting Refining	Cut-off

Table O.26: Transports/travel per functional unit for FTTH Network

Mode	CO_2 emission factor	Raw material acquisition transports		Production stage transports excluding final transport		Final transport (Production to use stage)		Use stage transports		EoLT transports		Total travels	
		Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton*km}	GWP 100 {kg CO_2e}	Transport work {ton×km}	GWP 100 {kg CO_2e}	Transport distance {km}	GWP100 {kg CO_2e}
Air	1 kg CO_2e/[ton ×km]					14 000	14 000					N.A.	N.A.
Other	Road									Included in studied product system but cut-off		N.A.	N.A.

Table O.27: Parts production

	Part categories included	Part Unit processes included	Handling of special issues
B1.1.1 Batteries	N.A	N.A	
B1.1.2 Cables	Fibre cables	Raw Material Acquisition, Cable final assembly	
B1.1.3 Electro-mechanics	Connectors	Raw Material Acquisition, Part final assembly	
B1.1.4 Integrated circuits (ICs)	Processors, DSPs, ASICs, Memories Microprocessors Transistors and diodes	Front-end: Special IC materials production, Wafer production, Chip production ("the wafer fab") Back-end: IC encapsulation	Package type for each Part and Good die area for each Part → Load Per B1.1.4
B1.1.5 Mechanics / materials	Fronts Frames Solder Nuts, bolts	Raw Material Acquisition, Part final assembly	
B1.1.6 Displays	N.A.	N.A.	
B1.1.7 Printed circuit boards (PCBs)	Plastic	Raw materials Acquisition for special PCB materials, Raw materials Acquisition for PCB semi-produced composite materials, PCB final assembly	
B1.1.8 Other PBA components	Resistors Capacitors Inductors Relays LEDs Potentiometers Quartz crystal oscillators		
B1.1.9 Packaging materials			Cut-off
B1.1.10 Black box modules			Cut-off
B1.1.11 Software			Cut-off

Table O.28: Use stage energy consumption per functional unit

	Energy consumption {kWh}	Source {long term average/standardized measurement/ modelled	Motivation/ comment
ICT equipment	1,050,000	Measured/Modelled by Operator according to ETSI standards	All energy is electricity of which most is for HGWs.
Support equipment	Cut-off		Fibre Cables is the only included Support Equipment. Air conditioner and Power Supply Systems are cut-off

Table O.29: EoLT

	Process categories included	Process Unit processes included	Handling of special issues
EHW treatment	EHW (destruction and energy "recovery") Special EHW landfill	In general: "Recovery"/"treatment" (one unit process or "site LCI model" for the entire EHW category)	Cut-off
Other Waste treatment	Landfill	One "site LCI model" for landfill	Diverse "recycling" and Energy "recovery" (e.g. incineration) are cut-off

Table O.30: LCI results per functional unit fort FTTH Network

	TOTAL	Raw materials acquisition *and* EoLT *and* Production	Use
Primary energy use	19 000 GJ	8 800 GJ	10 200 GJ
Total electricity use	1 450 MWh	400 MWh	1 050 MWh
Land use	13 000 m^2×years	6 900 m^2×years	4 900 m^2×years for electricity and 1,300 m^2×years for installation
Fresh water use	3 300 m^3	900 m^3	1 800 m^3 for electricity and 600 m^3 for installation

Table O.31: Impact category indicators per functional unit

Mid-point Impact Assessment Categories included	Impact category indicator value	LCIA methodology reference
A	9 ton SO_2e	Mid-point Category indicator: Infrared forcing as GWP100, IPCC as used by ReCiPe MidPoint (E) V1.05
CC	1 200 ton CO_2e	Mid-point Category indicator: Infrared forcing as GWP100, IPCC as used by ReCiPe MidPoint (E) V1.05

Table O.32: Network description per functional unit

End-user and CPE	Included ICT Equipment	Included infrastructure	Quantity [unit]	Operating Lifetime [year]
End-user equipment				
CPE	HGW	None	2 000 [p]	5
Operator Network and activities				
Access network	OLT	None	1 [sites/10 000 subscribers]	5
Control & core network	Not Applicable to the studied product system (N.A.)	N.A	[nodes/10 000 subscribers]	
Operator activities			[employees/10 000 subscribers]	30
Data Services				
Data transport	N.A.	N.A.	GB/10 000 subscribers	
Data centre(s)[3]	N.A.	N.A.	GB/10 000 subscribers	
Service provider(s) activities	N.A.	N.A.	employees/10 000 subscribers	

Table O.33: Reporting format for Network Energy consumption per functional unit

End-user and CPE	ICT equipment energy consumption	Support equipment energy consumption	Source {long term average/ standardized measurement/ modelled}
End-user equipment	2 750 MWh (CED)		ETSI standards used for power measurement
CPE			
Operator Network and activities			
Access network[1]	100 MWh (CED)		ETSI standards used
Control & core network			
Operator activities	2 100 MWh (CED)		
Data Services			
Data transport[2]	N.A.	N.A.	N.A.
Data centre(s)[3]	N.A.	N.A.	N.A.
Service provider(s) activities	N.A.	N.A.	N.A.

Table O.34: Matrix for data quality assessment applied to FTTH Network LCA

Data Quality Indicator	Applicable section	Comment
Methodological appropriateness and consistency	Entire specification	The applied LCI methods and methodological choices are in line with the goal and scope of the data. The methods have been applied consistently across all data.
Completeness	5.2.3	93 % of applicable LCI flows in Table E.1 are included in the LCI. The degree of coverage of the (A) LCIA indicator in Table F.10 is 99 % based on mass.
Uncertainty	5.5	The variability of the data elements used in the LCA is low enough to enable robust conclusions.
Data representativeness	5.2.4	"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.
Data age/timeliness	5.2.4	Most data used are < 6 years old. No data has been used for which the age were unknown.
Acquisition method	5.2.4	Some of the data used have been directly measured such as the number of Equipment and Fuel consumption for diesel machines. None of the data used are nonqualified estimations.
Supplier independence	5.2.4	Most of the data used are Independent source but based on unverified Information. "Verified data from independent source" to "No unverified information has been used".
Geographical correlation	5.2.4	"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from an area with similar production conditions" is used for the Use stage.
Technological correlation	5.2.4	"Data from process studied of the exact company" is used for Assembly and Use stage electricity. "Data from process studied of company with similar technology" is used for Battery production.
Rule of inclusion/exclusion (Elements/Flows/Unit process)	5.2.3	The cut-off criteria were homogeneously and transparently applied.

O.4.2 3G mobile network of operator

This example shows an LCA of a Network performed by an ICT manufacturer and an Operator.

This example does not follow the structure of tables reported in Annex F, but is just an example of application of methodology defined in the present document.

This example shows the implications from the present document on an LCA of a 3G mobile network performed by an ICT manufacturer and a telecom operator in cooperation.

The example is not aiming to outline all details of an LCA but to support the reader in interpretation of some important areas of the present document. For compliance with the present document all body text and annexes needs to be considered when performing an LCA, i.e. the example is not giving full information for specification compliance. References are not written out, only indicated in this example.

Goal definition:

The primary goal of the study was to assess the total energy consumption and Green House Gas (GHG) emissions, related to the 3G network part and the shared data services of the ICT network and to services of operator X.

Additionally other environmental impact categories, e.g. human and eco-system toxicity were assessed.

Scope definition:

The study object is the 3G networks of operator X including operator activities, which in addition to the network itself also covers the data transport, data centres and end-user equipment (phones and laptops), see table O.35.

A description of the system and its structure is given in Table O.35 together with quantities and life times which are presented per subscription.

Home network equipment for the 3G network (e.g. fixed wireless terminal), and service provider activities were not included in the scope. (For home network equipment limited impact was estimated due to their assumed low quantities. Service provider activities were excluded as being not part of the operation of the assessing organizations.)

Table O.35: 3G network description

End User equipment and CPE	Included ICT Equipment	Included infrastructure	Quantity [unit]	Lifetime [year]
End User equipment	a. Regular phones b. Smartphones c. Laptops (50 % of use and production/ EoLT allocated to 3G network use)	Electricity infra-structure included in all life cycle stages (true for all items in this table)	1 UE per subscription: a. 37,5 % b. 37,5 % c. 25 %	3 years for phones, 4 years for laptops
CPE	Not applicable	-	-	-
Operator ICT network and activities				
Access network	Base station (cabinets), transmission, battery equipment on site and antennas and antenna feeders	Antenna towers, foundations and site shelters are included as a main part of the network and not as a separate infrastructure item	X [sites/sub] Y % antenna tower equivalents (after sharing has been taken into account)	10 years for base station equipment, 20 years for antenna towers and site shelters
Control & core network	All C&C nodes (cabinets): RNC, MSC, HLR, SGSN, GGSN etc.	Telecom centre/site building including cooling and power infrastructure	Z [nodes/sub]	10 years for equipment
Operator activities	Offices, stores, vehicles (also 3rd part services), travel, commuting			n.a.
Data ICT Services				
Data transport	Transmission link equipment, both dedicated and shared, and IP edge/metro/ core network	Cable deployments are included as a main part of the network and not as a separate infrastructure item	M [GB/sub]	10 years for equipment, up to 40 years for cable deployments
Data centre(s)3	Servers, storage and data network equipment in data centres (or rooms) Submarine cables and IP core network for international traffic	Data centre building including cooling and power infrastructure Cable deployments (see above explanation)	N [GB/sub]	5 years for servers
Service provider(s) activities	Not incl.	-	-	-

General requirements

The various operating lifetimes are estimated to be from 3 years for mobile phones up to 40 years for cables infrastructure, see above.

Extended operating life time has been included by taking into account the whole life time, disregarding the number of consecutive users of various equipments.

Functional unit

The functional unit is one year of operation of the 3G network of operator X.

For the reporting also one year of primary 3G network subscription service provided by operator X which is the basic functional unit expressed per (average) subscription/user, short subyear.

As the intention was to study only the actual system and as no comparisons were planned it was not necessary to detail the traffic further in this LCA.

System boundaries

All unit processes and parts outlined in figure O.16 have been included except service provider activities (C4.).

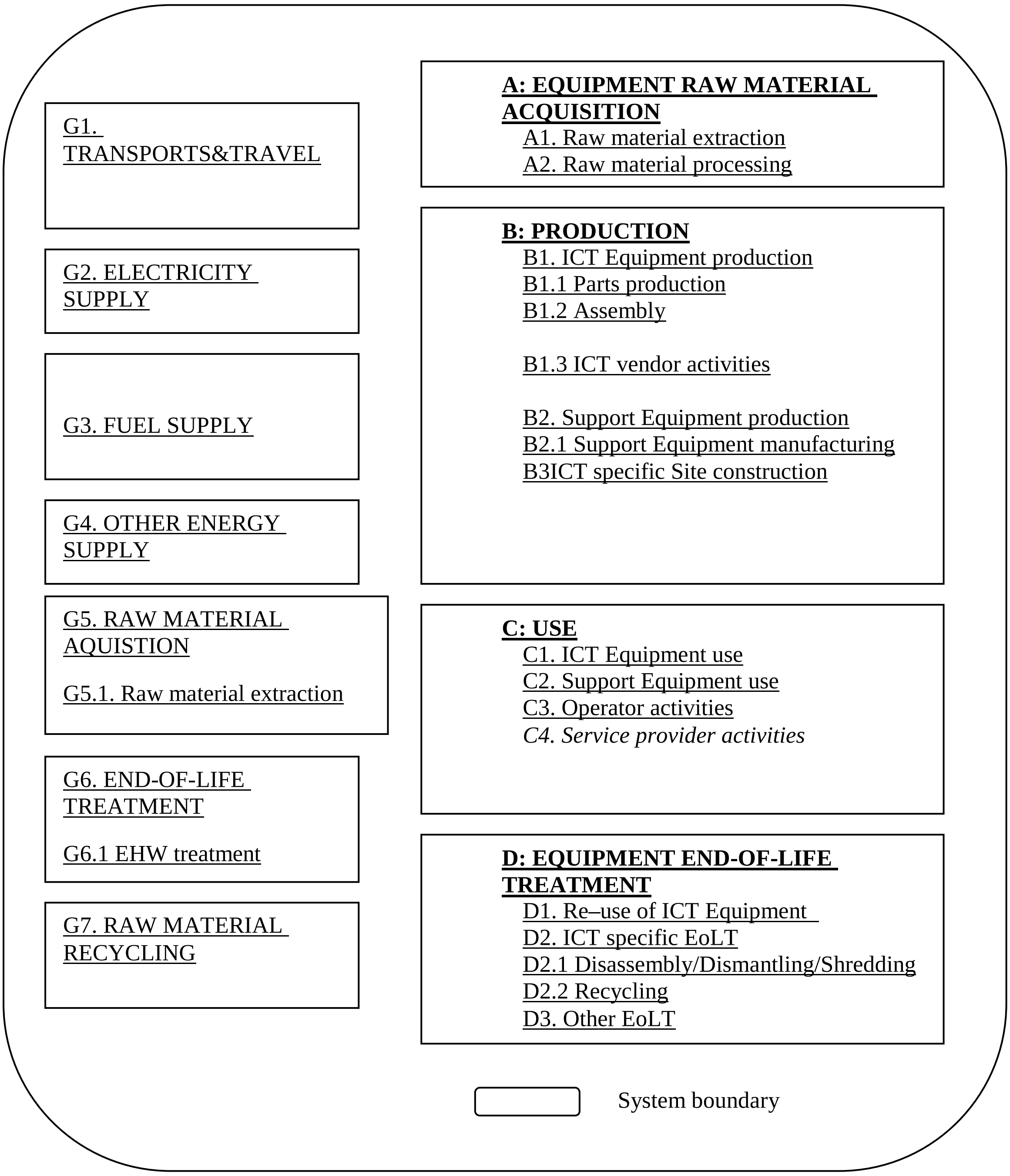


Figure O.16: System boundaries of the product system for LCA of 3G Network

Infrastructure related to generic activities (G1 to G7) has been included for life cycle impact of electricity use but not for transports and travel (i.e. vehicles, roads, airports etc) and not for district heating energy supply (power plants, pipes etc. in other energy supply, G4).

Support activities have been included for the operator and the equipment manufacturer and for 1st tier suppliers of phones. For other activities the extent to which support activities are included is unknown.

Infrastructure related to the 3G and shared ICT networks is included, e.g. antenna towers and their concrete foundations, land and submarine cable deployments and dedicated site shelters and buildings. The construction of office buildings and factories is not included.

Data collection and data sources

This study is partly based on several LCA studies that have been carried out by the ICT manufacturer and telecom operator earlier. This is applicable e.g. for mobile phones and submarine optical cable systems.

In addition to these LCAs, a number of other LCA studies regarding user equipment have been reviewed for validation f figures, e.g. mobile phones, smartphones and laptops.

Both top-down and bottom-up data collection approaches have been used to quantify network equipment and energy consumption.

The top-down data collection includes energy measurements of large data/telecom centres, office locations, stores and a majority of the facilities of operator X.

The bottom-up approach is based on investigations of equipment databases containing all network equipment based on which relevant energy consumption models have been created.

In addition to the network top-down and bottom-up data collection approaches, data was collected related to life time, energy consumption of laptops in homes, data traffic, etc.

Generic processes/data

Secondary data was used for G1 to G7. The EoLT data (G6, D) is based on industrialized "best in class" conditions. The data includes EHW treatment and aspects of recycling of ICT products: disassembly, shredding, valuable metal recycling, etc., from different fractions (PBA, batteries, cables etc.).

Table O.36: Network data sources for raw material, production and EoLT and for operator activities

End User equipment and CPE	Data sources
End User equipment	Phones including sales package: [ISO reviewed LCA results of the vendor] Laptop: [Based on several external laptop studies]
CPE	Not incl.
Operator ICT networks and activities	
Access network1 Core and control network	[ISO reviewed LCA results of the vendor for base station equipment, site shelters, antenna towers and foundations or mounting poles, antennas, feeders, batteries, cooling and power systems.]
Operator activities	[External ISO reviewed data for offices, stores, business travel, service vehicles (also 3rd part services) and commuting.] Consumables like computer HW and paper have been included using secondary data
Data ICT services	
Data transport	[Primary data of operator X includes data transmission links and all IP edge/metro/core switches and routers that make up the major part of the IP backbone
Data centre(s)	[Primary data of operator X] [ICT specific secondary server data. Source Z] [ICT specific data for submarine cables]
Service provider(s) activities	Not included in the studied product system

Data collection efforts have prioritized user equipment data (mobile phones) and base station site infrastructure data (antenna towers, foundations, shelters).

Energy consumption

Table O.37: Network Energy consumption

End-user equipment and CPE	ICT equipment energy consumption (electricity)	Support equipment energy consumption	Source {long term average/ standardized measurement/ modelled}
End User equipment	Regular phone: X1 kWh Smartphone: X2 kWh Laptop: X3 kWh (figure reflects that 50 % of use is allocated to 3G network use)	Defined as stand-by consumption of chargers, included in ICT equipment, about 40 % of the total	Limited user measurements of phones and energy models provided by manufacturers, annual laptop measurements exist for 400 households and for several offices
CPE	Not incl.	-	-
Operator ICT network and activities			
Access network1	X4 kWh/subyear	Cooling, power systems, top lights etc., included in ICT equipment energy consumption, about 25 % of the total	Nearly 40 % of all sites has continuously site energy measurements (representing about 2/3 of calculated/estimated total)
Control & core network	X5 kWh/subyear	Cooling, power systems, etc., included in ICT equipment energy consumption, about 33 % of the total	All nodes are included by continuously site energy measurements
Operator activities	Included in office and store total energy consumption, operator data centres are not included here but in Data centre(s) below	X6 kWh/subyear electricity resulting in X7 kg CO2e/subyear and X8 MJ fuels/subyear resulting in X9 kg CO2e/subyear	Offices, stores, business travel, service vehicles (also 3rd part) are measured on an annual basis by the operator
Data ICT services			
Data transport	X11 kWh/subyear (allocation of 3G network share based on data traffic)	Cooling, power systems, etc., included in ICT equipment energy consumption, about 33 % of the total	The major part of the data transmission and IP edge/metro/core networks are included by continuously site energy measurements
Data centre(s)	X12 kWh/subyear (allocation of 3G network share based on data traffic)	Cooling, power systems, etc., included in ICT equipment energy consumption, about 44 % of the total	More than 10+ data centres have been studied in detail but most data centres of operator X have been estimated based on average values and the number of servers
Service provider(s) activities	Not included	-	-

3rd part equipment energy consumption have been excluded from shared sites energy measurements. It was possible to subtract 3rd part equipment by combining top-down measurements and bottom-up energy consumption models. This activity turned out to be of high importance to assess the energy consumption for the 3G access network more accurately.

Allocation of data

Operator X also uses international networks which are allocated based on data traffic.

The 50/50 allocation method for material recycling have been applied consistent throughout the study and in internal background studies except for steel infrastructure were the suppliers have a total steel life cycle model including recycling.

The allocations are detailed in Table O.38.

Table O.38: Network data calculations and allocations of importance

End User equipment and CPE	Data calculations and allocations
End User equipment	Data subscription represents about x % of all subscriptions and the user equipment is represented/modelled by a laptop. The laptop is allocated 50 % to 3G network use. Other use is connected to e.g. LAN/WLAN and offline use. It is assumed that half of the mobiles are smartphones. All phones are allocated/modelled 100 % to 3G networks.
CPE	Not incl.
Operator ICT networks and activities	
Access network1	Based on the operator equipment data an average base station model has been created with representative site material/equipment. Shared antenna towers are allocated equally. (between the operators/technologies).
Control & core network	Control and core nodes are located together with other network equipment in telecom/data centres in which they share the same cooling and power systems.
Operator activities	The share of mobile activities has been allocated by the operator based on internal business information.
Data ICT services	
Data transport	Dedicated transmission has been allocated 100 % to the 3G networks. Other data transmission and IP edge/metro/core networks are allocated based on traffic statistics.
Data centre(s)	The data centres, including also enterprise networks, have been allocated to the 3G network based on data traffic. For the international distribution of data, dedicated enterprise data centres have been excluded before traffic based allocation of the involved data centres. It's assumed that 50 % [reference] of the international data traffic goes through an Atlantic equivalent submarine cable.
Service provider(s) activities	Not included in the studied product system.

Cut-off

In principle, no cut-offs have been made in the network study and in the LCA studies. When not primary data or good secondary data are available, data have been assumed based on other sources, e.g. for similar material/parts. Only for data that are of less importance to the study results secondary data is considered for replacement of secondary data this way.

Rather than cut-off the studied product system has been restricted to not include, e.g. service provider activates.

LCIA

The following impact categories and impact assessment methods were used in Table O.39.

Table O.39: Impact category indicators per functional unit

Mid-point Impact Assessment Categories included	Impact category indicator value	LCIA methodology reference
CC	U	Mid-point category indicator: GWP100 indicator as defined by IPCC
OD	V	IPCC
A	X	CML
POF	Y	CML
EA	Z	CML

Due to the data gaps and large uncertainties when quantifying environmental impacts, especially toxic impacts, no such results are included in this example.

Life cycle interpretation

Conclusions

End-user equipment production and 3G base station sites operation gives the largest contributions to the GWP indicator in a global operation environment. In a country with a low carbon electricity mix the contributions of operation to GWP would be much smaller, see figure # and #.

The total GHG emissions (presented as CO2e) are about 22 kg for an average 3G subscription in a low carbon electricity mix scenario, including also user equipment (mobile phones/Smartphones and laptops) and data services (data centres), and 44 kg in the global scenario.

NOTE: Numbers above are purely fictive.

From a raw material, production and EoLT point of view, user equipment is especially important for the GHG emissions. The part which gives the second largest contribution to the non-use-stage related impacts is base station site infrastructure.

Uncertainty

The uncertainty sources were identified according to the following for parameter/scenario and model uncertainty respectively.The uncertainty sources were identified according to appropriate paramenter/scenario modelling and steps were taken to reduce the uncertainties.

The uncertainty of the energy consumption values for the various network parts is low as they are based to a high degree on measurements. This statement is also true for data traffic measurements and allocations based on such measurements. However the measurements are applicable only for the specific conditions of operator X and the differences between networks may be significant.

Even as large resources have been spent on user equipment LCA data, the non use stage LCA data for user equipment remain uncertain. Internal studies and external studies [references] suggest the uncertainty is as high as ±30 %. This uncertainty is somewhat exaggerated as the life time uncertainty is reduced for operator X because sale statistics of user equipment and subscriptions are available for a long period of time.

However, the total uncertainty is higher as all different user equipment for many years and manufacturers is represented by only a few models. Then, available industry averages, e.g. for IC manufacturing energy consumption reduces the uncertainty again.

The data centre energy consumption is another uncertain figure for making more generalized conclusions as they are specific to operator X.

Sensitivity analysis

The models applied and the data used were assessed with respect to accuracy and a list of candidates bound for sensitivity analysis were identified, e.g. operating life time, transport distances between final assembly and customer, production region, traffic growth assumptions

Sensitivity analysis has been carried out individually for mobile phones and base station sites.

For sensitivity of results the following items are important:

- User product mix and allocation of user equipment to various subscription services (laptop 50 % to 3G users in this example).
- Data traffic and data centre model.

Reporting

Example of sentence to be inserted in the report.*"All omissions and deviations towards the present document were transparently reported and the reporting formats of the standards were followed in detail. Furthermore the reporting formats of the present document were used in the final report".*

Total results for the GWP indicator (CO2e) are given below in Figure O.17.

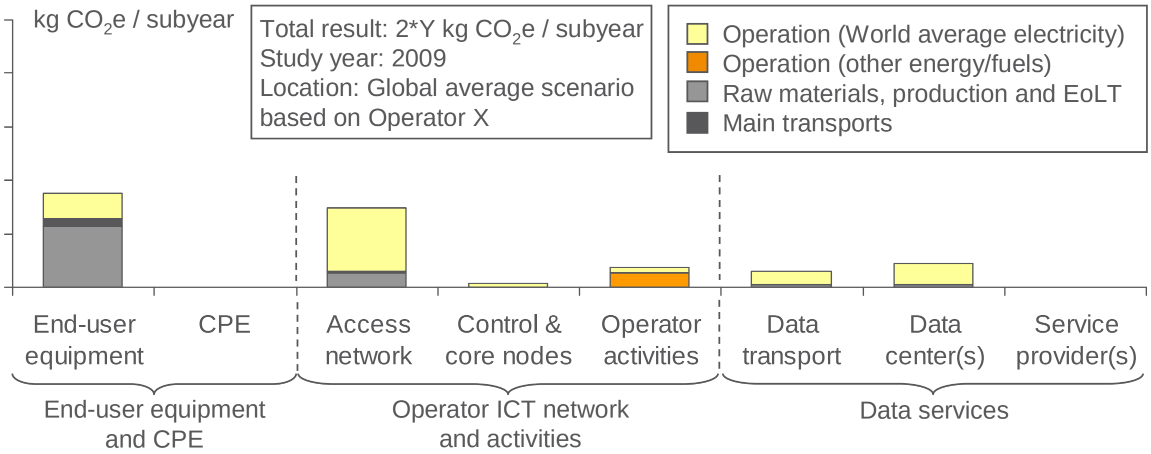


Figure O.17: Total carbon emissions (CO2e) for an average 3G subscription of operator X

The result values presented in this report are unique to the assumptions and practices of company X.

The result values are therefore not intended as a platform for comparability to other companies and/or products unless corresponding conditions apply for functional unit, system boundary, assumptions, data quality, etc.

The electricity production mix for operator X is based on a low carbon energy mix which gives rather low emissions for the operation phase.

To show the sensitivity of the results to the energy mix of the operator, Figure O.18 is included below. No other data besides the electricity model of the use phase is changed between the two figures.

As could be seen the results are sensitive to the electricity mix applied, however, for a specific operator the electricity mix, energy consumption and number of subscriptions are well known.

To reflect the conditions of an arbitrary operator also the lower share of smartphones and data subscriptions with laptops should be reflected. This is not considered in the global values presented.

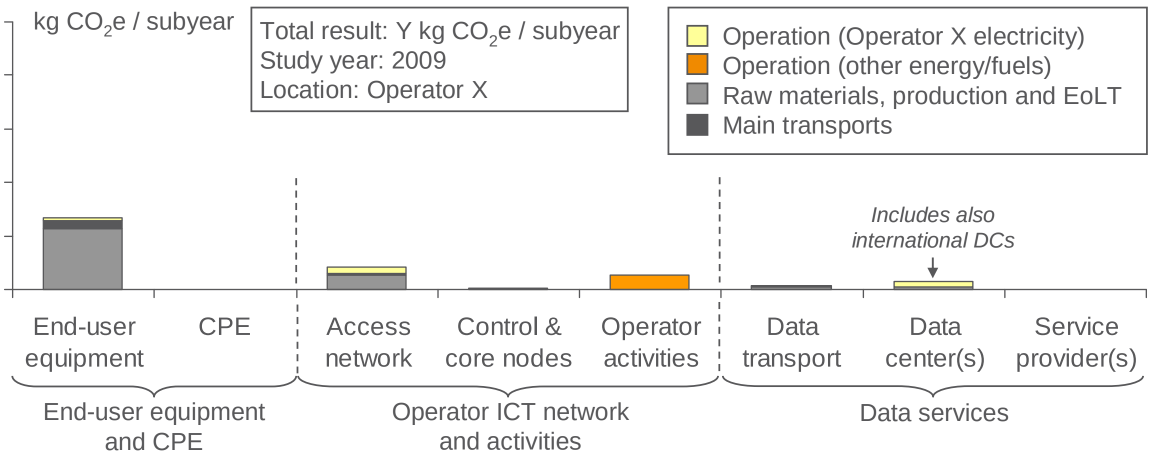


Figure O.18: Total carbon emissions (CO2e) for the global scenario

The result values presented in this report are unique to the assumptions and practices of company X.

The result values are therefore not intended as a platform for comparability to other companies and/or products unless corresponding conditions apply for functional unit, system boundary, assumptions and data quality, etc.

The consistency with some other equally mature 3G networks have been checked and the energy/subyear figures are consistent, about 15 kWh to 20 kWh/subyear. Higher figures have been presented in other LCA studies, related to assumptions regarding less subscriptions for the network service.

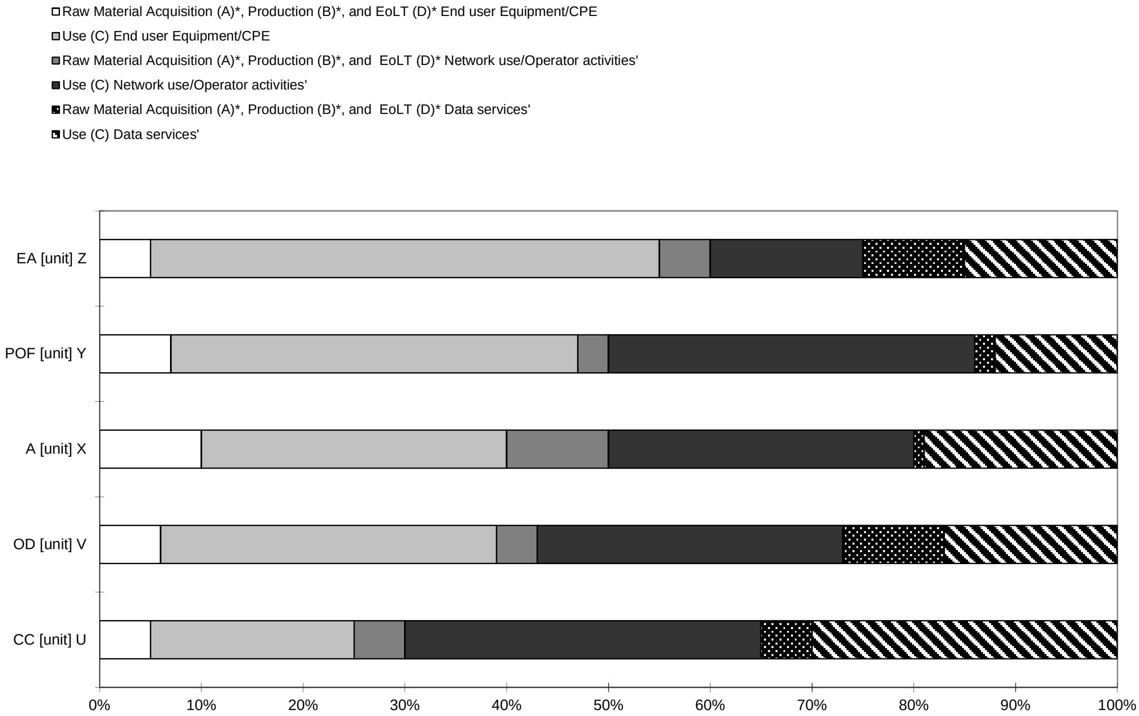


Figure O.19: Relative results for a number of chosen environmental impact categories

Main transports are reported according to the following (for the global scenario):

User equipment final transport (assembly location - store/user), not including users own transport (e.g. by car): 2,5 % of total CO2e.

Access network sites infrastructure and ICT equipment: 1 %.

Operator activities use stage business travel, service vehicles (3rd part services incl.), commuting: 5 %.

Other transports give minor contributions.

In this example no results for raw materials and detailed LCI results are shown, as they should in a real reporting situation.

O.5 Services

O.5.1 Video conference

This example shows an LCA of a *Service* performed by an *Operator.*

Goal definition:

The goal of this example LCA study is to clarify and understand the environmental impact of a videoconference *Service* during all stages of the lifecycle by estimate Climate Change (CC), Resource Depletion Mineral Resources (RDMR), Eutrophication, aquatic (EA), and Ozone Depletion (OD) mid-point impact category indicators for a videoconference Service *during its lifetime.*

The purpose of the LCA study is for external use in order to promote the videoconference *Service* and have a basis for comparison with reference product systems.

Scope definition:

The studied product system is one associated with video conference function used in France. *Two* video conference rooms are used in parallel for video conferencing. Except the operation system software programs, the video conference product system physically consists of building blocks such as: TV monitors, computers, video conference rooms, switches, routers, optical fibres, firewalls, servers, gateways, and, associated Networks, e.g. LAN, FTTH and IP.

The ICT Equipment building blocks can in turn be categorised according to Parts defined in Table B.1.

Other related equipment, which are not part of the studied product system are: support equipment chairs and video conference room infrastructure.

These following assumptions apply to the studied product system:

- Duration of typical service: 2 hours meeting.
- Life span of facility in which Service occurs: 30 years.
- Use rate: 10 meetings per week.
- Data transfer speed (100 Mbit/s).
- Electricity mix used: France average.
- Power usage for active and idle mode: various for active and idle modes for included Equipment
- ICT Equipments manufacturing location: World average.
- Installation of the facility in which the Service occurs: In France.
- Maintenance of the facility in which the Service occurs: In France.
- Servers per facility (e.g. dedicated servers per teleconference facility): One.

The **operating lifetime** is estimated to be 5 years based on the estimated lifetime of the studied type of video conference Technology. No extended operating lifetime or other lifetimes are considered.

The **applicable functional unit** is *Annual Service use.*

The packaging material related with parts production and assembly is included.

Details needed for the LCA of ICT Equipment and Networks ("cradle-to-gate" LCIs) are based on primary data from ICT manufacturers.

The assessment scope is also focused on direct operations and therefore infrastructure capacity buildings (like factories, roads, vehicles and telecommunications) are excluded. Also capital goods, like production machinery are excluded.

The assessed video conference *Service* is used in France. The geographical and temporal coordinates vary dynamically for the Raw Material Acquisition and Production of the *ICT Equipment* associated with the video conference *Service*. The presented results for Raw Material Acquisition and Production will therefore represent a global average but deployment and use in France.

System boundaries

Table 1 specifies the mandatory and optional life cycle stages/unit processes for *Services.* Listed below are the life cycle stages included in the studied product system for this LCA.

A1
A2
B1.1
B1.2
B2.1
B3
C1
C2
C3

C4
D2.1
D2.2
D3

D1 is not applicable to the studied product system.

Support activities *except* C3 and C4 are not considered for any unit processes because of lack of data and models.

Underlined Processes below in Figure O.20 were included in the studied product system.

Processes below in *italic* style were not included as they are optional or not part of the studied product system scope.

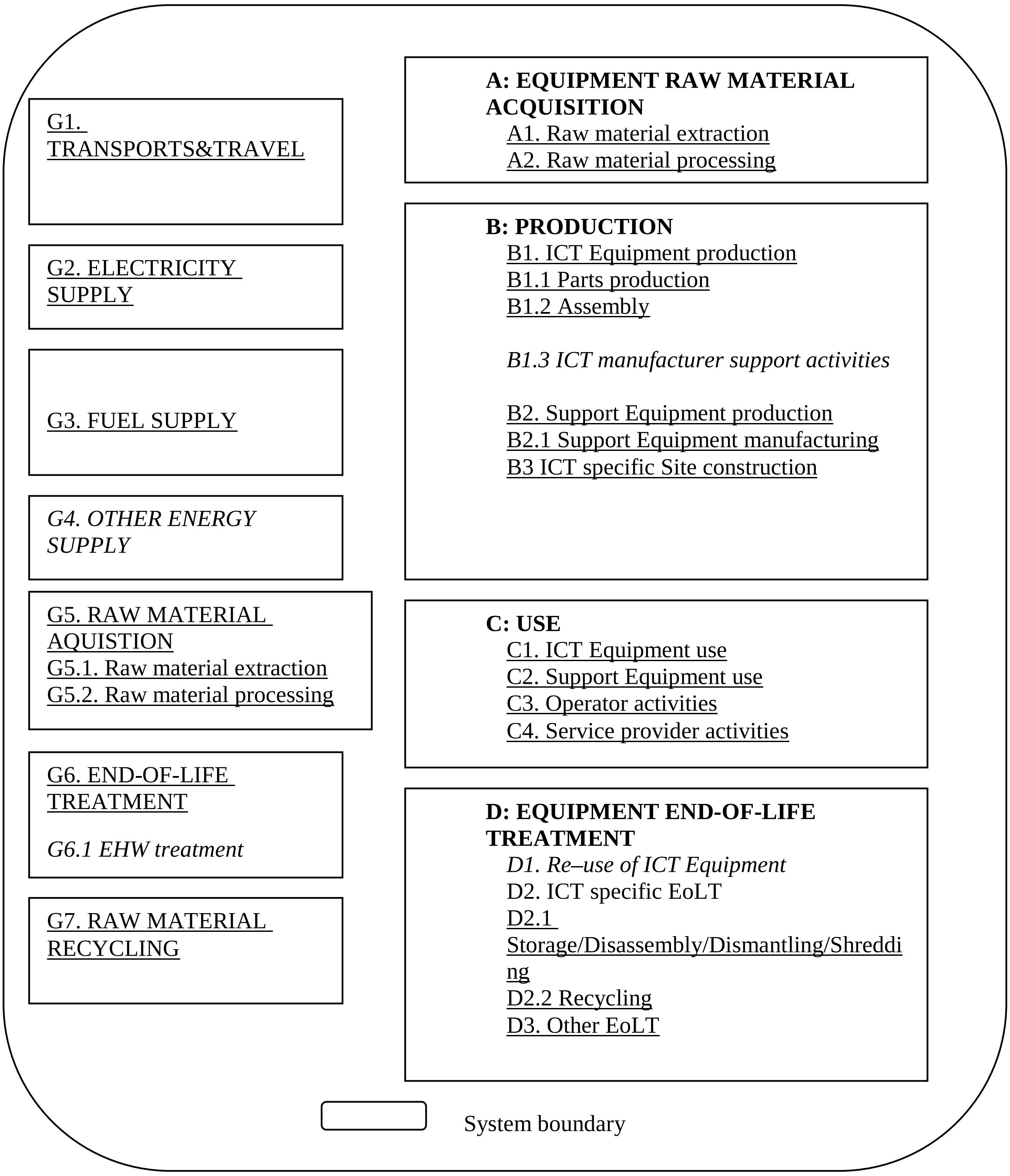


Figure O.20: The system boundary of the product system for LCA of the Video conference

Figure O.21 shows a product system flowchart showing where the generic re-occurring processes are used. Boxes in which the text is marked underlined and bold type style are modelled whereas boxes marked with *italic* style are cut-off. These *italic* processes are *within* the studied product system but are cut-off.

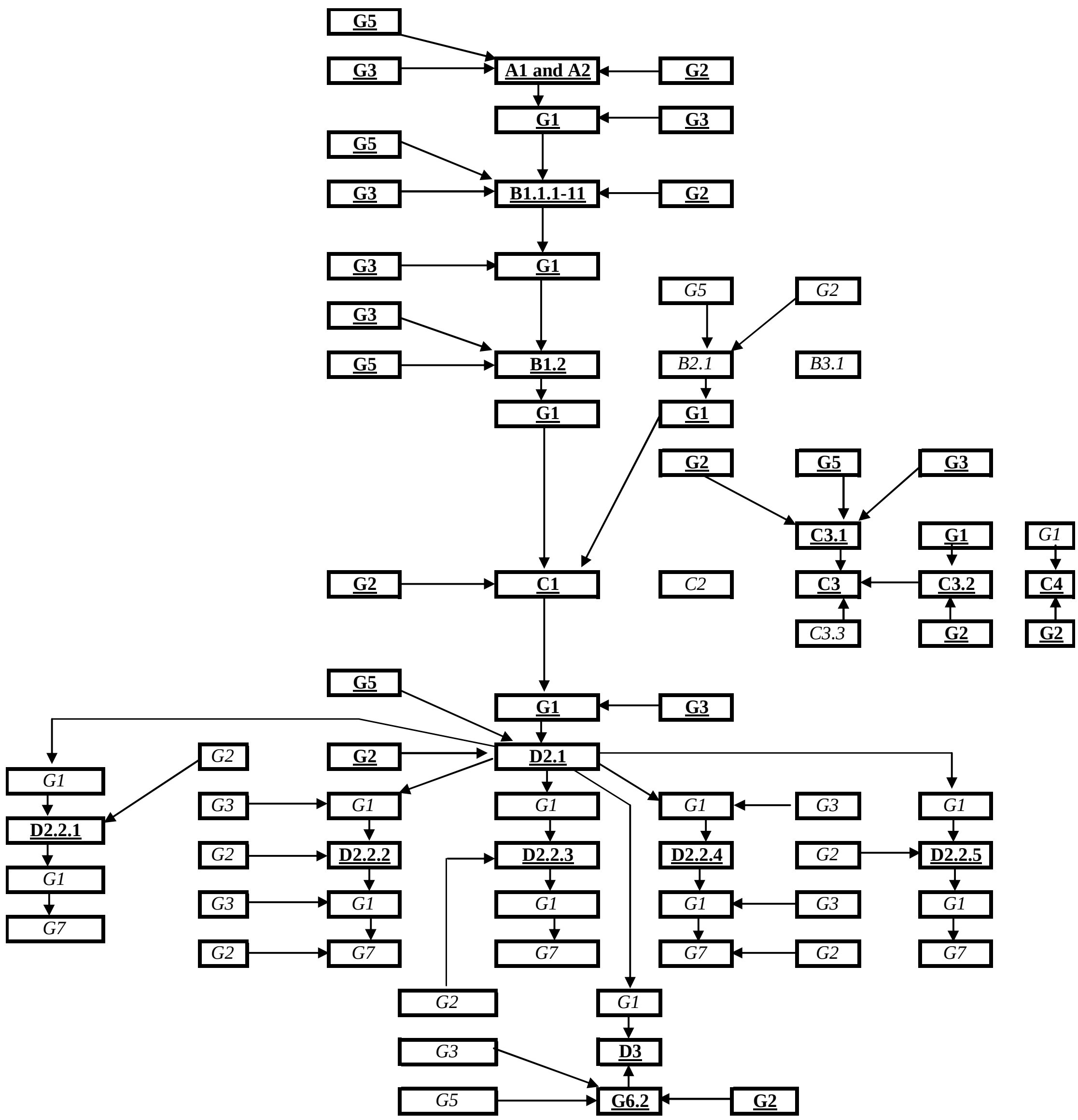


Figure O.21: The system boundary of the product system for LCA of the video conference Service showing connections with generic processes

Data collection

Equipment Raw material acquisition

Selected external data bases were used for raw material extraction and raw material processing data for activities under the financial or operational control of the Operator, e.g. raw materials used for installation of the video conference room.

Production

Primary data were collected from ICT manufacturers (suppliers) for Raw Material Acquisition and Production of ICT Equipment.

Use

Energy consumption for End-user and CPE use phase was measured directly based on the first alternative in clause 5.3.1.2.1.

Energy consumption for IP Network, Data transport and Data centre Equipment use phase was measured in laboratories.

Energy consumption for FTTH Network use phase was measured in laboratories for attributable Equipment annually based on the second alternative in clause 5.3.1.2.1 (with certain user profile / product category) including typical use of all functionalities of the multifunctional *ICT equipment.* Energy efficiency metrics were based on relevant ETSI standards. French average energy mixes were used as the video conference is intended for use in France.

Equipment End of Life Treatment

For end-of-life data are based on assumptions and external data bases.

Generic processes

For transports (G1) distances and own facilities consumption of (G2, G3) primary data is used. Relevant energy mixes were used from data bases.

Other information

For raw material acquisition no transparent data on transports (G1) were available (in databases or otherwise), thus impact from these transports cannot be reported separately.

Data calculation

Allocation of data

Raw material acquisition

The allocation performed for the database data used was not transparently reported by the database. For Equipment Raw material acquisition the ICT manufacturer LCI were used.

Production

ICT manufacturer used "cradle-to-gate" LCIs compliant with the present document. Allocations were done for Access network (FTTH), C&C Network (IP Network), Data transport Equipment and Data centers according to clause 5.3.3.3 to the studied video conference *Service*.

Use

There are several allocation needs in use stage in this study for Access network (FTTH), C&C Network (IP Network), Data transport Equipment and Data centers according to clause 5.3.3.4.

Equipment End of Life Treatment

End-user and CPE:

- D2.1, D2.2.2 and D2.2.5 are included. The Storage/Disassembly/Dismantling/Shredding and Recycling facility allocation was done per mass.

Access and C&C Network Equipment:

- D2.1 and D2.2.2-5 are included. The Storage/Disassembly/Dismantling/Shredding and Recycling facility allocation was done per mass.

Data transport Equipment and Data centers Equipment:

- D2.1, D2.2.1-5 are included. The Storage/Disassembly/Dismantling/Shredding and Recycling facility allocation was done per mass.

Generic processes

See Raw material acquisition and Production.

Support activities:

No support activities have been included except C3 and C4.

Cut-off

Two Cut-off criteria were set: 5 % based on the total mass flow input, and 5 % addition to the first iteration LCA score for CC, RDMR, OD and EA. That is, if the excluded activities/processes did not increase the total CC, RDMR, OD, and EA scores with more than 5 % the cut-off criteria was justified.

Based on these criteria several cut-offs were done from the studied product system: B1.1.11, B2.1 (air conditioners for OLT, chairs in video conference rooms), B3.1 (Site construction for ICT Equipment/Networks facilities), C2 (Air conditioner for OLT in FTTH Network use), C3.3 (De-installation), Transports in C4, EoLT transports, Raw Material and Electricity consumption for EoLT activities, Raw Material Recycling (G7).

Data quality

Methodological appropriateness and consistency:

- The applied LCI methods and methodological choices are in line with the goal and scope of the data. The methods have been applied consistently across all data.

Completeness (total LCA level):

- 90 % of applicable LCI flows in Table E.1 are included in the LCI. The degree of coverage of the RDMR LCIA indicator in Table F.10 is 95 % based on mass.

Uncertainty:

- The variability of the data elements used in the LCA is low enough.

Data representativeness:

- Representative data from a sufficient number of facilities over and adequate time period have been used

Data age (timeliness):

- Data <3 years old have been used according to LCI databases used and ICT manufacturer LCI data.

Acquisition method:

- Some of the data used have been directly measured such as the number of Parts. None of the data used are nonqualified estimations.

Supplier independence:

- Most of the data used are Independent source but based on unverified Information. Verified data from independent source to No unverified information has been used.

Geographical correlation:

- "Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from the exact area " is used for the Use stage.

Technological correlation:

- "Data from process studied of the exact company" is used for Assembly and Use stage electricity. "Data from process studied of company with similar technology" is used for Battery production.

Cut-off rules (rules of inclusion/exclusion):

- The cut-off criteria were homogeneously and transparently applied.

LCIA

The following impact categories were included: CC, RDW, RDMR and OD.

The impact assessment methods applied were those applied in "EIME V8.0": "GWP" for CC, "WE" for EA and ET. "RMD" for RDMR, "ODP" for OD.

"EIME v8.0" "ED" was used as indicator for Primary energy consumption.

Life cycle interpretation

Conclusions

The results indicate that in the entire life cycle (cradle-to-grave) for CC and OD the *Use stage* and *Raw Material Acquisition and Production* stages are the around 50 % each. End-user and CPE Use stages account for 35 % of the total impact for CC and 27 % of OD. For EA the *Use stage* is the around 70 % of the total with similar contributions from End-user/CPE, Network and Data services. For RDMR the *Raw Material Acquisition and Production* stages account for 99 % of the total impact of which End-user and CPE is 98 %.

The percentages for CC, OD and EA are mostly dependent on:

- Duration of typical service (e.g. 2 hours meeting).
- Use rate (e.g. number of meetings per week).
- Power usage for active and idle mode.

Uncertainty

The uncertainty for the Use stage electricity measurements is relatively low whereas the Raw Material Acquisition and Production stages have relatively large inherent uncertainty.

Sensitivity analyses

By contribution analysis the most contributing elementary LCI flows and unit processes were identified for each impact category. Subsequently models applied and the data used were assessed with respect to accuracy and candidates bound for sensitivity analysis were identified, e.g.:

- Duration of typical service (e.g. 2 hours meeting).
- Use rate (e.g. number of meetings per week).
- Power usage for active and idle mode.

Figure O.22 shows these candidates for sensitivity analyses.

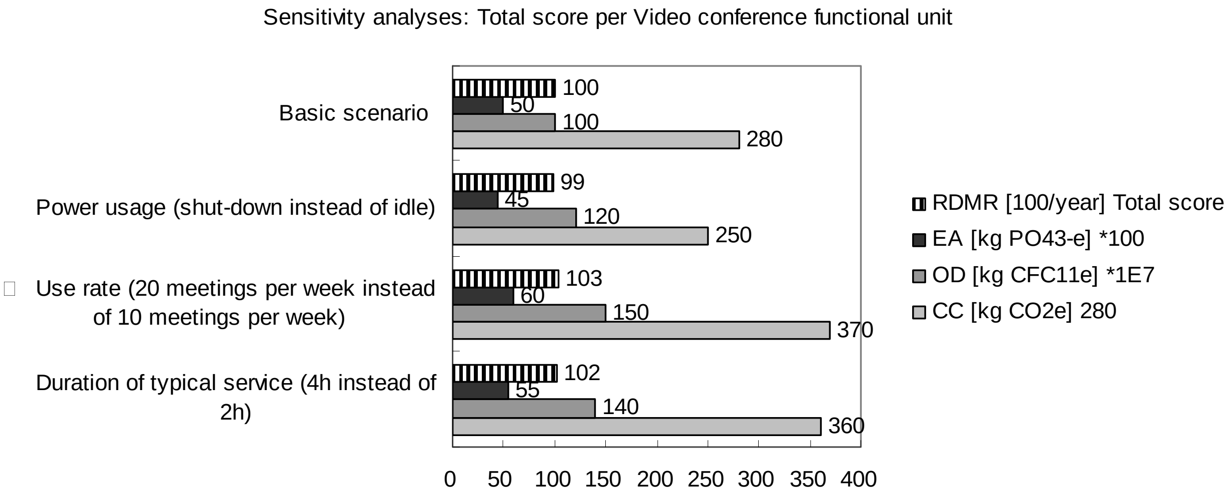


Figure O.22: Sensitivity analyses for Video conference Service

Moreover, the sensitivity of the cut-off of B2.1 (air conditioners for OLT, chairs in video conference rooms), B3.1 (Site construction for ICT Equipment/Networks facilities), C2 (Air conditioner for OLT in FTTH use), C3.3 (De-installation), Transports in C4, EoLT transports, Raw Material and Electricity consumption for EoLT activities , and Raw Material Recycling (G7) was tested by inserting a range of approximations from literature for each activity/process.

These sensitivity analyses revealed that the conclusions were stable. The Use stage will be more dominant if C2 was included.

Reporting

All omissions and deviations towards the present document are transparently reported.

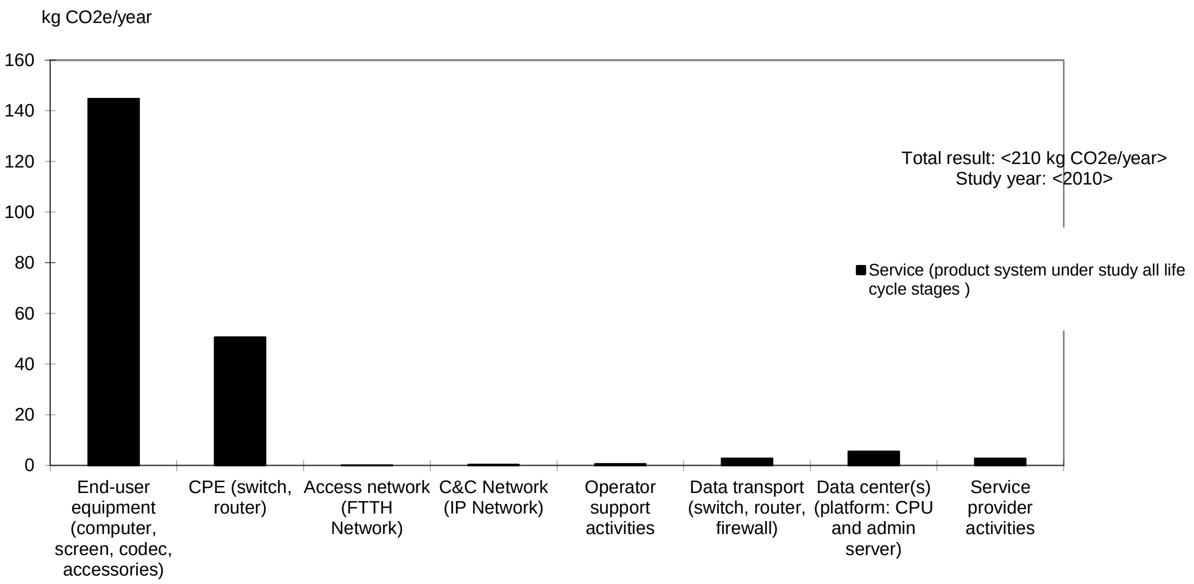


Figure O.23: Environmental impact category indicator result diagram example for Video conference Service (diagram for Global Warming Potential (GWP100) (CO_2e)

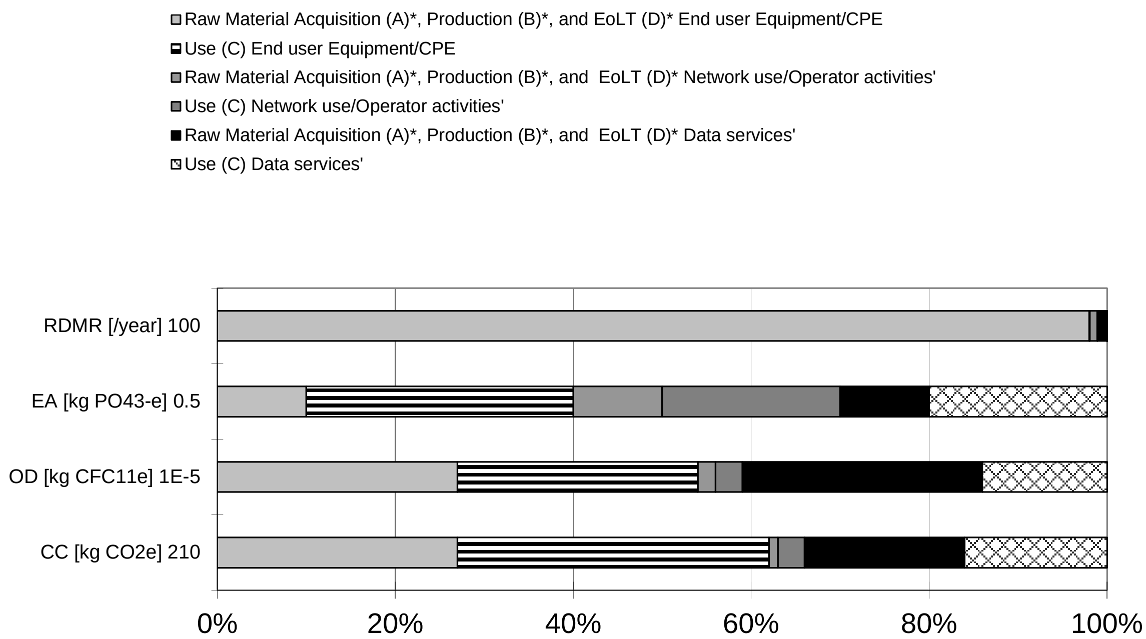


Figure O.24: Environmental impact category indicators overview for Services

Table O.40: Life cycle stages, activities and generic processes

Tag	Life cycle stage	Unit process	Included (Yes/No)	Electricity mix (specific/country/world average	Support activities included (Yes/No)	Transport activities included (Yes/No)	Other generic activities included (Yes/No)	Motivation/Comment
A	Equipment Raw Material Acquisition							
A1	Raw material extraction		Yes	Specific	No	Yes	Yes	Transports are not transparent from LCI databases used.
A2	Raw material processing		Yes	Specific	No	Yes	Yes	Transports are not transparent from LCI databases used.
B	Production							
B1	ICT equipment production							
B1.1		Parts production	Yes	World	No	Yes	Yes	Provided by ICT manufacturer.
B1.2		Assembly	Yes	World	No	Yes	Yes	Provided by ICT manufacturer.
B1.3		*ICT manufacturer support activities*	*No*					
B2	Support equipment production							
B2.1		Support Equipment manufacturing	Yes	World	No	Yes	Yes	Air conditioners for OLT cut-off.
B3		ICT specific Site construction	Yes	World	No	Yes	Yes	Refers to site construction of Network sites. Facility for OLT cut-off.
C	Use							
C1	ICT equipment use		Yes	France	No	No	No	
C2	Support equipment use		Yes	France	No	No	No	Cut-off. Tested in sensitivity analysis.
C3	Operator activities		Yes	France				

Tag	Life cycle stage	Unit process	Included (Yes/No)	Electricity mix (specific/country/world average	Support activities included (Yes/No)	Transport activities included (Yes/No)	Other generic activities included (Yes/No)	Motivation/Comment
C3.1	Installation				Yes	Yes	Yes	Includes FTTH deployment and the "site construction" of the video conference room.
C3.2	Maintenance				Yes	Yes	Yes	G5 cut-off. Tested in sensitivity analysis.
C3.3	De-installation				No	Yes	Yes	Cut-off. Tested in sensitivity analysis.
C4	Service provider activities		Yes	France	Yes	Yes	No	Travelling is cut-off. Tested in sensitivity analysis.
D	Equipment End of Life Treatment							
D1	Re-use of ICT Equipment		*No*					
D2	ICT specific EoLT		Yes					
D2.1		Storage/Disassembly/Dismantling/ Shredding	Yes	France	No	Yes	Yes	.
D2.2		Recycling	Yes	France	No	Yes	Yes	G7 Cut-off. Tested in sensitivity analysis.
D3	Other EoLT		Yes	France	No	Yes	Yes	G6.2 Landfill and incineration included.

Table O.41: Generic processes per functional unit

Generic process	Generic process categories included	Unit processes included (for each generic process category)	Important issues
G1. Transports&Travel	Road Air	Direct (during transport) emissions Fuel supply chain	No travel included
G2. Electricity	World electricity mixes, France electricity mixes	Fuel supply chain, Direct emissions (during electricity production)	
G3. Fuels	Oil Diesel Petrol Jet-fuel Coal Gas	Fuel supply chain:	
G4. Other energy			
G5. Raw material acquisition	See Annex 4	Extraction Processing	e.g. Concrete used in C3.1 for FTTH installation (deployment)
G6. End-of-life treatment	Landfill Incineration	One "site LCI model" for landfill site One "site LCI model" for incineration site	G1 and G5 cut-off. G2 included
G7. Raw material recycling	Metal recycling	Smelting Refining	Cut-off

Table O.42: Transports/travel per functional unit for video conference Service

Mode	CO_2 emission factor	Raw material acquisition transports		Production stage transports excluding final transport		Final transport (Production to use stage)		Use stage transports		EoLT transports		Total travels	
		Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton×km}	GWP100 {kg CO_2e}	Transport work {ton*km}	GWP 100 {kg CO_2e}	Transport work {ton×km}	GWP 100 {kg CO_2e}	Transport distance {km}	GWP100 {kg CO_2e}
Air	1 kg CO_2e/[ton×km]					10	10						
Other													

Table O.43: Parts production

	Part categories included	Part Unit processes included	Handling of special issues
B1.1.1 Batteries	Lead batteries Lithium batteries	Raw Material Acquisition, Battery cell assembly Battery module (pack) assembly	
B1.1.2 Cables	Coaxial cables Fibre cables Power cables Network/signal cables	Raw Material Acquisition, Cable final assembly	
B1.1.3 Electro-mechanics	Connectors Electric motors Chargers Speakers Microphones Camera objectives Hard Disc Drives Lighting (lamps)	Raw Material Acquisition, Part final assembly	
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	Package type for each Part and Good die area for each Part → Load Per B1.1.4
B1.1.5 Mechanics / materials	Nuts, bolts, screws Fronts Frames Racks Cabinets Towers Containers Solder	Raw Material Acquisition, Part final assembly	
B1.1.6 Displays	PDP LCD	Raw Materials Acquisition Raw Materials Acquisition for special display panel materials, Display module assembly, Display panel assembly	
B1.1.7 Printed circuit boards (PCBs)	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	
B1.1.8 Other PBA components	Resistors Capacitors Inductors Relays LEDs Potentiometers Quartz crystal oscillator	Raw Material Acquisition, Part final assembly	
B1.1.9 Packaging materials	Paper Cardboard Plastics Wood Steel	Raw Material Acquisition	

	Part categories included	Part Unit processes included	Handling of special issues
B1.1.10 Black box modules	Screen	"Cradle-to-gate" LCA from supplier	
B1.1.11 Software	Software	Development: Daily way to work for programmer, Business trips for programmer, Electricity usage of ICT Equipment used by programmer, Office lighting. Distribution: Manuals production, Data medium production. Usage: Deployment of SW, Maintenance of SW	Cut-off

Table O.44: Use stage energy consumption per functional unit

	Energy consumption {kWh}	Source {long term average/standardized measurement/ modelled	Motivation/ comment
ICT equipment	1,500	Measured by Operator	All energy is electricity.
Support equipment	Not included		Fibre Cables is the only included Support Equipment. Air conditioner and Power Supply Systems are cut-off

Table O.45: EoLT

	Process categories included	Process Unit processes included	Handling of special issues
G6.1 EHW treatment	None	None	Handled as Cut-off
G6.2 Other Waste treatment	Landfill Incineration	Site LCI data set for each process category	

Table O.46: LCI results per functional unit

	TOTAL	Raw materials acquisition *and* EoLT *and* Production	Use
Primary energy use	19,300 MJ	1,300 MJ	18,000 MJ
Total electricity use	1,600 kWh	100 kWh	1,500 kWh
Land use	6 m^2×years	2 m^2×years	4 m^2×years
Fresh water use	9,5 m^3	0,5 m^3	9 m^3

Table O.47: Impact category indicators per functional unit

Mid-point Impact Assessment Categories included	Impact category indicator value	LCIA methodology reference
RDMR	100 / year	Mid-point Category indicator: Natural Resources Depletion Indicator (RMD) as used by EIME V3.0
OD	1E-5 kg CFC-11	Mid-point Category indicator: Stratospheric Ozone Depletion Potential Indicator (ODP) as used by EIME V3.0 as used by EIME V3.0
EA	0,5 kg PO4e	Mid-point Category indicator: Water Eutrophication Indicator (WE) as used by EIME V3.0
CC	280 kg CO_2e	Mid-point Category indicator: Infrared forcing as GWP100, IPCC as used by EIME V3.0

Table O.48: Network description per functional unit

End-user equipment CPE	Included ICT Equipment	Included infrastructure	Quantity [unit]	Operating Lifetime [year]
End-user equipment	Computer	None	2/3 [p] (see note 1)	3
	Screen	None	2/3 [p]	3
	CODEC	None	2/5 [p] (see note 2)	5
	Accessories	None	2/3 [p]	3
CPE	Switch	None	2/5 [p]	5
	Router	None	1/4 [p] (see note 3)	8
Operator Network and activities				
Access network (FTTH)	Router	None	1 [p]	5
	WDM amplifier	None	1 [p]	5
Control & core network (IP)	Switch	None	2 [subscribers]	5
	Switch core	None	2 [subscribers]	5
	Router	None	2 [subscribers]	5
Operator activities	N.A.	None	1 [employees]	5
Data Services				
Data transport	Switch	None	GB/subscriber	5
	Router	None	GB/subscriber	5
	Firewall	None	GB/subscriber	5
Data centre(s)[3]	CPU Gateway	None	GB/subscriber	5
	Admin server Gateway	None	GB/subscriber	3
Service provider(s) activities		None	Employees/500 Service users	5
NOTE 1: Two computers are used for two video conference rooms. Operation lifetime of studied product system is 5 years. Operation lifetime of computer is 3 year - >(2×5/3)/5 = 2/3 computers per year for two video conference rooms. NOTE 2: Two CODEC are used for two video conference rooms. Operation lifetime of studied product system is 5 years. Operation lifetime of CODEC is 5 year - >(2×5/5)/5 = 2/5 CODEC per year for two video conference rooms. NOTE 3: Two Routers are used for two video conference rooms. Operation lifetime of studied product system is 5 years. Operation lifetime of Router is 8 year - >(2×5/8)/5 = 1/4 Router per year for two video conference rooms.				

Table O.49: Network Energy consumption per functional unit

End-user equipment CPE	ICT equipment energy consumption	Support equipment energy consumption	Source {long term average/ standardized measurement/ modelled}
End-user equipment	670 kWh	N.A.	Long-term average power measurement
CPE	300 kWh	N.A.	Long-term average power measurement
Operator Network and activities			
Access network[1]	30 kWh		power measurement
Control & core network	50 kWh		power measurement
Operator activities			Measurement
Data Services			
Data transport[2]	160 kWh		power measurement
Data centre(s)[3]	280 kWh		power measurement
Service provider(s) activities		10 kWh	Modelled by Service provider

Table O.50: Service hardware allocation

End-user equipment and CPE	Allocation method	Allocation of use stage [%]	Allocation of all non-use stages [%]
End-user equipment	Use Time of Service	100 %	
CPE	Use Time of Service	100 %	
Operator Network and activities			
Access network	Data traffic of Service		
Control & core network	Data traffic of Service		
Operator activities	Use Time of Service		
Data Services			
Data transport	Data traffic of Service		
Data centre(s)	Number of Service users	Specific data centre(s) data mandatory	
Service provider(s) activities	Number of Service users	Specific service provider(s) data mandatory	

Table O.51: Matrix for data quality assessment applied to Video conference Service LCA

Data Quality Indicator	Applicable section	Comment
Methodological appropriateness and consistency	Entire specification	The applied LCI methods and methodological choices are in line with the goal and scope of the data. The methods have been applied consistently across all data.
Completeness	5.2.3	90 % of applicable LCI flows in Table E.1 are included in the LCI. The degree of coverage of the RDMR LCIA indicator in Table F.10 is 95 % based on mass.
Uncertainty	5.5	The variability of the data elements used in the LCA is low enough.
Acquisition method	5.2.4	Some of the data used have been directly measured by ICT manufacturers such as the number of Parts and the power in the Use stage. None of the data used are nonqualified estimations.
Supplier independence	5.2.4	Most of the data used are Independent source but based on unverified Information. Verified data from independent source to No unverified information has been used.
Data representativeness	5.2.4	"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from the exact area" is used for the Use stage.
Data age/timeliness	5.2.4	Data <3 years old have been used according to LCI databases used and ICT manufacturer LCI data. No data has been used for which the age were unknown.
Geographical correlation	5.2.4	"Average data from a larger area" has been used for Raw Material Acquisition and Production and Transports and EoLT. "Data from the exact area " is used for the Use stage.
Technological correlation	5.2.4	"Data from process studied of the exact company" is used for Assembly and Use stage electricity. "Data from process studied of company with similar technology" is used for Battery production.
Rule of inclusion/exclusion (Elements/Flows/Unit process)	5.2.3	The cut-off criteria were homogeneously and transparently applied.

O.5.1 An ICT logistic service based on static positioning using a 3G mobile network and its reduction potential

This example shows the implications from the present document on an LCA of an ICT service using a 3G mobile network to help positioning vehicles for logistics purpose. *The example is not aiming to outline all details of an LCA but to support the reader in interpretation of some important areas of the present document. For compliance with the present document all body text and annexes needs to be considered when performing an LCA, i.e. the example is* ***not*** *giving full information for specification compliance. References are not written out, only indicated in this example.*

Goal definition:

- The primary goal of the study was to assess the total energy consumption and green house gas (GHG) emissions related to a ICT mobile positioning system service using a 3G network. The secondary goal was to assess the potential reduction in vehicle operation (distance driven) the ICT service could enable, and the related emission reductions, also taking infrastructure (vehicles, roads etc.) into account.

Scope definition:

- The ICT service study is build upon a study of a 3G network but certain parts have been adjusted for the ICT service, see Table O.52. The reduction potential is based on another study that also included potential vehicle operation (distance driven) reduction. The study uses a global scenario that includes 3G network operation with global average electricity.

The various **lifetimes** is estimated to be from 3 years for mobile phones up to 40 years for cables infrastructure se Table O.35.

The basic **functional unit** is *one year of ICT positioning (GPS) service using 3G network* (including all parts described above and listed in Table O.35). For practical reasons, the reported basic/applicable functional unit is *one year of primary 3G network subscription service in country X* which is the basic functional unit expressed per (average) subscription/user, short *subyear*.

Refer to the network example, which this ICT service LCA is based upon, for more information on goal and scope.

System boundaries

All unit processes and parts of a 3G network outlined in figure # have been included and adopted for the specific ICT positioning (GPS) service.

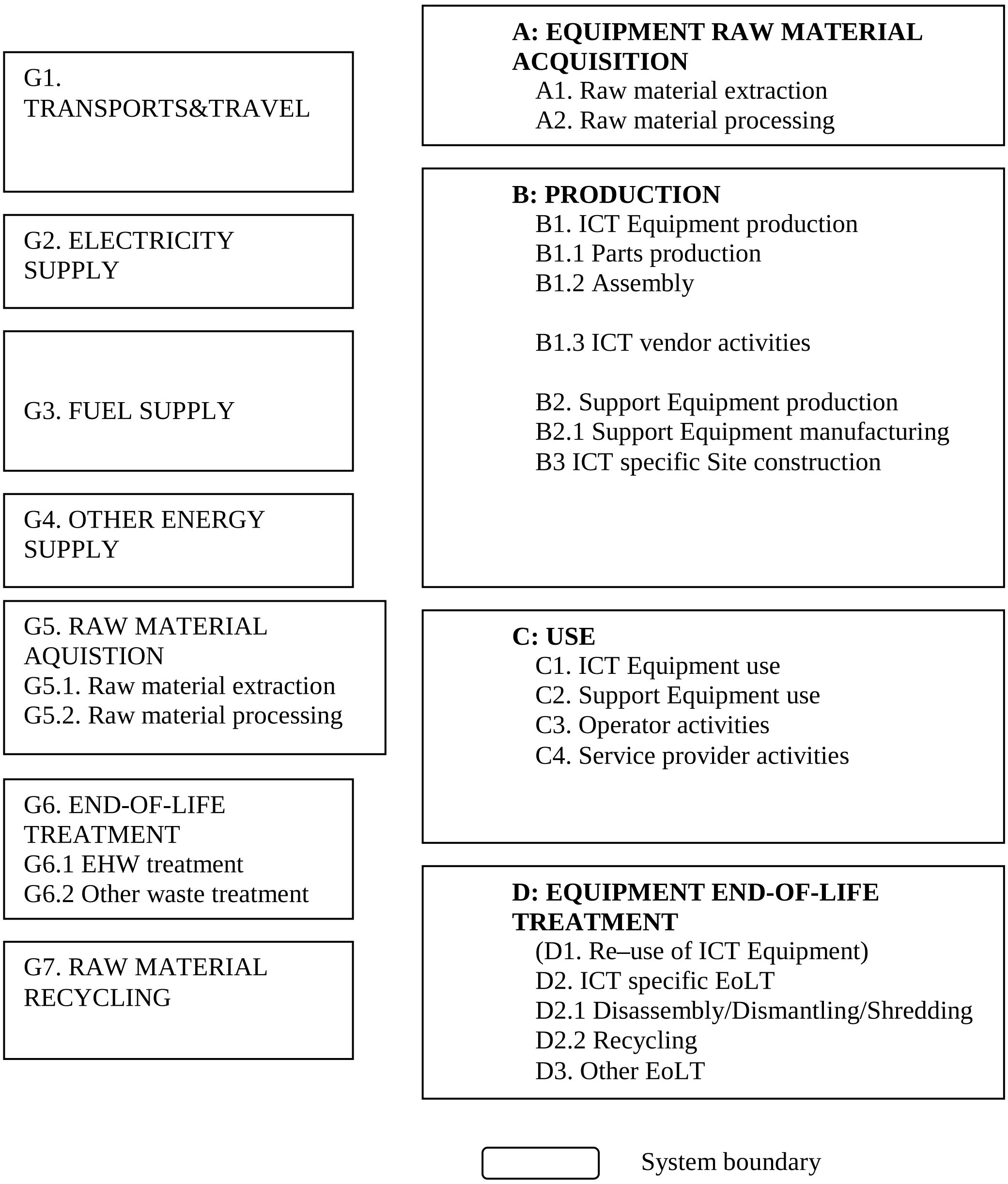


Figure O.25: The system boundary of the product system or LCA of the ICT logistic service

Data collection and data sources

Please refer to the network LCA example which this ICT logistic service LCA builds upon for more information on data collection and data sources.

Table O.52: 3G network description adopted for ICT service with Service provider activities included

END User equipment and CPE	Included ICT Equipment	Included infrastructure	Quantity [unit]	Lifetime [year]
End User equipment - ADJUSTED study part compared to network example	a. Regular phones b. Smartphones (laptops are not included in the ICT service case study)	Electricity infra-structure included in all life cycle stages (**true for all items in this table**)	1 UE per subscription: a. 50 % b. 50 %	3 years for phones
CPE - New part compared to network example but included under the *Data ICT service*	Back and front office PCs are included in service activities under the *Data ICT service*	-	-	-
Operator ICT network and activities	**Please refer to the network example this ICT positioning (GPS) service LCA is based upon. Same description applies.**			
Data ICT Services				
Data transport	Please refer to the network LCA example which this ICT positioning (GPS) service LCA builds upon.			
Data centre(s)[3] and Service provider(s) activities - NEW study part compared to background 3G network study	Servers, storage and data network equipment in data centers (or rooms), Back and front office PCs and enterprise network (office LAN)	Data centre building including cooling and power infrastructure, enterprise network infrastructure		5 years for servers, 4 years for PCs

Electricity infrastructure (construction of power plants, dams, the grid itself, etc.) is included in the electricity models used in the study, as electricity plays such a fundamental role in ICT LCAs.

Infrastructure related to vehicle travel (i.e. vehicles, roads, tunnels, bridges etc) are **included** in the study as *infrastructure related indirect emissions* from the potential reductions in vehicle operation (based on distance driven).

Infrastructure related to the 3G and shared ICT networks is included as a main part of the network and not as a separate infrastructure item, e.g. antenna towers and their concrete foundations, land and submarine cable deployments and dedicated site shelters and buildings. The construction of office buildings are not included, not for the support activities by the operator or by the manufacturer. Construction of factories is also not included.

Table O.53: Network data sources for all raw material acquisition, production and EoLT and operator activities (use stage)

END User equipment and CPE	Data sources
End User equipment - ADJUSTED compared to network example	Regular phone: [Reference: Internal LCA study of regular phones together with manufacturers, ISO reviewed] Smartphone: [Based on same mobile phone LCA study / LCI data as referenced above with certain component parameters changed] The phone models also includes charger, USB, CD, documentation, packaging etc. - the full delivery package for a mobile phone.
CPE - NEW part compared to network example but included under the *Data ICT service*	Back and front office PCs are included in service activities under the *Data ICT service.*
Operator ICT networks and activities	Please refer to the network example which this ICT positioning (GPS) service LCA builds upon. Same description for data sources.
Data ICT services	
Data transport[2]	Please refer to the network example which this ICT positioning (GPS) service LCA builds upon.
Data centre(s)[3] and Service provider(s) activities - NEW study part compared to background 3G network study	Servers: [Reference - External studies of servers] Desktop and laptop PCs: [Reference - Based on several external desktop and laptop PC studies, a best approximation or average model have been created] Enterprise network: [Reference - Internal study of an enterprise network / office LAN].

Allocation of data

Refer to the network example which this ICT positioning (GPS) service LCA builds upon for more information on allocation and energy consumption.

Use time has been used as allocation key throughout the study and not amount of data traffic. The reason is that data traffic would give a much smaller share (lower emissions) allocated to the service. The use time estimate is also considered to be on the high end.

Table O.54: ICT service allocation

End-user equipment and CPE	Allocation method	Allocation of use stage [%]	Allocation of all non-use stages [%]
User equipment - ADJUSTED part compared to network example	Use time of service part of all active use	5 %	5 %
CPE	Back and front office PCs are included in service activities under the *Data ICT service*	-	-
Operator ICT network and activities			
Access network	Use time of service part of all active use	5 %	5 %
Control & core network	Use time of service part of all active use	5 %	5 %
Operator activities	Use time of service part of all active use	5 %	5 %
Data ICT services			
Data transport	Use time of service part of all active use	5 %	5 %
Data centre(s) - NEW study part compared to background 3G network study	The specific ICT services data centre is allocated per user it serves, the actual servers in the specific data centre have been studied	Specific data centre(s) data used, see network description, data sources and energy consumption tables	
Service provider(s) activities - NEW study part compared to background 3G network study	The specific ICT service provider activities is allocated per user it serves, the actual service provider activities have been studied	Specific service provider(s) data used, see network description, data sources and energy consumption tables	

Table O.55: Network Energy consumption

End-user equipment CPE	ICT equipment energy consumption (electricity)	Support equipment energy consumption	Source {long term average/ standardized measurement/ modelled}
End User equipment - ADJUSTED study part compared to network example	Regular phone: X_1 kWh/subyear * 5 % = $0{,}05X_1$ kWh/subyear Smartphone: X_2 kWh/subyear * 5 % = $0{,}05X_2$ kWh/subyear	Defined as stand-by consumption of chargers, included in ICT equipment, about 4X % of the total	Limited user measurements of phones and energy models provided by manufacturers
CPE - NEW part compared to network example but included under the *Data ICT service*	Back and front office PCs are included in service activities under the *Data ICT service*	-	-
Operator ICT network and activities	Refer to the network example which this ICT positioning (GPS) service LCA builds upon. Same total energy consumption apply. 5 % will be allocated onto the ICT service based on use time.		
Data ICT services			
Data transport	X_3 kWh/subyear * 5 % = $0{,}05X_3$ kWh/subyear	Cooling, power systems, etc., included in ICT equipment energy consumption, about Y % of the total	The major part of the data transmission and IP edge/metro/core networks are included by continuously site energy measurements
Data centre(s)[3] and Service provider(s) activities - NEW part compared to the network example	Data centers: X_4 kWh/subyear (allocation per user) Back and front end office PCs including office LAN: X_5 kWh/subyear (allocation per user)	Cooling, power systems, etc., included in ICT equipment energy consumption, about Z % of the data centers part	The actual servers in the specific data centre have been studied and specific service provider(s) data used

The reduction potential of the ICT service

In another LCA, all life cycle emissions for an average road vehicle (car, truck etc.) were investigated. All different life cycle stages and aspects of the vehicle/road system were investigated, including: fuel supply chain, vehicle manufacturing, road infrastructure (including bridges, tunnels etc.), services and repair, gas stations and a few other items. That LCA is the basis for emission reductions connected to reduction in driven distance (vehicle km).

The reduction in vehicle operation (annual distance travelled) could be reduced by 5 % to 10 % as a result of three somewhat limited investigations (<1 000 vehicles in total, three different LCAs, part time of year). Several other studies gave results in the interval 5 % to 15 % .

Three scenarios for service vehicles (service technician, e.g. servicing telecom network sites) have been created:

- Low reductions (5 %) and low average annual vehicle emissions (3 ton CO2).
- Average reductions (10 %) and low average annual vehicle emissions (3 ton CO2).
- High reductions (15 %) and medium/high average annual vehicle emissions (5 ton CO2).

The study and scenarios are not including larger trucks used for heavy transportation as that is another type of service.

There is an ongoing debate about inclusion of infrastructure, and the potential reductions of infrastructure.

In this example all such aspects have been considered, as it is the view of the project behind the study that infrastructure related emissions is not something that may be reduced in the distant future, but can happen as a result of our decisions already today. For example, a new vehicle may not be purchased as it is no longer needed. New road constructions in the future may be cancelled.

It should however be clearly noted that the savings reported are potential and may not take place in reality, i.e. the LCA indicates potential savings but the prerequisites for these savings to actually occur is beyond the control of the practitioner.

Cut-off

Refer to the network example which this LCA was based upon.

LCIA

Refer to the network example which this LCA was based upon.

Life cycle interpretation

Conclusions

The difference between the ICT service direct (use/operation) and indirect (production, network infrastructure) emissions (total emissions) and the corresponding baseline scenario emission are large.

Even for the low-end scenario, the reduction factor (defined as ICT emissions: reduced emissions) is about 40, and more than 200 for the higher scenario.

The conclusion is thus that there is a large potential to reduce vehicle fleet emissions by being able to see/communicate their position in real time.

Uncertainty

Reduced amount of annual vehicle kilometres is scenario based and as such quite uncertain. The inclusion of secondary enabling effects adds also to the uncertainty.

Sensitivity analysis

The uncertainty and sensitivity analysis revealed the conclusions are stable as the difference between the ICT service and the reference scenario is large enough to compensate for the uncertainties.

Reporting

All omissions and deviations towards the present document were transparently reported and the reporting formats of the present document were followed in detail. Furthermore the reporting formats of the present document were used in the final report.

Total GWP indicator (CO2e) results for the ICT service without reductions is given below in Figure O.26.

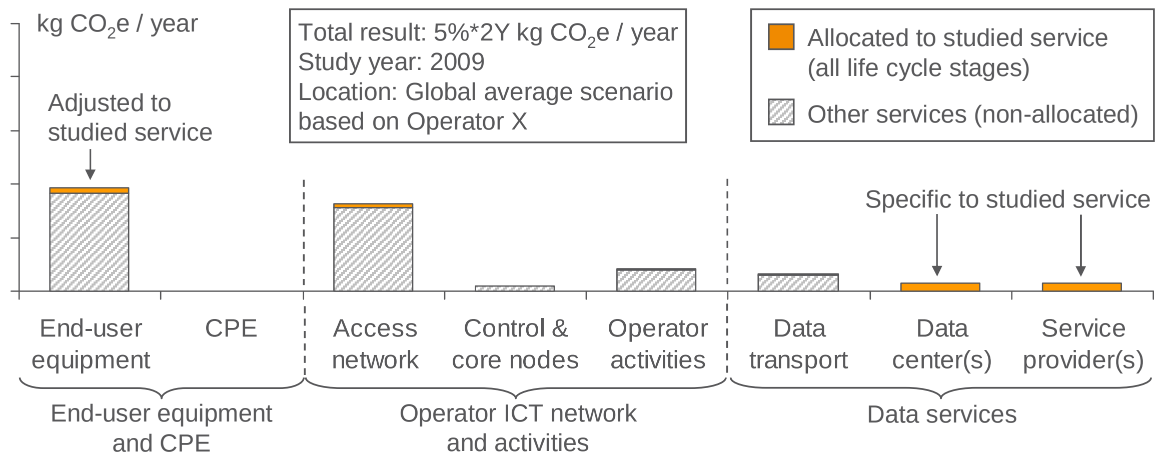


Figure O.26: Total carbon emissions (CO2e) for an average ICT positioning (GPS) service user (vehicle)

The total value is compared to the potential reductions that the service can enable, see Figure O.27.

The total transports contribution is about 10 % of the total service emissions or 0,3 kg CO2e/service year. Other transports give minor contributions.

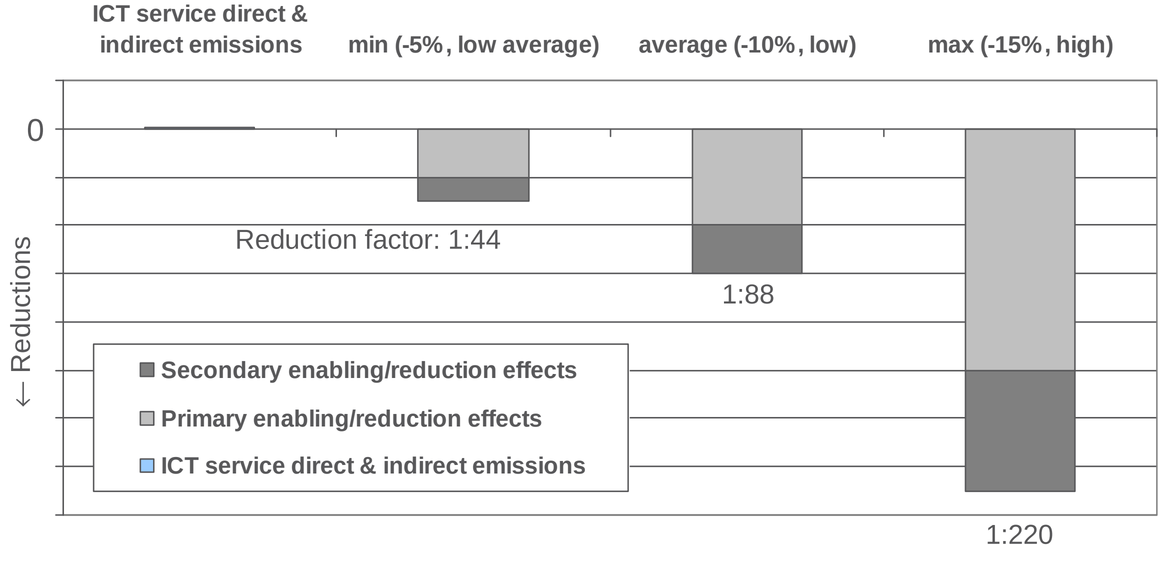


Figure O.27: Total carbon emissions (CO2e) reduction potential results for an average ICT positioning (GPS) service user (vehicle)

The reductions that are enabled by the ICT positioning service is large, more than 40 times larger than the impact of the ICT service itself.

The infrastructure related reductions are about 50 % of to the more direct operation related reductions.

These reductions may not take place and are beyond the control of the practitioner.

Annex P (informative): Summary of recommendations and options

This annex summarizes all recommendations and options present in the main body of the present document.

It is recommended to:

- Report a graph showing transports between sub-unit processes within each life cycle stage for ICT Equipment.
- Include the ICT Manufacturer support activities for Equipment, Networks and Services, Operator support activities for Networks and Services and Service Provider support activities for Services, and other support activities.
- Include the Construction of ICT specific Site (B3) if Support Equipment is included in the studied product system of ICT Equipment and for Networks and Services.
- Services provider support activities and data centres for Networks when choosing the product system to be studied.
- Apply a broad approach in terms of environmental impacts to give a broad understanding of the environmental impact of the studied ICT product system.

It is optional to:

- Include the construction of plants in which ICT or Support Equipment are manufactured. The life cycle stages are further described in clause 5.2.2.
- Consider the embedded impact of operating systems and other widely spread software (e.g. simulating tools).
- Include Support Equipment manufacturing (B2) for ICT Equipment LCAs for studied product systems which do not include Support Equipment.
- For B1.2 Assembly to include Testing & Repair.
- Include the data centre infrastructure Production, e.g. the construction of the data centre building and cooling and power infrastructure.
- Energy recovery of incineration processes.
- In LCIA, to make the link to end-point categories.
- Report recycling numbers for Other materials than Steel, Aluminium alloys, Copper alloys, Gold and Silver.
- For Transports and Travel (G1) to include: Vehicle production and Infrastructure production.
- For main grid Electricity(G2) to include: power plant production, dam production, the grid production, nuclear waste treatment.
- For Other energy supply(G4) to include: Power plant construction, Infrastructure production.
- Show a graph showing distribution between sub-activities within each life cycle stage for Networks in the same way as for ICT equipment.
- Add other data, graphs, statements etc. than required by clause 6 to the report based on the scope and purpose of the LCA.
- Show life cycle stage distribution for other LCI flows than Primary energy use Total electricity use Land use Fresh water use.
- Include impact from consultants and services used by the organization.

Annex Q (informative): Bibliography

OECD (2009): "Guide to measuring the ICT Sector". The 2006-07 OECD ICT sector definition (based on International Standard Industrial Classification (ISIC) Rev. 4).

History

Document history		
V1.1.1	November 2011	Publication