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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services

Recommendation ITU-T L.1410

ITU-T

International Telecommunication Union

Recommendation ITU-T L.1410

Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services

Summary

Recommendation ITU-T L.1410 deals with the assessment of the environmental impact of information and communication technology (ICT) goods, networks and services. It is organized in two parts:

Part I (clause 5) – ICT life cycle assessment: framework and guidance.

Part II (clause 6) – Comparative analysis between ICT and a reference product system (baseline scenario); framework and guidance.

Part I deals with the life cycle assessment (LCA) methodology applied to ICT goods, networks and services (ICT GNS). Part II deals with comparative analysis based on LCA results of an ICT GNS product system and a referenced product system.

This Recommendation provides specific guidance on energy and greenhouse gas (GHG) impacts.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T L.1410	2012-03-08	5

Keywords

Comparative analysis, energy consumption, environmental impact, goods, greenhouse gas emissions, GHG, information and communication technologies, life cycle assessment, networks, services.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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

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

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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Table of Contents

Page

Introduction

This Recommendation is part of a series of Recommendations dealing with the environmental impact assessment of ICTs. Recommendation ITU-T L.1400 "Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies" provides a general framework and guidance and describes the full series.

This Recommendation has been developed to complement ISO 14040 and ISO 14044 for the assessment of the life cycle impact of ICT goods, networks and services. It focuses on the assessment of energy consumption and greenhouse gas (GHG) emissions.

The development of information and communication technologies (ICTs) has led to concerns regarding its environmental impact. Taking into consideration the ongoing efforts within the United Nations Framework Convention on Climate Change [b-UNFCCC] to combat climate change, ITU-T decided to develop an internationally agreed methodology to help the ICT sector to assess the environmental impact of ICT goods, networks and services, focusing on energy consumption and GHG emissions.

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

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

- First order effects (or the environmental load of ICTs): the impacts created by the physical existence of ICTs and the processes involved, e.g., energy consumption and GHG emissions, e-waste, use of hazardous substances and use of scarce, non-renewable resources.
- Second order effects (or the environmental load reduction achieved by ICTs): the impacts and opportunities created by the use and application of ICTs. This includes environmental load reduction effects which can be either actual or potential, such as travel substitution[1], transportation optimization, working environment changes, use of environmental control systems, use of e-business, e-government, etc.
- Other effects:
  – may include the impacts and opportunities created by the aggregated effects on societal structural changes by using ICTs;
  – may, for some ICT services such as tele-working or video conferencing, include the time gained by an end user using an ICT service which then may cause additional impact e.g., a leisurely drive and economic activities, which are difficult to track. Such additional impacts are often defined as "rebound effects".

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

Most of the benefits of ICTs lie in the second order effects via increased efficiency, transparency, speed of transactions, rapid market-clearing, long-tail effects and so on. There are environmental impacts associated with the first order: environmental impact of ICT goods, networks and services (hereafter "ICT GNS") such as resource consumption and carbon emissions during manufacturing and the disposal of hardware. Other effects await further exploration due to the many uncertainties involved. While these other effects may be critical in constructing a more sustainable society, much more research on this remains to be done. Thus, this Recommendation focuses on the first and second order effects. Further research in the area of other effects is encouraged.

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

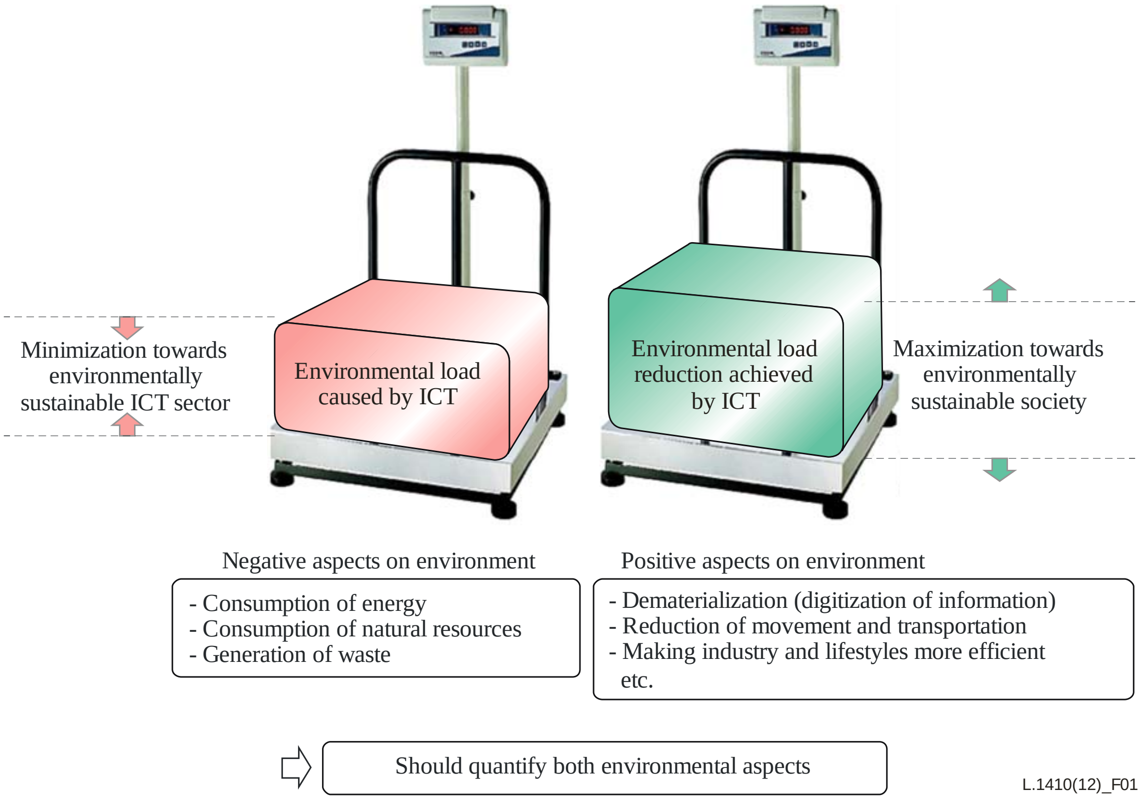

Figure 1 – Schematic model for the environmental assessment of ICT goods, networks and services

The first order effect (or environmental load caused by ICT) can be quantified by performing a life cycle assessment (LCA). The second order effect (or environmental load reduction achieved by ICT) can be quantified by the comparison between the ICT GNS product system and the reference product system performing the same function.

To reflect the first two order effects, this Recommendation is structured into two parts.

- Part I (clause 5) – ICT life cycle assessment: framework and guidance. This part deals with the LCA methodology applied to ICT goods, networks and services.
- Part II (clause 6) – Comparative analysis between ICT and a reference product system (baseline scenario): framework and guidance. This part deals with comparative analysis based on LCA results of the ICT GNS product system and the reference product system.

The structure of both parts is based on [ISO 14040] and [ISO 14044] in order to support the practitioner. Each part is thus structured in accordance with:

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

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

This Recommendation is intended for LCA practitioners wanting to assess ICT GNS impacts.

Recommendation ITU-T L.1410

Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services

1 Scope

This Recommendation aims to provide a methodology for evaluating the environmental impact of ICTs objectively and transparently, and is based upon the life cycle assessment (LCA) methodology standardized in [ISO 14040] and [ISO 14044].

This Recommendation can be read by anyone aiming for a better understanding of the specific conditions and requirements applicable to the LCA of ICT goods, networks and services (GNS). However, the Recommendation is especially intended for LCA practitioners with a prior knowledge of LCA standards, i.e., [ISO 14040] and [ISO14044].

The purpose of this Recommendation is to:

– provide ICT-specific requirements, in addition to those of [ISO 14040] and [ISO 14044], to ensure a minimum quality of LCA studies of ICT GNS;

– ensure the credibility of LCAs of ICT GNS;

– increase the transparency and facilitate the interpretation of LCA studies of ICT GNS;

– facilitate the communication of LCA studies of ICT GNS; and

– provide a methodology for telecommunication operators and service providers to assess the environmental load of one or more services carried by their ICT networks.

While recognizing [ISO 14040] and [ISO 14044], including Annex A of [ISO 14040] "Application of LCA", as normative references, this Recommendation will give generic requirements for the LCA of ICT GNS. The Recommendation is valid for all types of ICT goods including end-user equipment, and also for ICT networks and services. It focuses on environmental load and impact stemming from energy consumption and GHG emissions of ICT GNS. Practitioners are however encouraged to also consider other environmental aspects in accordance with [ISO 14040] and [ISO 14044].

Comparisons between environmental assessments of ICT GNS, assessments which have been performed by different organizations are beyond the scope of this Recommendation, as such comparisons would require that the assumptions and context of each study are exactly equivalent.

2 References

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

[ITU-T L.1400] Recommendation ITU-T L.1400 (2011), *Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies.*

[ISO 14040] ISO 14040:2006, *Environmental management – Life cycle assessment – Principles and framework.*

[ISO 14044] ISO 14044:2006, *Environmental management – Life cycle assessment – Requirements and guidelines*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 comparative assertion: See [ISO 14040] clause 3.6.

3.1.2 functional unit: See [ISO 14040] clause 3.20.

3.1.3 ICT good: please refer to [ITU-T L.1400].

3.1.4 ICT network: please refer to [ITU-T L.1400].

3.1.5 ICT service: please refer to [ITU-T L.1400].

3.1.6 life cycle: See [ISO 14040] clause 3.1.

3.1.7 product system: See [ISO 14040] clause 3.28.

3.1.8 raw material: See [ISO 14040] clause 3.15.

3.1.9 waste: See [ISO 14040] clause 3.35.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 commercial lifetime: The time a good is owned before a new one is bought to replace it.

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

3.2.3 depreciation time: The time over which the loss of value in an asset impacts on an organization's finances and, in some countries, its taxes.

3.2.4 economic input-output approach (EIO): Method using tables, called input-output (IO) tables, that describe financial transactions between economic sectors in a national economy, to approximate environmental impacts.

3.2.5 environmental impact: Impact including positive and negative aspects on the environment.

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

3.2.7 environmental load: Environmental aspect which potentially causes interference with environmental conservation.

3.2.8 environmental load intensity: The numerical value of environmental load per unit.

3.2.9 environmental load of ICTs: ICT environmental loads over its life cycle. These include the environmental loads of ICT GNS in the processes of raw material acquisition, production, use, and end of life treatment.

3.2.10 environmental load reduction effect from using ICTs: The effect that noticeably reduces the environmental load of ICTs. The effects of "improving energy efficiency", "improving the efficiency of and reducing the production and consumption of goods", and "reducing the movement of people and goods" are brought about by using ICTs.

3.2.11 extended operational lifetime: The aggregated duration of the actual use periods of the first user and consecutive use periods associated with reuse.

3.2.12 first order effects: The impact created by the physical existence of ICTs and the processes involved, e.g., GHG emissions, e-waste, use of hazardous substances and use of scarce, non-renewable resources.

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

3.2.14 GHG emission intensity: The numerical value of greenhouse gas (GHG) emissions per unit.

3.2.15 hybrid LCAs: Method that combines the approach of process-sum and economic input-output LCAs. Different models exist, prioritizing data from either process-sum or input-output data.

3.2.16 lifetime: A duration which may correspond to commercial lifetime, operational lifetime, extended operational lifetime or depreciation lifetime.

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

3.2.18 operational lifetime: The duration of the actual use period (consisting of both active and non-active periods) for the first user. Storage time is not included in the operational lifetime.

3.2.19 other effects: Effects that are not first or second order effects.

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

3.2.21 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 data source. In practice primary data may be emission factors and/or activity data.

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

3.2.23 public data: Data which is available to the public without access being restricted by requirements of membership, non-disclosure agreements or similar.

3.2.24 reuse: A good is used again by a new owner or in a new context.

3.2.25 second order effects: The impact and opportunities created by the use and application of ICTs. This includes environmental load reduction effects which can be either actual or potential.

3.2.26 secondary data: Quantified value of a unit process or an activity within the product system obtained from sources other than direct measurements at its original source. Such sources can include databases, published literature, national inventories, and other generic sources.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BAT Best Available Technology

BOM Bill Of Material

BS Base Station

CD Compact Disc

CO_2 Carbon Dioxide

CRT Cathode Ray Tube

DVD Digital Versatile Disc

EHW Environmentally Hazardous Waste

EI Environmental Impact

EIO Economic Input-Output

EoLT End of Life Treatment

GHG Greenhouse Gas

GNS Goods, Networks and Services

IC Integrated Circuit

ICT Information and Communication Technology

LCA Life Cycle Assessment

LCD Liquid Crystal Display

LCI Life Cycle Inventory

LCIA Life Cycle Impact Assessment

LR Location Register

MNO Mobile Network Operator

MPLS Multi-Protocol Label Switching

MS Mobile Station

NW Network

UPS Uninterruptable Power Supply

VoIP Voice over Internet Protocol

5 Part I: ICT life cycle assessment: framework and guidance

5.1 General description of an LCA for ICT goods, networks and services

5.1.1 General description of an LCA

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

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

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

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

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

This Recommendation could also apply to studies not covering the full life cycle. In that case, please refer to clause A.1.2 in [ISO 14040].

ICT GNS have the potential to reduce the environmental load and impact by reducing the amount of energy consumption and materials used in society. This potential of reducing the environmental impact is referred to as second order effects and is covered by Part II (clause 6).

Often the impact from second order effects outweighs the first order effects, leading to a net positive environmental impact when systems of ICT GNS product systems are applied.

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

- goal and scope definition
- life cycle inventory (LCI)
- life cycle impact assessment (LCIA)
- life cycle interpretation.

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

LCA is by nature an iterative technique, where each phase or step is dependent on the results or methodologies used in another (previous or subsequent) phase or step. For example, defining the target product system is a step that directly impacts on the subsequent steps of boundary setting, data collection and allocation.

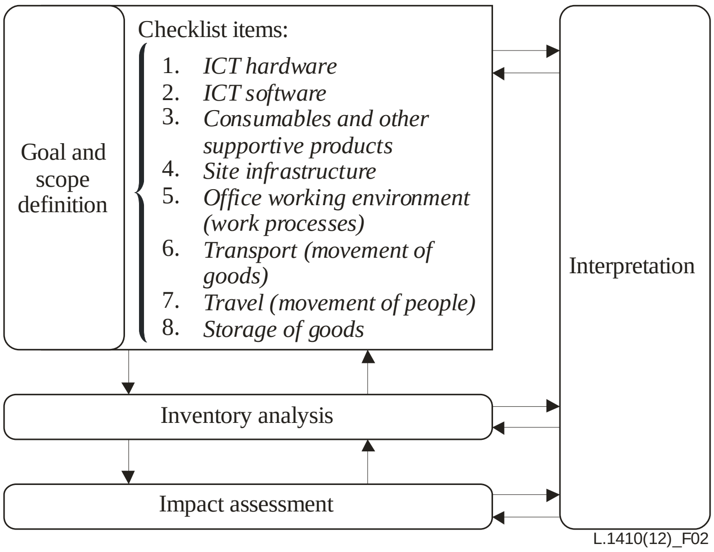

Figure 2 – Framework of Part I of Recommendation ITU-T L.1410

Figure 2 shows the framework of Part I which is based on Figure 1 of [ISO 14040]. When performing an LCA of ICT GNS, the eight checklist items specified in clause 5.2.2.3.2 should be considered in the system boundary setting to identify activities associated with the ICT GNS life cycle for which data will be collected. Other items may also exist.

5.1.2 Relationship between methodologies of LCAs for ICT GNS

Figure 3 shows the product systems targeted by the impact assessment methodologies of ICT goods, ICT networks, and ICT services. In this context, ICT networks and ICT services can be seen as logical structures, which are physically made up by ICT goods, including hardware and software, but also rely for instance on building premises, civil works to create cable ways, air conditioning, power generators and power storage such as UPS (uninterruptable power supply).

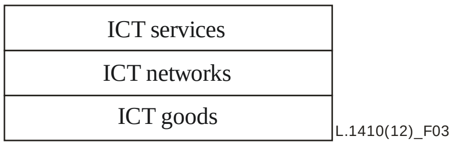

Figure 3 – Relationship between ICT goods, networks and services

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

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

Due to the use of ICT GNS in projects, organizations, cities and countries, this Recommendation forms a basis for the environmental impact assessment methodologies of the use of ICTs for projects, organizations, cities and countries as defined by the ITU-T L.1400-series of Recommendations.

5.2 Methodological framework

5.2.1 General requirements

When assessing the environmental impact of ICTs, the requirements of [ISO 14040] and [ISO 14044] shall be applied.

5.2.2 Goal and scope definition

5.2.2.1 Goal of the study

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

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

5.2.2.2 Functional unit

5.2.2.2.1 General

It is required to define a functional unit for the LCA. The functional unit shall be chosen in accordance with the goal and scope of the LCA. The functional unit defines the performance characteristics delivered by the ICT GNS being studied. It provides a reference to which the inputs and outputs are related or normalized (in a mathematical sense). Such a reference is necessary to ensure comparability of LCA results[2]. The functional unit shall be clearly defined and measurable.

Based on the functional unit, the reference flow (amount of ICT goods, ICT network or ICT service needed to fulfill the function) is determined as the good, network or service required to realize the functional unit.

Example (laptop):

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

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

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

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

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

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

5.2.2.2.2 ICT goods

The following functional unit should be used:

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

For ICT goods, additional more specific functional units may also be considered when the result is presented, e.g., the time during which one uses a phone and the number of e-mails sent.

The reference flow could be one sales package of an ICT good (e.g., one server, one PC or one phone), including all inbox materials and accessories, delivered to an end customer. Since the content of the sales package may vary from one package to another package or from company to company, the content considered should be described in the assessment together with the results.

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[2] Note that comparisons are only possible if assumptions and other conditions are equivalent.

Example (mobile phone):

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

Example (software):

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

5.2.2.2.3 ICT networks

ICT networks can be seen as a system composed of different types of ICT goods.

The following functional unit should be applied for ICT networks used during at least one year:

- annual network use.

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

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 phone line, per amount of users, or per transmitted data, or per coverage area (if applicable). If using more specific functional units it is recommended to base them on data which is easily understood by the users, e.g., the functional unit of the circuit switching type and the packet switching type should be expressed in terms of communication time and amount of information, respectively.

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

Example (ICT network):

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

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

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

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

5.2.2.2.4 ICT services

The following functional unit should be applied:

- annual service use.

Corresponding realistic use scenarios shall be defined. The annual service use should be defined with respect to the usage scenario to make it possible to define the reference flow, i.e., the number of different node types needed to perform the intended function. Generally these amounts are based on an allocation of network capacity between the service under study and other services.

Additionally, other more specific functional units may be applied as well, based on the scope and purpose of the LCA, e.g., per one hour or per gigabit.

5.2.2.3 System boundaries

5.2.2.3.1 General

The system boundaries define the unit processes across the life cycle of the studied ICT goods, networks and services that are to be assessed in terms of data collection and calculation of environmental load from energy consumption and GHG emissions. The selection of the system boundary shall be consistent with the goal of the study.

5.2.2.3.2 Eight items to consider

The following eight checklist items should be considered in the system boundary setting to identify activities associated with the ICT GNS life cycle for which data will be collected. These checklist items may then also be used to structure data and reporting but other structures are also possible.

NOTE – It is important to avoid double-accounting taking place between the eight checklist items.

1) ICT hardware

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

2) ICT software

This checklist item refers to the life cycle impact (including design, development and use[3]) of ICT software (e.g., individual software, packages, middleware and operating systems). Examples of software impact are the use of electricity and paper by the designers.

3) Consumables and other supportive products

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

[3] In practice it may be hard to assess use of SW and HW separately.

4) Site infrastructure

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

5) Transport (movement of goods)

This checklist item refers to the impact from transportation of products such as ICT goods, components, materials, etc. This also includes supportive goods for transport (e.g., pallets), use of fuels as well as fuel supply chains[4] of cars, trains, buses, etc.

6) Travel (movement of people)

This checklist item refers to the impact from travel. This checklist item includes commuting, professional travel and travel by customers depending on scope and purpose of the study. It includes the use of fuels as well as fuel supply chains of cars, trains, buses, etc.

7) Storage of goods

This checklist item refers to the storage of products such as ICT goods, components, materials, etc., in an applicable storage place. This implies in particular that the energy consumption for cooling and lighting should be considered.

8) Working environment

This checklist item refers to the use of working environments by the personnel of an organization for business purposes[5]. This checklist item mainly deals with the use of buildings but tentatively the building life cycle could also be considered. The associated impact includes the energy consumption from cooling or heating systems, lighting, PCs, etc. This checklist item includes all utilization of the working environment applicable to all the other checklist items.

Annex A defines a method for assessing the environmental impact of the working environment.

The intention of the eight checklist items above is to ensure that all relevant impacts are considered for all life cycle stages when defining the impact from a product system viewpoint. Table 1 below illustrates the relationships between the checklist items and the life cycle stages. However, the purpose of Table 1 is to check whether all relevant items for data collection are included, it may not be part of the overall assessment reporting.

The following table presents a mapping of checklist items towards life cycle stages. The organisation may decide whether this table is for internal purposes or for public disclosure.

[4] Except for fuel supply chain, only use stage need to be considered for transport.

[5] The office could sometime be located in a factory or a home. Production areas of factories belong to checklist item 1.

Table 1 – Mapping of checklist items on life cycle stages

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

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

As indicated above, the eight checklist items are items that should be considered in the system boundary setting to identify activities associated with the ICT GNS life cycle for which data will be collected. Other items may be considered if applicable.

In terms of assessment, the checklist items may be considered separately or together depending on the purpose and scope of the study. The checklist items can be used for ICT GNS, but are considered especially appropriate to better structure the impact of ICT services and for comparative assessment as detailed in Part II (clause 6).

5.2.2.3.3 Lifetime

Operational lifetime is critical for the interpretation of the results of the LCA and shall be reported when presenting LCA results. Assumptions related to the lifetime of ICT goods shall be clearly described in the reporting.

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

Operational lifetime should be based on available information on actual goods use[6] (e.g., statistics for similar goods, networks and services or information on commercial lifetime) and should model a real operational lifetime as closely as possible. If information on actual use of goods, networks and services cannot be found, economical statistics may be used to estimate operational lifetime, e.g., depreciation time. However, such estimates are considered as less accurate and should be avoided.

Storage time is not included in operational lifetime.

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

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

5.2.2.3.4 Handling of software

5.2.2.3.4.1 General

Software shall be considered as well as hardware.

Any ICT good or network consists of both hardware and software. For the production stage software development impacts on the number of people involved in the development work and thus impacts on the amount of buildings and travel associated with the development of the product or network, in the same way as hardware development does. For the use stage the software impacts e.g., maintenance and energy use. In general, it is not relevant to distinguish between software and hardware impacts for the use stage but rather to focus on the impact from the good or network itself.

For specific software applications, such as music distribution applications, the software is to be seen as an ICT service and shall be assessed according to the requirements outlined for services. In these cases the hardware needed to operate the software shall be considered as well.

Due to the uncertainties of allocation it is not recommended to consider the embedded impact from generic operating systems when assessing the software impact.

For users of generic operating systems embedded in products, the life cycle impact of usage of this software may be considered as negligible. However, for the developer of this software the impact of the usage of this software shall be taken into account.

5.2.2.3.4.2 Assessment of software

Many software products are used in ICT GNS. The software categories include, but are not limited to, operating systems, middleware (information system management, databases, etc.), application software (software for electronic applications, etc.) and software customized for specific users, according to the structure shown in Figure 4 below.

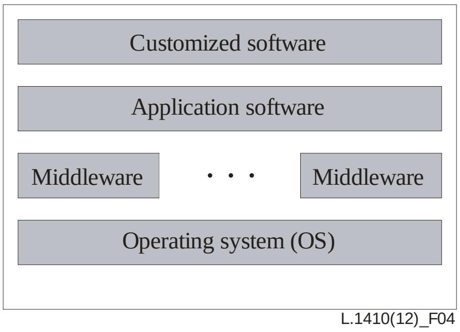

Figure 4 – Software structure of an ICT system (example)

A user, e.g., an operator, often designs or purchases customized software and also purchases other shared software. The following table further details the figure and also the corresponding allocation principles.

Table 2 – Classification and allocation principles for ICT software

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

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

As stated in clause 5.2.2.3.4.1, generic operating systems should not be included in assessments performed by its user as the uncertainty of allocation is high.

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

5.2.2.3.5 ICT GNS product system

The ICT GNS product system to be assessed shall be clearly described as well as relevant functions and characteristics.

5.2.2.3.5.1 ICT goods

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

In-depth information about the product composition is required before setting the system boundary of the product. Often, bill of material (BOM) data (where parts information including weight and material composition is listed) is necessary to understand the full product composition. Table D.1 provides generic information about the composition of ICT goods. A process tree showing the interconnectivity among parts and various items in each life cycle of ICT goods can be developed using the product composition information. By arranging parts in descending order of weight and by calculating the cumulative weight of each part, a basis is given for a cut-off of insignificant parts from the product system. Note however that other cut-off criteria apply as well. The detailed content and connection between all life cycle stages and the different processes are further described in Appendix I.

5.2.2.3.5.2 ICT networks

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

ICT networks are often grouped into fixed and wireless networks. Each ICT network consists of (a) customer premises (e.g., terminal, terminating equipment, and protectors), (b) access network equipment (e.g., telephone poles, conduits, changers, local switches, and base stations), and (c) core networks (e.g., routers and transmitters).

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

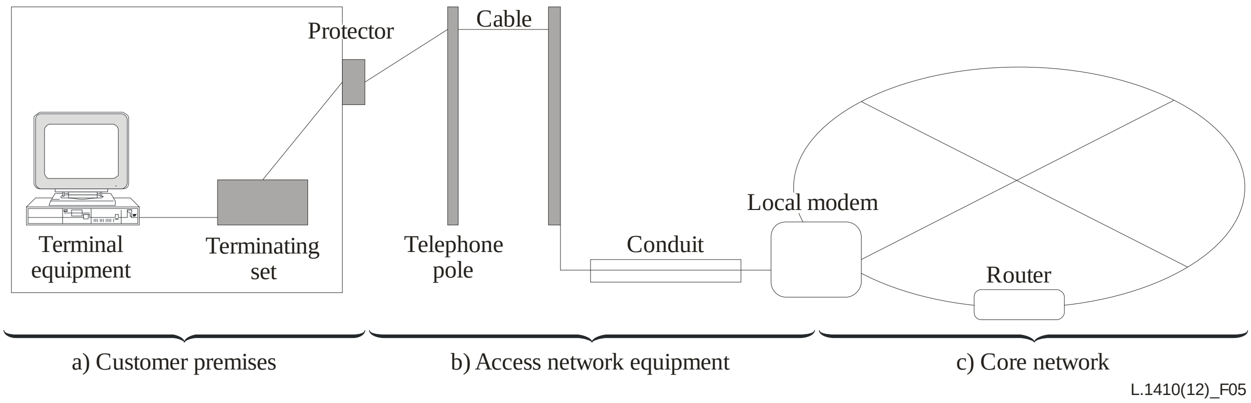

Figure 5 – Fixed telecommunication network – simplified physical view

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

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

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

Examples of how the functional unit, system boundaries and the data to be gathered may be defined are given in clauses VII.1, VII.2 and VII.6.

5.2.2.3.5.3 ICT services

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

5.2.2.3.6 Life cycle stages

The following four high-level life cycle stages apply to ICT GNS and shall be assessed in accordance with the goal and scope:

- raw material acquisition
- production
- use
- end of life treatment

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

It is important that the GHG emissions and energy consumption arising from the transport processes both within and between each life cycle stage are considered in the assessment. The data collected should be structured in such a way that the GHG emissions and energy consumption arising from these transport processes can be reported transparently as far as possible[7].

[7] The assessment of the raw material acquisition stage is generally based on secondary data from databases. At this stage such databases often do not report transport transparently and it may be difficult to separate the emissions deriving from transport.

The system boundaries outline the life cycle activities that are of relevance to define the life cycle of the ICT GNS to be assessed. Within these system boundaries, the cut-off rules according to clause 5.2.2.4 apply. This means that activities that are found negligible may be cut-off although they are within the system boundary.

Annex F defines the detailed life cycle stages which further defines the system boundary and which are to be considered when assessing the life cycle impact of ICT GNS. In particular, it is important to cover all processes whose relevance is marked as high in that table. The study report should transparently show and justify whenever processes marked with high relevance are not taken into account.

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

Appendix I gives additional information on the different stages and on the interfaces between the processes.

5.2.2.3.6.1 ICT goods

The system boundary of the ICT goods should encompass all life cycle stages specified in clause 5.2.2.3.6 and in Annex F.

In order to set the system boundary of ICT goods the life cycle stages listed in clause 5.2.2.3.6 shall be detailed. Further guidance is given in Annexes C, D, F, G and Appendix I.

As stated in clause 5.2.2.3.4, the environmental impact from both hardware and software shall be considered, if applicable.

5.2.2.3.6.2 ICT networks

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

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

For each type of ICT good constituting the ICT network, the rules defined for ICT goods in this Recommendation apply.

5.2.2.3.6.3 ICT services

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

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

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

The impact of the data centres where the service is operated shall be assessed. The associated activities of the service provider should also be considered.

Important data that defines the hardware associated with the service is the 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 system boundary of the ICT services provided by the ICT network shall be established based on either the actual use scenario of the ICT services, if available, or on an estimated use scenario, e.g., covering energy consumption during the period of services provided, any waste disposal or emissions due to the services, etc.

5.2.2.4 Cut-off rules

Cut-off in an LCA is defined as the process for the exclusion of input and output flows associated with unit processes from the product system. Several cut-off criteria exist and are further outlined below.

By invoking cut-off, the assessment can be simplified by excluding processes that will not significantly change the overall conclusions of the study, as long as the intended application is met.

Cut-off of processes or input/output data within the system boundaries however, requires careful consideration and should be avoided. A recommended alternative to cut-off is often to model unavailable data based on known data.

The cut-off criteria include mass, energy and environmental significance[8]. Cut-off is only acceptable if allowed by all the above-mentioned criteria.

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

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

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

Regarding the environmental significance criteria, a qualitative approach can be accepted, as the estimate of the total impact is often not possible at an early stage.

Any cut-off made shall be clearly described and documented.

It is further recommended that processes and input/output data that have been accepted for cut-off be considered when performing the sensitivity analysis.

5.2.2.5 Data quality requirements

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

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

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8 Environmental significance refers to contribution of for instance GHG emissions.

In addition, highly accurate and precise data is preferred.

For all data categories the data quality requirements from [ISO 14040] and [ISO 14044] clause 4.2.3.6 apply.

A qualitative description on the data quality and any efforts taken to improve data quality shall be given.

In general, the age of data and technology are especially important aspects in LCAs for ICT GNS due to the fast technology evolution and the growth in network traffic. Typically for data traffic, the most recent available figures shall be used, as data traffic grows considerably year by year. The availability of most recent figures may vary from one organization to another. Older figures tend to give overestimated results for energy use and related emissions per amount of data. A table in Appendix II gives an example of the recommended choice of data.

If support activities (e.g., ICT manufacturer activities and operator activities) are included in the LCA scope, data representative to the processes for which they are collected applies for all individual processes under the financial or operational control of the organization undertaking the LCA. Data should be representative of the processes for which they are collected.

5.2.3 Life cycle inventory (LCI)

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system.

5.2.3.1 Data collection

5.2.3.1.1 General

The data for inclusion in the inventory shall be collected for each unit process that is included within the system boundary. The collected data, whether measured, calculated or estimated, are utilized to quantify the inputs and outputs of a unit process.

When data has been collected from public sources, the source shall be referenced.

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

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

For data collection requirements according to [ISO 14040] clause 5.3.2 and [ISO 14044] clause 4.3.2 applies.

Before the collection of data can be made, each life cycle stage needs to be refined into items, also referred to as unit processes, which represent the basic physical flows (materials and energy) of the life cycle. For details on applicable unit processes for ICT GNS, refer to clause 5.2.2.3 "System boundaries".

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

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

It should be noted that commercially available data sets may not be transparent with respect to a detailed split of values. As an example, transport, travel and energy supply may often be embedded in a total figure. It is therefore recommended that the practitioner describes if such embedded data occurs.

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

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

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

5.2.3.1.2 ICT goods

Data shall be collected at least for the processes marked with high relevance in Annex F, unless these are found negligible in accordance with the cut-off rules.

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

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

5.2.3.1.2.1 Use stage energy consumption of ICT goods

From a data quality perspective, the best way to determine the energy consumption of ICT goods during the use stage would be to measure a large number of ICT goods operating in a live network over a long period of time (e.g., a year to capture all aspects of variations in traffic, temperatures etc.). This is facilitated if network equipment is equipped with remotely accessible energy meters.

If obtaining data from such measurements is not technically or economically feasible, another alternative would be to estimate the energy consumption based on available data measured in a laboratory context. However, this method will only give a snapshot of the energy really consumed and is considered less accurate.

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

5.2.3.1.2.2 ICT goods data for other life cycle stages

In the absence of primary or specific LCA data for the production stage of ICT goods, use stage to embodied ratios (i.e., ratio of environmental loads resulting from use stage and those resulting from all life cycle stages other than the use-stage) could be used to estimate this data. The LCA results could then be updated based on more specific data once available. The method adopted for different data sets should be documented.

5.2.3.1.2.3 Energy mixes

The LCA practitioner is encouraged to use the most accurate assessment of the energy mix that is consumed by the ICT goods under assessment, when calculating the potential environmental impact from the use stage. When known, specific data on energy mixes for a given locality or region gives the most accurate results.

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

Appendix VI gives guidance on how to consider energy mix related matters.

5.2.3.1.2.4 Handling of LCI results for electricity and energy

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

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

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

Annexes J and K contain important life cycle inventory (LCI) elementary flows (emissions and resources) and fuels that should be taken into account in LCA studies for ICT.

5.2.3.1.3 ICT networks

As ICT networks consist of ICT goods, the principles in clause 5.2.3.1.2 also apply for data collection of ICT networks.

As per the approach described in clause 5.2.2.3.6.2, the life cycle inventory (LCI) phase does not need to be repeated for goods for which LCA studies have already been performed.

5.2.3.1.4 ICT services

As for networks, the life cycle inventory (LCI) phase, which is usually the most time and resource consuming part of an LCA, does not need to be repeated for products and services for which LCA studies have already been performed. If such data is available, the LCI is reduced to data collection at a system level, focusing on how the service is carried out and used, and on the resources needed.

Use time, equipment type, data traffic and network access type give important statistical data that needs to be collected in order to quantify the use of ICT systems.

5.2.3.2 Data calculation

5.2.3.2.1 General

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

5.2.3.2.2 ICT goods

ICT goods consist of hardware and software. For both hardware and software, design, development, production, procurement and operation and maintenance activities are of interest and should be considered in accordance with clause 5.2.2.3, "System boundaries".

In terms of life cycle stages, most of these activities can be seen as support activities as detailed in clause 5.2.2.3, and the associated environmental impact emerges from the use of buildings, office equipment and consumables, from travel and transport, and from the generation of waste. All of these should be assessed as fully as possible, but it is not necessary to make a distinction between them, i.e., the total energy consumption of the office of the designers should be allocated between the designers, but it is not necessary to make a distinction between energy for heating and energy for office equipment associated with each designer.

For applicable allocation rules, refer to clause 5.2.3.3, "Allocation procedure".

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

5.2.3.2.3 ICT networks

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

First, the functional unit is established in accordance with clause 5.2.2.2.3 and then the corresponding environmental load is estimated. Since each ICT network is continuously evolving, the life cycle of an ICT network cannot be generalized with terms such as "from cradle to grave". Each ICT good, which is part of the considered ICT network, is regarded as a product system and is assessed separately.

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

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

For instance, for a theoretical mobile access network composed by 1000 identical base stations and 10 identical radio network controllers, the annual environmental load of this mobile access network is calculated as 1000 times the individual annual environmental load of one base station plus 10 times the individual annual environmental load of the radio network controller.

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

For the assessment of fixed access networks, a constant value is generally applicable for the use stage energy-related environmental load (e.g., per subscriber), as the equipment is connected to the access network whether or not the subscriber is using it. However, when power-saving features are used, a fixed value may not be applicable.

For the mobile access network, the environmental load of BSs should consider the two main activities of the BS, namely:

- To handle basic network signalling such as monitoring of the subscriber location. For instance, the wireless network needs to determine to which BS a mobile station (MS) belongs. To achieve this each MS is registered in the location register (LR) database at different fixed times, when it is turned on or it moves to a new location area, or periodically.
- To transfer data between the terminal/user-equipment and the core network. For instance, data is transferred for wireless communication after the LR registration of the MS.

Therefore, the environmental load of a BS consists of two parts:

- The environmental load associated with basic signalling which is constant regardless of the traffic.
- The environmental load associated with data transfer (i.e., payload and dedicated signalling) is proportional to the usage time and amount of data.

Therefore, as shown in Figure 6, the evaluation of the environmental load must consider both a fixed part which is independent of the usage and a variable part which correlates to the usage.

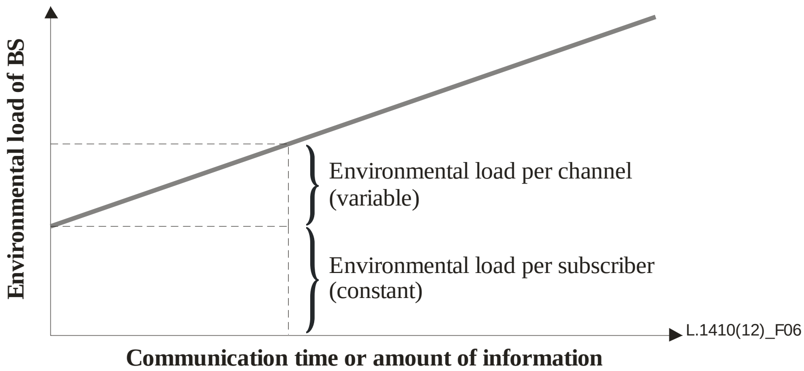

Figure 6 – Environmental load from BS

As for the wireline access network, the core network should generally be modelled as a constant value. However, when power-saving features are used, a fixed value may not be applicable.

5.2.3.2.4 ICT services

Data calculation for services is to a large extent related to the allocation of an appropriate amount of network data to the targeted service. For further details refer to clause 5.2.3.3.

5.2.3.3 Allocation procedure

5.2.3.3.1 General

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

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

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

Step 1: Wherever possible, allocation should be avoided by dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes, or expanding the product system to include the additional functions related to the co-products.

Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned based on the underlying physical relationships between them (e.g., mass).

Step 3: If step 2 is not feasible, the inputs should be allocated between the products and functions reflecting other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of each product (e.g., market value of the scrap material or recycled material in relation to the market value of primary material).

NOTE – This Recommendation does not give any guidance on how to share impact from recycling between the provider and user of recycled materials. The handling of this aspect must be considered when comparing different LCAs performed by different practitioners.

5.2.3.3.2 ICT goods

Allocation principles stated in clause 5.2.3.3.1 apply to allocations for ICT goods.

5.2.3.3.3 ICT networks

Allocation principles stated in clause 5.2.3.3.1 apply to allocations for ICT networks.

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

5.2.3.3.4 ICT services

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

If an ICT good is shared among several ICT services, the environmental load should be allocated according to the estimated usage of these various ICT services, as illustrated in Figure 7.

ICT services	Service A
ICT networks	
ICT goods	

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Figure 7 – Allocation procedure for ICT services

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

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

Access use time is preferred for circuit-switched networks and data traffic is preferred for packet-switched networks. Data traffic is also preferred for mobile access networks.

As an example, the environmental load of an ICT hardware, which is present in customer premises, is assessed based on its usage situation. The allocation for ICT hardware is calculated based on the communication time or amount of information used.

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

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

5.2.4 Life cycle impact assessment (LCIA)

For LCIA the requirements according to [ISO 14044] clause 4.4 apply.

The life cycle impact assessment (LCIA) aims to describe and indicate the impact of the environmental loads quantified in the inventory analysis. LCIA is a stepwise aggregation of the information given by the life cycle inventory (LCI) results.

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

The most recent global warming characterization factors from the Intergovernmental Panel on Climate Change [b-IPCC] for each GHG should be used and the timeframe should be 100 years.

Impact categories

In general, one single impact category cannot solely evaluate the environmental impact of a product. Instead, multiple impact categories are needed[9].

Of various impact categories, the single most important impact category to the ICT GNS can be climate change (global warming). ISO states that the selection of impact categories shall reflect a comprehensive set of environmental issues related to the product system being studied, taking the goal and scope into consideration.

However, the single impact category of climate change [in units of kg CO_2e] is the only impact category in focus within this Recommendation.

5.2.5 Life cycle interpretation

Interpretation is the phase of LCA in which the findings from the life cycle inventory (LCI) analysis and the life cycle impact assessment (LCIA) are considered together. The interpretation comprises several elements:

- identification of the significant issues based on the results of the LCI and LCIA phases of LCA;
- an assessment that considers completeness, sensitivity and consistency checks;
- conclusions, limitations, and recommendations.

5.2.5.1 Sensitivity analysis

The results of the LCI or LCIA phases shall be interpreted according to the goal and scope of the study. The interpretation should include a sensitivity check of the significant inputs, outputs and methodological choices, and defined use scenarios, in order to understand the uncertainty of the results.

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9 Examples of additional impact categories are water consumption [l H20], human toxicity [kg 1,4-DB eq], Resource depletion [kg Sb-eq], Acidification [kg S02-eq], Eutrophication [kg PO4-eq] and Ozone layer depletion [kg CFC 11-eq.]

5.2.5.2 Uncertainty analysis

The uncertainty of the results of an LCA study should be assessed in accordance with [ISO 14044] to the extent needed to understand the study results. Appendix III gives more information regarding uncertainty categories and important uncertainty sources for the different life cycle stages of ICT GNS. Appendix IV gives more information regarding opportunities and limitations in the use of LCA for ICT GNS.

5.3 Reporting

5.3.1 General

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

Reporting shall be performed in accordance with [ISO 14044]. In the case of reporting, a public GHG inventory report, the key accounting principles (relevance, accuracy, completeness, consistency, and transparency) shall be met.

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

In addition to the reporting obligations outlined by [ISO 14040] and [ISO 14044], the report shall include the following information:

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

The reporting of results shall include:

- total GHG emissions reported as amount of CO_2e per functional unit for ICT good, network and service that have been assessed
- percentage for each life cycle stage contributing to the total results
- electricity (with use stage separated from the other stages)
- primary energy[10]
- fuels
- value and sources of emission factors for CO_2 and CO_2e, and Global Warming Potential (GWP) metric used in the report
- other data, justifications and explanations as stated throughout this report.

5.3.2 ICT goods

The study report should transparently show and provide justification if processes marked highly relevant are not taken into account.

Each life cycle stage can be divided into appropriate sub-stages. The sub-stages below are to be seen as examples only.

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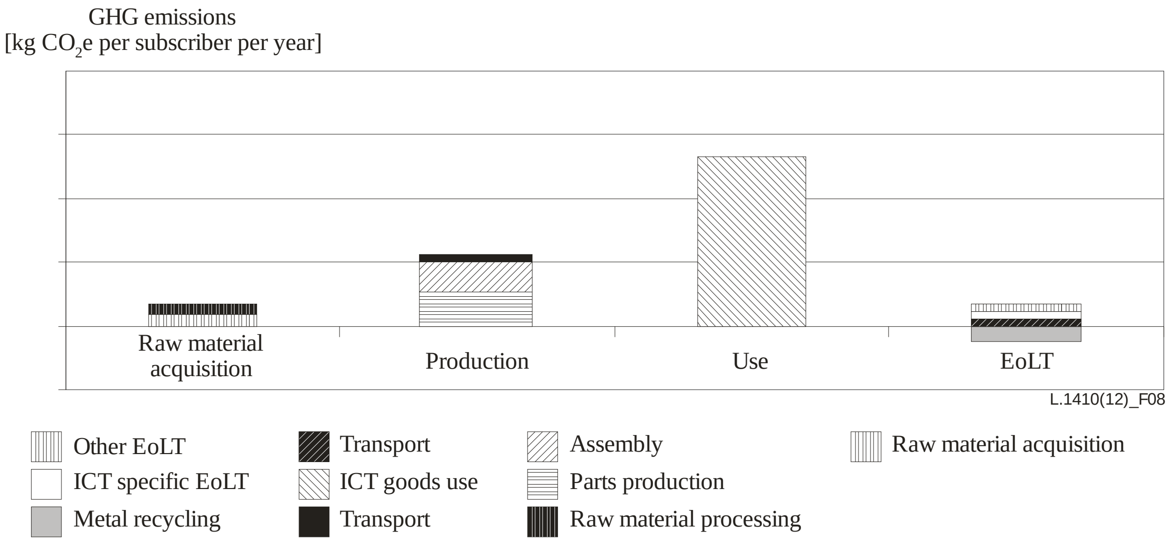
[10] Note that primary energy and electricity cannot be summarized because electricity is contributing to the total primary energy.



O&M = Operation and maintenance
EoLT = End of life treatment

Figure 8 – Example of a reporting structure for a goods level LCA

5.3.3 ICT networks

Figure 9 below illustrates how network-level LCA reporting can be built up by the goods level LCA data, using a typical wireless network as an example. The same principle applies for other types of networks, e.g., broadband, traditional fixed voice, IP-voice, LAN and IPTV networks.

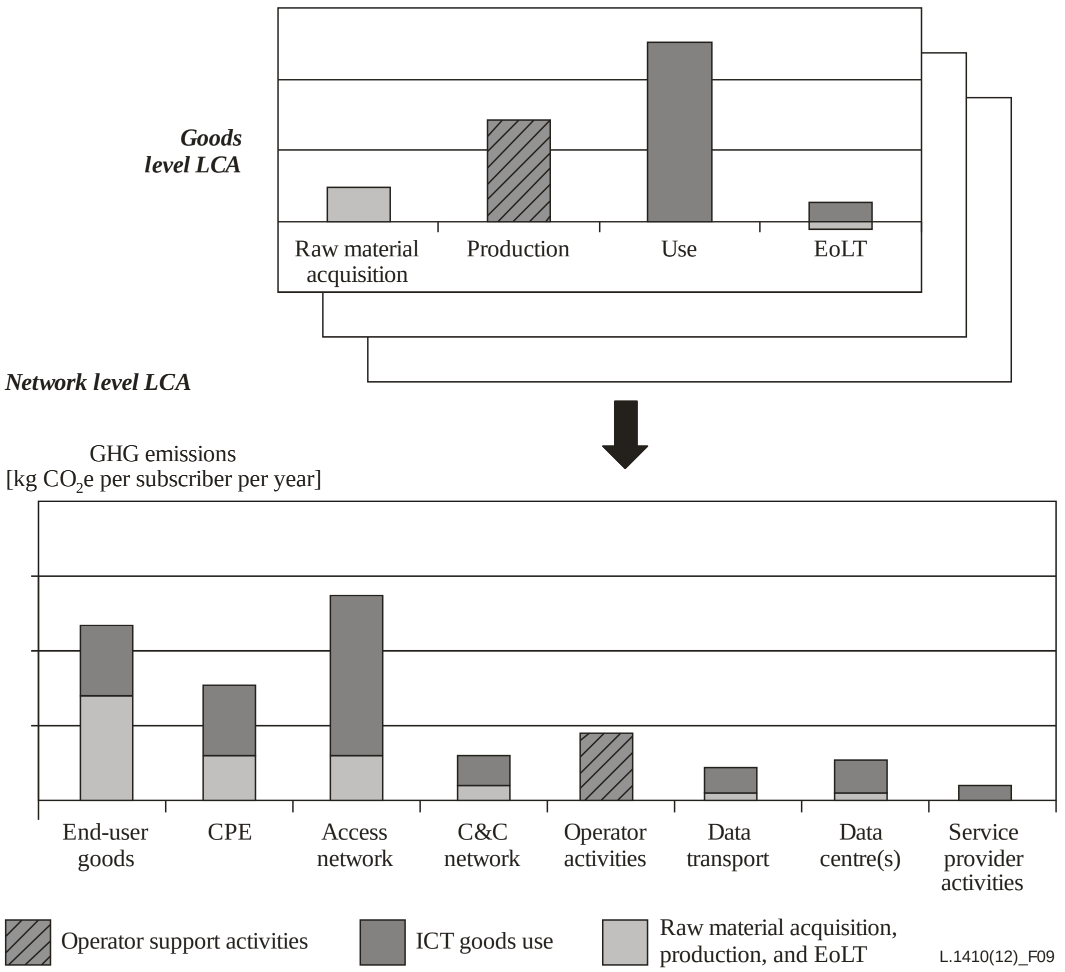


Figure 9 – Example of a reporting structure for a network-level LCA

Additionally, the proposed network structure can also be used to report important high-level parameters such as quantities and energy consumption of included goods (see Table 3).

Table 3 – Example of reporting structure

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

5.3.4 ICT services

Reporting at the service level may be structured based on the various network parts used by the ICT service, in the same way as networks are reported. Each bar should then show the relation between the dedicated impact of the ICT service under study and the impact associated with all other ICT services (see Figure 10), in order to illustrate the relative contribution of each activity to the total amount of environmental load.

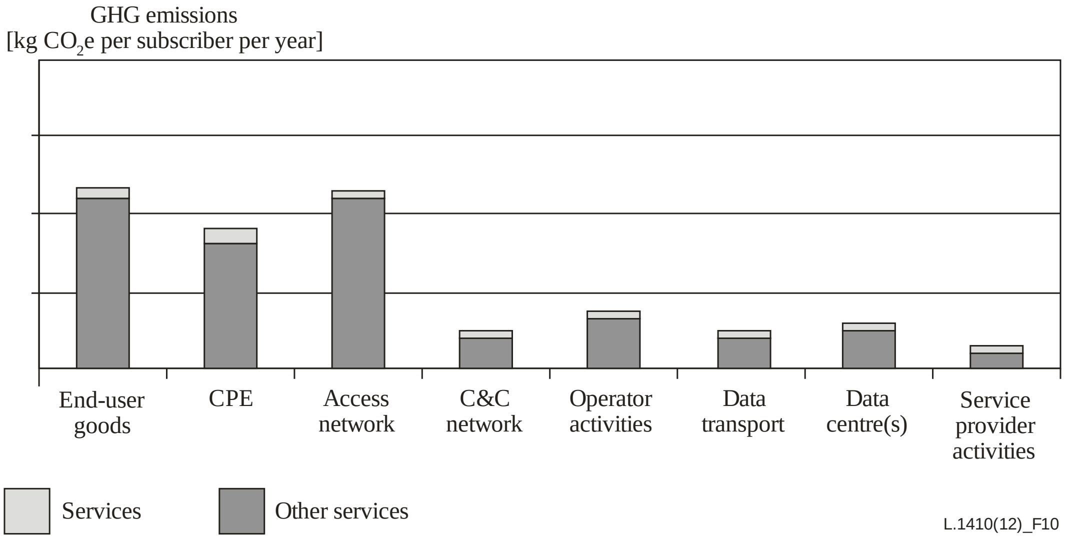


Figure 10 – Example of a reporting structure for ICT services

If the eight checklist items outlined in clause 5.2.2.3.2 are kept apart in the assessment and in the reporting then Figure 11 shows an example of a possible reporting format.

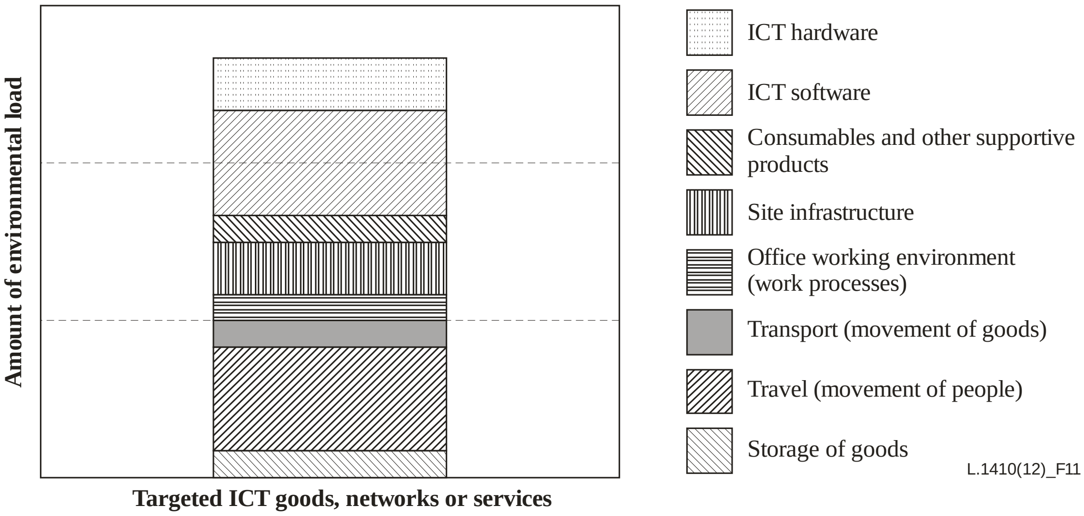


Figure 11 – Example of results of an LCA per functional unit separating checklist items

5.4 Critical review

Critical review is a process to verify whether an LCA has met the requirements for methodology, data, interpretation and reporting and whether it is consistent with the principles. The scope and type of critical review desired shall be defined in accordance with [ISO 14044] clause 4.2.3.7.

In case of comparative assertions intended for public disclosure, the report of the LCA should be reviewed by a panel of interested external parties. In this case, the practitioner should refer to [ISO 14040] and [ISO 14044] for further details.

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

6.1 General description of comparative analysis

6.1.1 Need for comparative analysis

With the growth of ICT, the use of ICT GNS will continue to increase as will the associated environmental load, also referred to as the first order effect. This effect represents the life cycle environmental load emerging from processes such as design, production and installation of software and hardware, installation of ICT devices and networks, and from disposal and recycling, as well as from the use stage. However, by its second order effects, ICT offers the potential to replace or rationalize more energy and resource intensive processes, and is in many cases expected to deliver a net positive impact on the environment.

The above could be illustrated by video conferencing, which offers the potential for reducing the environmental load by reducing the need for travelling. It should, however, be noted that the actual load may not be reduced if buses and trains operate according to unchanged timetables. Still, it is reasonable to assume that a wide spread of video conferencing systems will reduce traffic volume and impact timetables in the long-term. Based on this assumption, it can be justified that such environmental load reduction potentials can be considered even when the reduction is not immediately achievable, as long as it is made clear what is the immediate potential impact if a service is applied and what depends on other factors.

To be able to quantify the net environmental impact when introducing an ICT-based service, the environmental impact of both the ICT service itself and of the reference product system need to be assessed from a life cycle perspective. For further guidance refer to Part I (clause 5).

To make sure that the comparative assessment gives a correct result, the full life cycle of both systems should always be considered. If some processes are found negligible or are identical between the systems, cut-off could potentially be performed in accordance with clause 6.2.2.3.

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

6.1.2 Target systems for comparative analysis

Two different applications for comparative assessment are targeted by this Recommendation.

First case: comparison between a reference product system and an ICT service

In this case, the two target systems are the reference product system and the ICT service. The former is the business-as-usual case or baseline case where no ICT service is applied. The latter is the case where the ICT service is applied. The purpose of this comparison is to understand the second order effects when introducing an ICT based product system as a replacement for a reference system. Such effects include a reduction in environmental impact in terms of GHG emission savings in for instance, commuting, air flights, hotel stays, etc.

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

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

6.1.3 Principles of comparisons between systems (comparative analysis)

6.1.3.1 First case: comparison between a reference product system and an ICT service

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

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

Using ICTs has the potential to enhance energy efficiency and reduce the need, for instance, for transport and travel, etc. To assess the impact on the second order effects, it is important to consider the environmental load reduction effects by using ICT. The most important effects are listed in clause 6.2.5 and Appendix V. In addition, other load reduction effects may also be relevant and should then be considered as well.

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

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

6.1.3.3 Common principles

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

A schematic illustration of a comparative assessment is shown in Figure 12. The figure indicates that the reference product system and the ICT GNS product system are assessed separately and then compared. For the comparison, the contributions from the environmental load reduction effects listed in Appendix V could be considered to further detail the results.

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

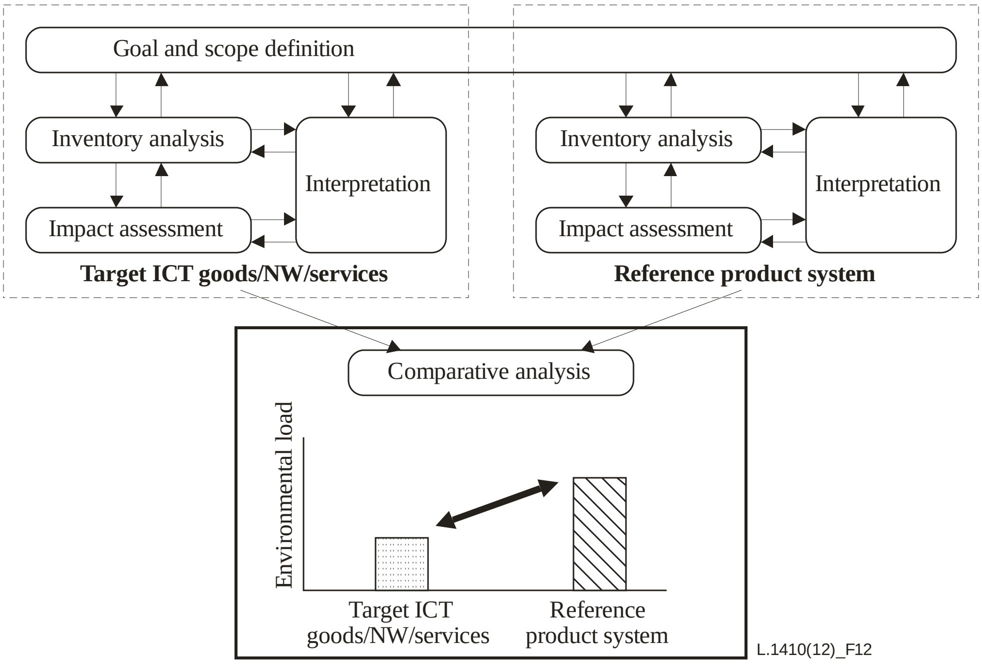


Figure 12 – Comparative assessment of a reference product system and an ICT GNS product system

6.1.4 Procedures of comparisons between systems (comparative analysis)

As indicated above, the assessment procedure contains several steps:

- definition of goal, functional unit and scenarios
- definition of system boundaries for each product system
- life cycle inventory including data collection for each product system
- life cycle impact assessment for each product system
- life cycle interpretation including comparison.

6.2 Methodological framework of comparative analysis

6.2.1 General requirements

In the comparative situation, the full life cycle applies to both the ICT product system and the baseline system, unless cut-off is allowed in accordance with the cut-off rules outlined in clause 6.2.2.3.

The most important reduction effects by using ICT are listed in Appendix V. In addition, other load reduction effects may also be relevant and should then be considered as well.

6.2.2 Goal and scope definition

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

Defining the scope includes defining the system boundaries of the ICT GNS product system and the reference product system.

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

6.2.2.1 Functional unit

The functional unit shall take into account the general rules outlined in Part I, clause 5.2.2.2 "Functional unit" and [ISO 14044] clause 4.2.3.2.

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

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

6.2.2.2 System boundaries

Two different system boundaries shall be defined which are applicable for the ICT GNS product system and for the reference product systems respectively.

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

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

As the electricity mix changes in different regions, countries or world, considerations must be paid to which electricity is used when assessing the environmental impact of the ICT GNS product system and the reference product systems.

For the ICT GNS product system the system boundaries outlined in Part I, clause 5.2.2.3 applies.

6.2.2.3 Cut off

6.2.2.3.1 General

Generally, the cut-off rules in Part I (see clause 5.2.2.4 for details) apply for both ICT goods, networks and services and the reference product system.

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

6.2.2.3.2 Identification of life cycle stages and items important for comparison

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

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

6.2.2.4 Allocation

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

6.2.2.5 Data quality requirements

The data quality requirements in Part I, clause 5.2.2.5, are applicable to both systems compared.

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

6.2.3 Life cycle inventory

The calculation for the inventory analysis shall be performed in accordance with Part I, clause 5.2.3.2.

6.2.4 Life cycle impact assessment

The life cycle impact assessment is to be performed in accordance with Part I, clause 5.2.4.

6.2.5 Life cycle interpretation

6.2.5.1 General

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

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

Results of a comparative analysis between a reference product system and systems of an ICT GNS product system can be obtained by calculating the difference in environmental impact between the reference product system and the systems of ICT GNS. The difference is termed secondary effect. Equation 6-1 shows the calculation formula.

$$EI_{difference,i} = EI_{reference,i} - EI_{ICT\ GNS,i} \tag{6-1}$$

where:

EI = environmental impact,

i = i-th comparison category,

$EI_{difference,i}$ = i-th secondary effect,

$EI_{reference,i}$ = i-th EI of the reference product system,

$EI_{ICT\ GNS,i}$ = i-th EI of the systems of ICT GNS.

Summing up $EI_{difference,i}$ over i gives total $EI_{difference}$ or the secondary effect of the systems of ICT GNS over the reference product system. Equation 6-2 shows the formula for calculating the secondary effect.

$$\text{Total } EI_{difference} = \sum EI_{difference,i} \tag{6-2}$$

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

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

Table 4 shows an example of comparison categories, based on six comparison items, and the potential corresponding second order effects. Depending on the type of ICT services and corresponding reference product system, these categories may not be used and other categories may be added. Additionally, the practitioner may choose to structure the data based on other factors, e.g., per sub-network type.

Table 4 – Comparison category and its secondary effects

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

Appendix V lists examples for calculating second order effects for the six comparison categories.

6.2.5.2 Sensitivity analysis

For the handling of sensitivity analysis refer to Part I, clause 5.2.5.1.

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

6.2.5.3 Uncertainty analysis

For the handling of uncertainty analysis refer to Part I, clause 5.2.5.2.

6.3 Reporting

In addition to general reporting rules outlined in Part I, clause 5.3, the following specific consideration applies for comparative assessment.

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

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

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

Some examples are shown below.

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

Percentage change in environmental impact through the introduction of ICT systems:

$$\text{ICT GNS} = \text{EI}_{\text{difference}}/\text{EI}_{\text{reference}} \times 100 \quad (6\text{-}3)$$

where EI is the assessed environmental impact.

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

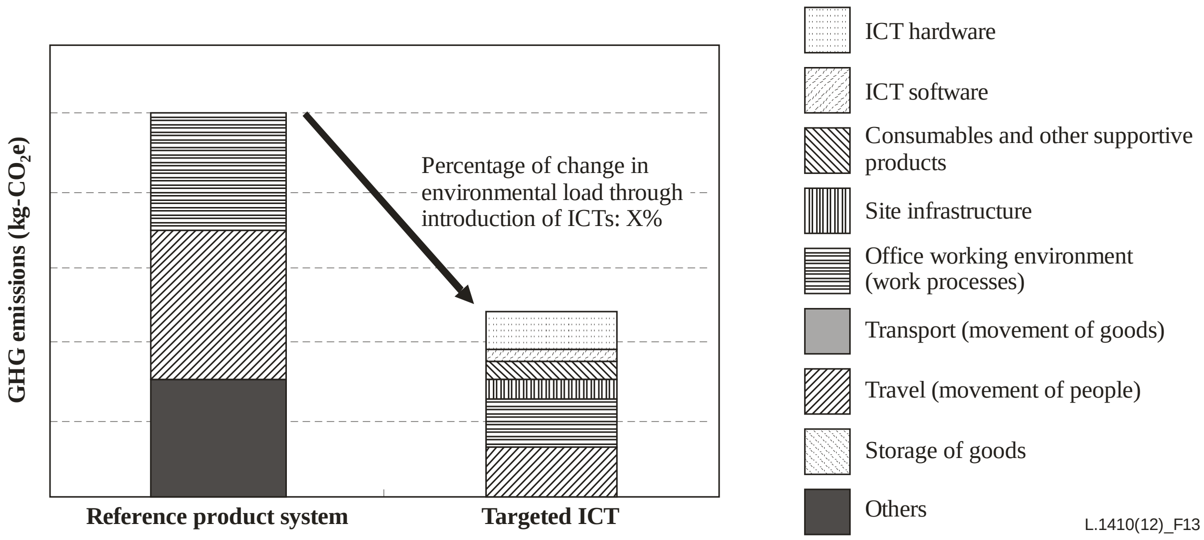


Figure 13 – Example of comparative analysis between an ICT GNS product system and a reference product system with checklist items

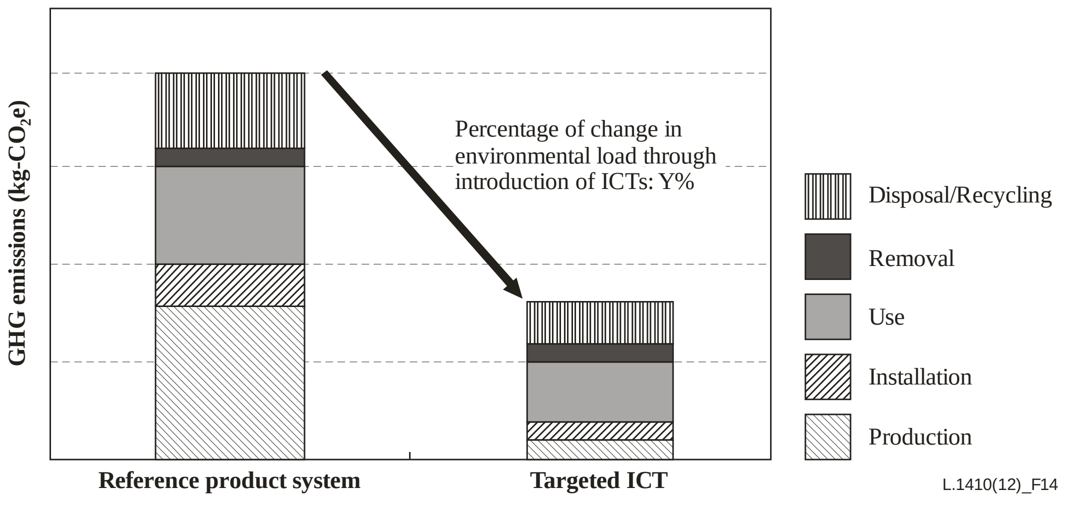


Figure 14 – Example of comparative analysis between an ICT product system and a reference product system with stages of a life cycle

It should be noted that the reporting structure in this example (Figure 14) is different compared to that of Part I, clause 5.2.2.3.6 and Table 1.

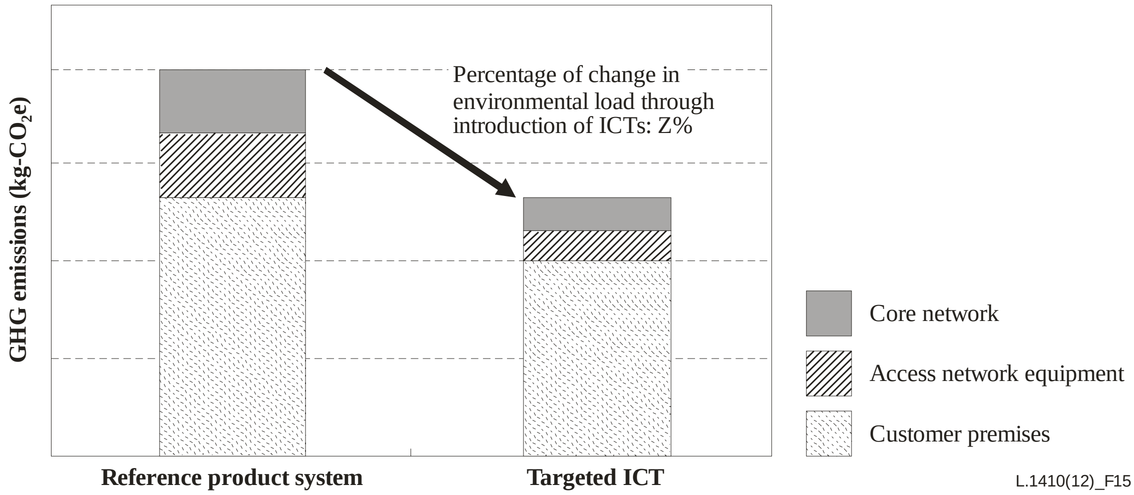


Figure 15 – Example of comparative evaluation between ICT and reference technology with details of sub-networks

6.4 Critical review

The critical review should be performed in accordance with principles outlined in Part I, clause 5.4 for the ICT product system, the reference product system and the comparison between them.

Annex A

A method for assessing the environmental load of the working environment

(This annex forms an integral part of this Recommendation.)

This annex describes a methodology to assess the environmental load of the working environment.

- This methodology may be used in order to assess the impacts related to ICT GNS Part I (clause 5).
- It may also be used in order to assess the impacts related to the working environment when performing a comparison implying better office space usage thanks to ICT (Part II, clause 6).

An example of an assessment of the environmental impact of the working environment based on this methodology is provided in clause VII.4.

A.1 Purpose of targeting the working environment in the assessment of ICT GNS

The working environment is one of the important checklist items to consider when assessing the environmental impact of ICT GNS in Part I.

In addition, improved work efficiency thanks to ICT GNS is listed as a category for comparison in Part II. To perform a comparison, an assessment of the working environment is often necessary.

Employment and work styles are undergoing a transformation in many countries and there are several types of office spaces in addition to the traditional ones, such as small offices home offices (SOHO), mobile office, etc.

A.2 Functional unit

A functional unit of the "working environment" may be defined as a "provision of working space and working environment for one year".

Another functional unit of the "working environment" may be defined as a "provision of working space and working environment for one year per person".

A.3 System boundary

A system boundary for evaluating the working environment may be described as shown in Figure A.1. Once the functional unit is defined, energy consumption should be calculated by considering the energy consumption of the heating system, air conditioning system, other motive powers (e.g., for automatic doors, elevators), lighting and appliances used for business purposes and related to targeted work. As for other energy consumption data, GHG emissions should then be derived from the energy consumption values.

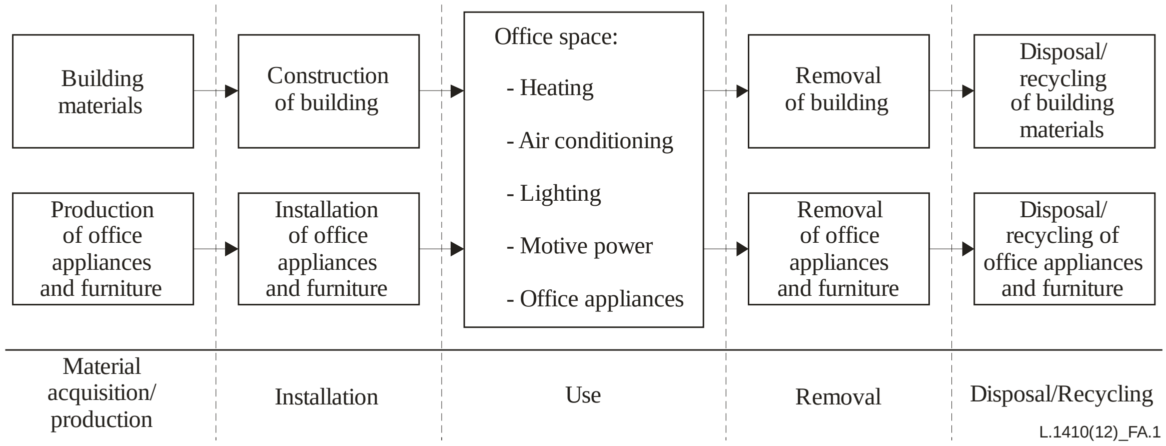


Figure A.1 – System boundary of working environment

A.4 Life cycle inventory (LCI)

A.4.1 Data collection

To evaluate the energy consumption and GHG emissions of the working environment (whether at the office or at home), data on energy consumption, the space occupied by each person, and the number of working hours per year could be calculated based on available statistical data.

A.4.2 Data calculation

Regarding the environmental impact of the working environment, energy consumption should first be assessed for all activities within the system boundaries, e.g., heating; air conditioning; lighting; motive power, etc.

NOTE – Depending on the type of data available (aggregated or distributed), classification into these activities may not be applicable.

Secondly, energy consumption should be classified into fuel categories in accordance with Annex K.

Thirdly, energy consumption and GHG emissions should be calculated for each fuel category in:

- Energy (J)
- GHG emission (kg-CO_2e).

Finally, total energy consumption and GHG emissions should be calculated by adding the environmental impact of all fuel categories.

A.4.3 Allocation procedure

To evaluate energy consumption and GHG emissions of offices at home, an allocation between working activities and other activities is required. This distinction between working activities and other activities should be based on appropriate assumptions and should be documented.

Overall, publicly available statistical data to be considered for allocation in a home office:

- working style
- working hours
- percentage of workers who work only at home or at home and also at the office.

Considering the above-mentioned factors, the home office impact intensity would be obtained by allocating the environmental load to the working activities and household activities.

Annex B

Details regarding the handling of software

(This annex forms an integral part of this Recommendation.)

This annex details some central aspects for the assessment of software.

Life cycle stages and allocation principles for software

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

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

Activities associated with the use of software

The following items are examples of activities related to software design and production that cause an environmental impact.

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

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

Procedures for data collection

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

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

In this case, the environmental impact for these activities may be calculated using the below formula by adding up the different environmental impact for different activities:

$$Ea=E1+E2+E3+ \text{---------} +En$$

Ea: Quantity of environmental load for software design and production

E1, E2, E3, En: Quantity of environmental load for each activity

For procured software, the following method based on addition of environmental load per software can be applied:

$$Eb=O+B1+B2+M1+M2$$

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

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

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

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

$$Eb=(W/p1)\times S1$$

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

W: Total amount of all software to be procured (selling price, etc.)

p1: Amount of software for which their environmental loads are known (CO_2 emission, etc.)

S1: Quantity of the environmental load of software (w1) well-known quantity of environmental load (CO_2 emission, etc.)

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

$$S=w1\times k$$

S: Environmental load with the design and production of software

w1: Price of software to be targeted

k: The emission factor in CO_2 emission

Annex C

Generic processes

(This annex forms an integral part of this Recommendation.)

Table C.1 details the recurring generic processes which should be included in LCAs of ICT goods, networks and services, when applicable, if no specific rules according to this Recommendation allow cut-off. See Appendix I for further details.

Table C.1 – Generic unit processes and their importance

Part	Generic process categories	Unit processes (for each category)	Product flow unit	Important issues
G1. Transport & Travel	Road Air Ship Train	High: direct (during transport) emissions & fuel supply chain. Medium: vehicle production & infrastructure production.	tonne×km, kg×km, Ctonne×km	Chargeable weight = Ctonne×km (function that also considers volume or density).
G2. Electricity	National, regional and producer electricity mixes	High: fuel supply chain, direct emissions (during electricity production). Medium: power plant production, dam production, grid production, nuclear waste treatment.	kWh	
G3. Fuels	Oil Diesel Petrol Jet-fuel LPG LNG Coal Gas	High: Fuel supply chain: extraction and production, distribution (transport) and emissions related to the incineration of the fuel is connected to a unit process or "site LCI model".	mass, volume, energy content	
G4. Other energy	District heating (hot water) District heating (steam) District cooling (cold water) as electricity	High: fuel supply chain, direct emissions during energy/electricity production. Medium: power plant construction, infrastructure production.	kWh	Electricity is also an energy source or district heating/cooling production.

Table C.1 – Generic unit processes and their importance

Part	Generic process categories	Unit processes (for each category)	Product flow unit	Important issues
G5. Raw material acquisition		High: extraction processing	mass, volume	
G6. End-of-life treatment	See Annex G			
G7. Raw material recycling	Metal recycling	High: smelting, refining		Other materials should be considered.

Annex D

Part types of ICT goods

(This annex forms an integral part of this Recommendation.)

Table D.1 lists parts which shall be taken into account, when applicable to the ICT good (not ICT network), when performing an LCA of ICT goods, as well as the corresponding categories and unit processes. However, parts which are found insignificant according to the cut-off rules may be excluded. The list is to be regarded as a list of high relevance and more parts/part categories/unit processes may be included. Other part types may be taken into account, e.g., fuel cells.

NOTE – The intention of the list is to state what shall be considered. Additional processes and parts may be identified and can then be considered as well.

Table D.1 – Specific part types of ICT goods (not ICT networks) that shall be included when applicable to the ICT good

Part	Part categories	Part unit processes (for each category)	Product flow unit	Important issues
B1.1.1 Batteries	Lead batteries, lithium batteries, nickel-cadmium batteries	Raw material acquisition, battery cell assembly, battery module assembly.	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 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 materials production, wafer production, chip production ("the wafer fab"). Back-end: IC encapsulation.	Piece, front-end: good die area [cm2], back-end: piece package type Transistors and diodes: Piece, mass	Yield in chip production. Business activities. Factory and machinery.

Table D.1 – Specific part types of ICT goods (not ICT networks) that shall be included when applicable to the ICT good

Part	Part categories	Part unit processes (for each category)	Product flow unit	Important issues
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 LED	Raw materials acquisition for special display panel materials, display panel assembly, display module assembly.	Piece, mass, active area	Yield, business activities, factory and machinery.
B1.1.7 PCB	Plastic Ceramic Flex-film	Raw materials acquisition for special PCB materials, raw materials acquisition for PCB semi-produced composite materials, PCB final assembly.	Piece, mass, cm2×layer	Yield, business activities, factory and machinery.
B1.1.8 Other PCBA components	Resistors Capacitors Inductors Relays LEDs Potentiometers Quartz crystal oscillator	Raw material acquisition, part final assembly.	Piece, mass	
B1.1.9 Packaging materials	Paper Cardboard Plastics Wood Steel	Raw material acquisition	Mass, volume	Lifetime, reuse, energy recovery.
B1.1.10 complex modules	Modules bought by ICT goods producer as complete products (e.g., cameras, modules, memories, printer cartridges).	"Cradle-to-gate" LCA from supplier.	Piece, mass	Size, mass, technology
B1.1.11 Software	Software development			

Annex E

ICT network overview

(This annex forms an integral part of this Recommendation.)

An ICT network is commonly described in terms of boxes, each of which is associated with a specific function or a set of coherent functions. Typically, major network functions could be represented as shown below. The network elements below are part of existing ICT networks. However, this Recommendation is not restricted to these ICT network elements but will also apply when assessing any existing or future ICT networks.

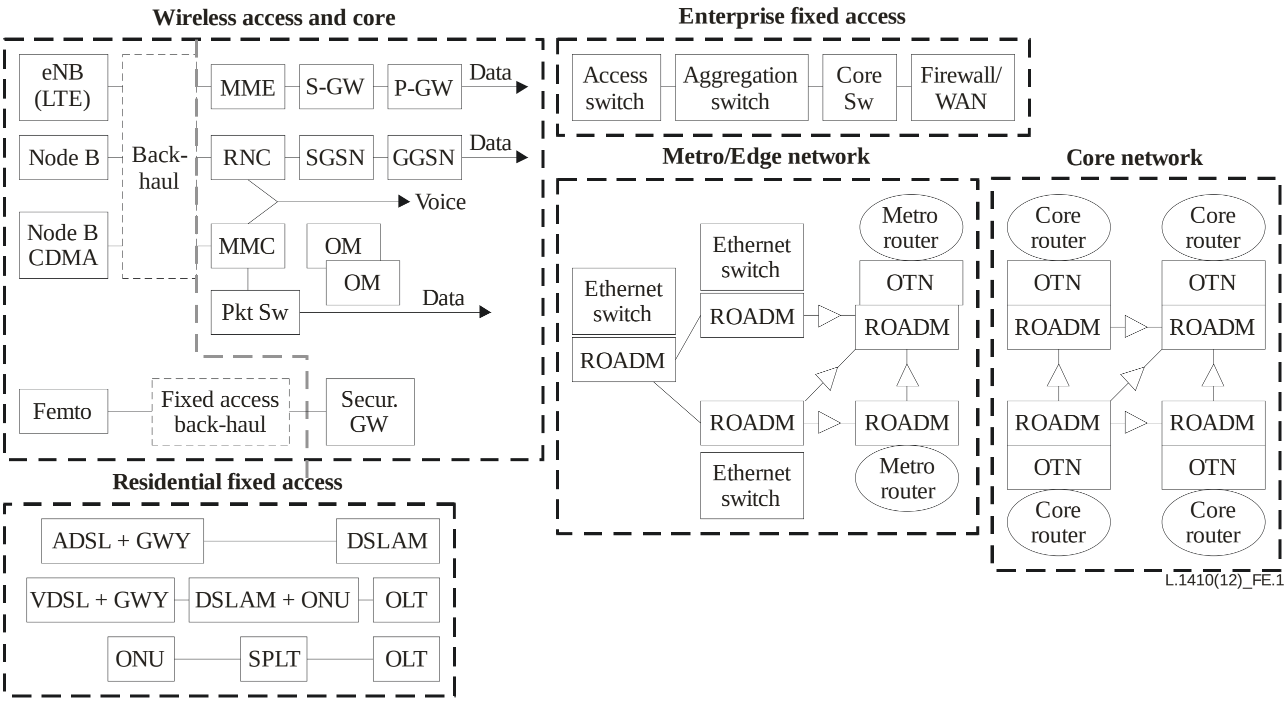


Figure E.1 – Example of an ICT network reference model

A wireless access and core network consists of an access and a core domain. Examples of wireless technologies include GSM, W-CDMA, LTE. Typically, for LTE/EPC the core network (known as the evolved packet system) provides IP connectivity using the access network (E-UTRAN). For GSM and UMTS, the core network consists of a circuit switched domain (comprising MSC/VLR) and a packet switched domain (GPRS core comprising SGSN, GGSN) which supports interworking with IP-based networks. The mobile access network consists of physical entities which manage the radio resource (BTS/BSC, node B/RNC, enode B) and provide the user with mechanisms to access the core network.

The residential fixed access network provides the end user with an access to the network carrying digital signals used for voice band and digital data.

The metro/edge network provides connectivity and transport to large areas with a high concentration of business customers. These ICT networks provide the bridge between the long-haul environment and the access environment.

The enterprise fixed access network includes a local area network (LAN) used to connect an end system to an edge router. There are many different types of LAN technology and Ethernet technology is currently by far the most prevalent access technology in enterprise networks. The edge router is then routing packets that have destinations outside of the LAN.

The long-haul network interconnects cities and regions covering hundreds of kilometres between several central offices. It includes core routers operating in the Internet backbone and forwarding IP packets at a very high speed through optical transport infrastructures.

From an end-user perspective, some other devices are used when they are offered as an end-to-end service. Typically, terminal devices (mobile phones, fixed phone sets, personal computers, printers, scanners) are needed to initiate a call, to surf the Internet or to print documents. GPS devices are also required to propose optimized routes when driving a vehicle. Moreover, it is expected that innovative services will be provided in the future to the general public that will drastically change the environmental impact of end users (such as smart meters for example). Also, enterprises are using a variety of equipment for running their business (PBX switches, PC, printers, scanners).

An example of functions of a wireless mobile telecommunication network is shown below.

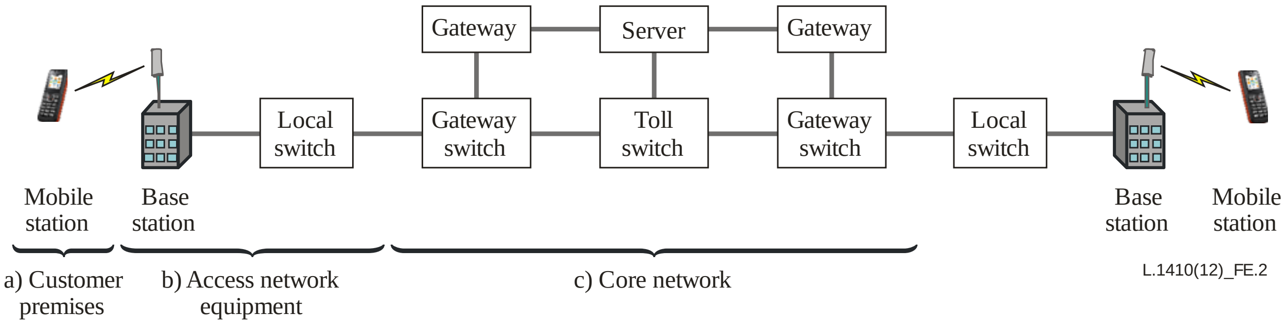


Figure E.2 – Example of functions of wireless mobile telecommunication network

Annex F

Specific ICT unit processes

(This annex forms an integral part of this Recommendation.)

Table F.1 below details the life cycle stages applicable for LCAs of ICT goods, networks, and services. "High relevance" means that the life cycle stage/unit process should be included in LCAs of ICT GNS unless they are found to be negligible according to the cut-off rules. If such life cycle stage/unit processes are omitted then they shall be clearly stated and reported together with the results. If an assessment is made for a specific part of the life cycle only, that shall also be clearly stated and reported.

The life cycle stages with medium relevance are recommended for inclusion but may be left out of the LCA depending on the scope and purpose of the LCA.

Table F.1 – Specific ICT unit processes that should be considered if applicable

Tag	Life cycle stage	Unit process	Class and relevance: High/Medium/Low		
			ICT Good	ICT Network	ICT Service
A	**Raw material acquisition**				
A1	Raw material extraction		High	High	High
A2	Raw material processing		High	High	High
B	**Production**				
B1	Goods production				
B1.1		Parts production (for further details refer to Annex D Part types and Appendix I)	High	High	High
B1.2		Assembly	High	High	High
B1.3		ICT manufacturer support activities	Medium	Medium	Medium

Table F.1 – Specific ICT unit processes that should be considered if applicable

Tag	Life cycle stage	Unit process	Class and relevance: High/Medium/Low		
B2	Support goods production				
B2.1		Support goods manufacturing[1)]	Medium (High if Support goods is included in the Scope)	High	High
B3	Construction of the ICT specific Site		Medium	High	High
C	**Use**				
C1	Goods use		High	High	High
C2	Support goods use		Medium (High if Support goods is included in the Scope)	High	High
C3	Operator activities[1)]		Medium	High	High
C4	Service provider activities		Not applicable	Medium	High
D	**End of life treatment**				
D1	Preparation of ICT goods for re-use		High	High	High
D2	ICT-specific EoLT		High	High	High
D2.1		Storage/disassembly/dismantling/shredding	High	High	High
D2.2		Recycling	High	High	High
D3	Other EoLT		High	High	High
[1)] Not applicable for end-user goods.					

A more detailed overview, showing the detailed content and connection between all life cycle stages, is shown in Appendix I.

All stages in the life cycle are associated with different support activities. The term support activities refers to, e.g., offices including ICT use for marketing, sales and R&D, and also to business travel, commuting and service vehicles. The support activities are of medium relevance with regards to their inclusion.

Annex G

EoLT processes

(This annex forms an integral part of this Recommendation.)

Table G.1 below defines the different secondary and specific EoLT processes to be included (if applicable) in LCAs for ICT goods as well as process categories of high relevance and corresponding EoLT process unit processes of high relevance. The list is to be regarded as a short list of high relevance and more EoLT processes/process categories/unit processes may be included.

Table G.1 – Examples of EoLT processes for an LCA of ICT goods

G6. End of life treatment	Examples of process categories	EoLT process unit processes (for each category)	Goods flow unit
G6.1 EHW (environmentally hazardous waste) 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).	mass, (energy content)
G6.2 Other Waste treatment	Diverse material recycling Energy recovery (e.g., incineration) Landfill	In general: recycling/recovery/treatment (one unit process or "site LCI model" for each material/ waste categories).	mass, (energy content)
D. EoLT	D1. Re-use of ICT goods D2. ICT-specific EoLT D2.1 Storage/disassembly/dismantling/ shredding D2.2 Recycling D2.2.1 Battery recycling D2.2.2 Printed circuit board assembly (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 (one unit process per material/waste category).	Mass

Annex H

Modelling of unit processes

(This annex forms an integral part of this Recommendation.)

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 as a large percentage 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 H.1 below. 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.

In many cases, a facility handles not only the product system targeted by the LCA but also other product systems. In this situation, the facility data needs to be allocated to the targeted product system in an appropriate way.

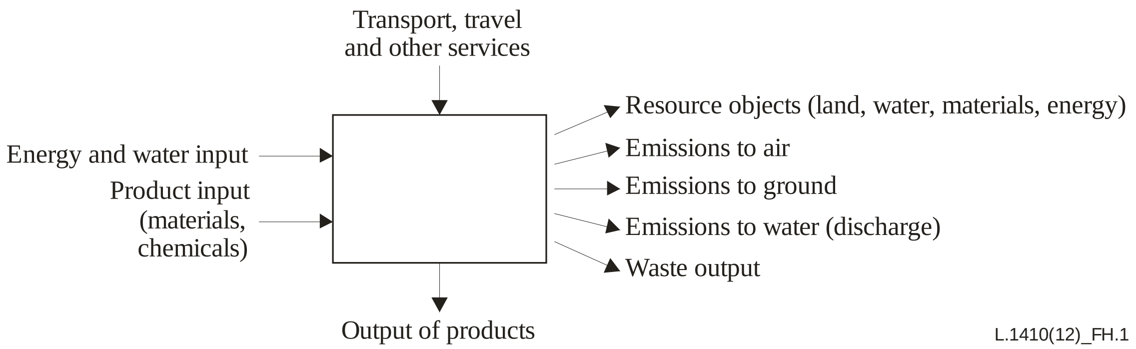


Figure H.1 – The generic unit process model

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

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

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

Emissions (elementary flows)

The following emissions should be considered for ICT:

- emissions to air
- emissions to water
- emissions to ground.

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

Resource objects (elementary flows)

The following resource objects should be considered 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 aesthetic values are beyond the scope of this Recommendation.

Energy, product and services inputs

Additionally, the following inputs should also be considered for ICT:

– Electricity
– Other forms of delivered energy (district heating and cooling)
– Fuels (typically indicates the fuels are combusted 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)
– Transport, travel and other services (can be seen as a special non-material secondary product input).

Product, water and waste output

Finally, the following flows should also be considered:

– water discharge (to municipal sewage or recipient)
– waste fractions (residual waste fractions or waste fractions that need further treatment, also including material recycling and energy recovery)
– Product output (the main purpose with the unit process or activity).

Annex J

Elementary flows (emissions and resources)

(This annex forms an integral part of this Recommendation.)

For **GWP** the elementary flows listed below (for emissions to air) should be taken into account.

- CH4, methane
- CO_2, carbon dioxide
- N_2O, dinitrogene oxide (laughing gas)
- NOx

  NOTE – There is an ongoing discussion among scientists on how to calculate climate impact from NOx
- CFC (CClF3)
- CFC-11 (CCl3F)
- CFC-12 (CCl2F2)
- CFC-113 (Cl2FC-CClF2)
- CF4 (CFC-14)
- C2F6 (CFC-116)
- Halon 1211 (CBrClF2)
- Halon 1301 (CBrF3)
- HFC-23 (CHF3)
- HFC-134a
- HFC-143a
- HFC-125
- HCFC-22
- HCFC-141b
- Other CFCs/HFCs/HCFCs/PFCs and blends of the ones listed above (the most common)
- NF3, nitrogen trifluoride
- SF6, sulphur hexafluoride
- Other (new) "high GWPs"

The recommended unit is mass (unless otherwise stated): **g, kg, tonne**.

For global warming potential factors refer to the IPCC 2007 Fourth Assessment Report (AR4) [b-IPCC] by Working Group 1 (WG1), Chapter 2 (Changes in Atmospheric Constituents and in Radiative Forcing).

Other elementary flows which are of interest may be added when enough scientific consensus is available.

For **energy** the following resources[11] apply:

- Oil
- Gas
- Coal
- Uranium
- Energy related to hydro-electric power
- Biofuels
- For renewable energy sources use generated energy

Different qualities of fossil fuels have different contents of C/H (coal/hydrogen) and then also different energy content measured in kgOE or TOE or MJ.

The recommended unit is **kgOE, TOE (kg or tonne oil equivalents) or MJ**.

[11] Mainly primary energy.

Annex K

Fuels

(This annex forms an integral part of this Recommendation.)

At least the following fuels should be taken into account in LCA studies for ICT:

Fuels

- Heating oil
- Bunker oil/ship diesel
- Diesel
- Petrol
- Jet fuel
- Liquid petroleum gas (LPG)
- Liquid natural gas (LNG)
- Biofuels
- Oil, gas, coal and uranium used to generate electricity in power plants.

Appendix I

Life cycle stages overview

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

Figure I.1 encompasses the entire life cycle of ICT goods as well as identifying significant processes in each life cycle stage. Based on this figure, a process tree of ICT goods can be developed.

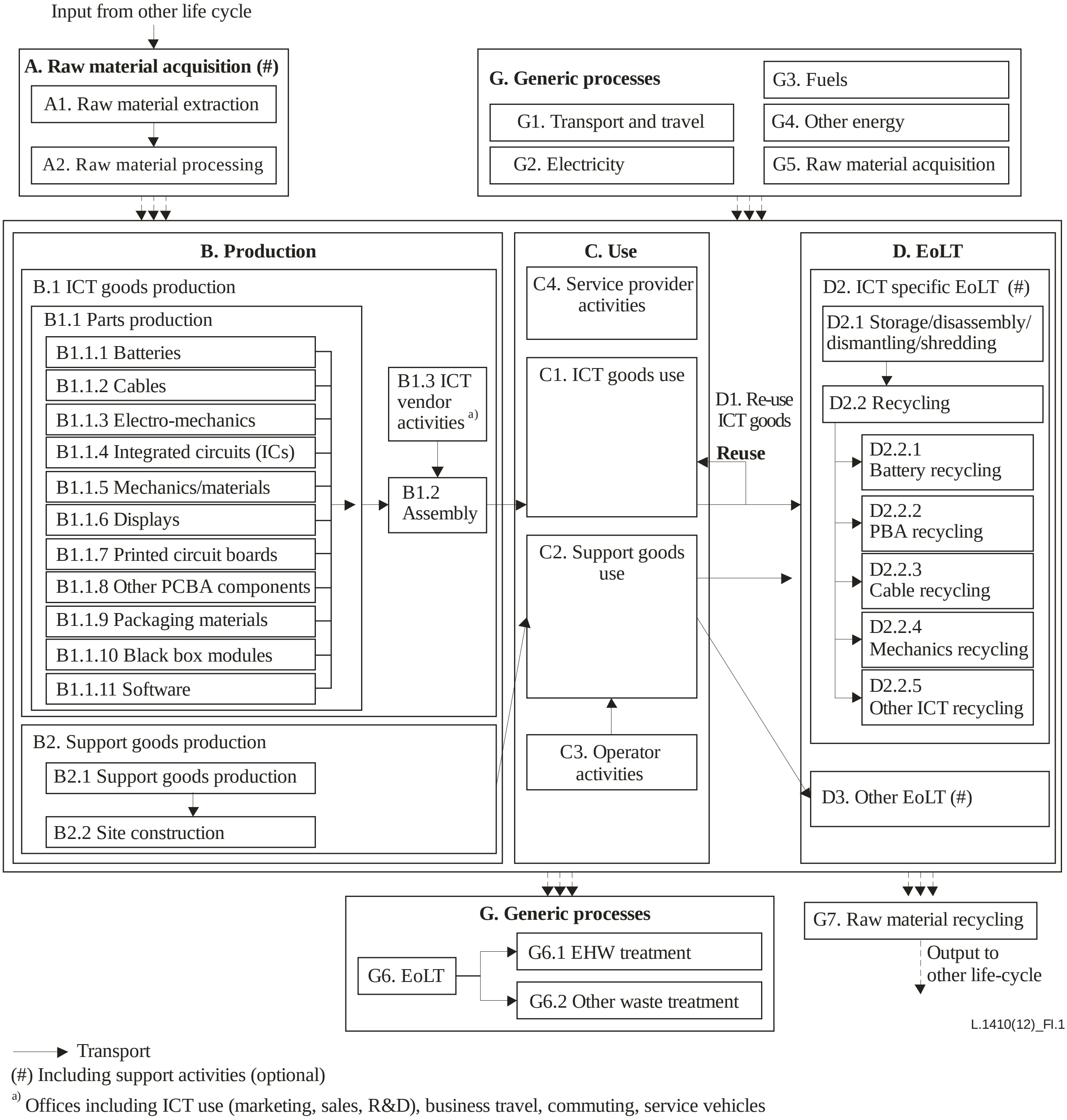
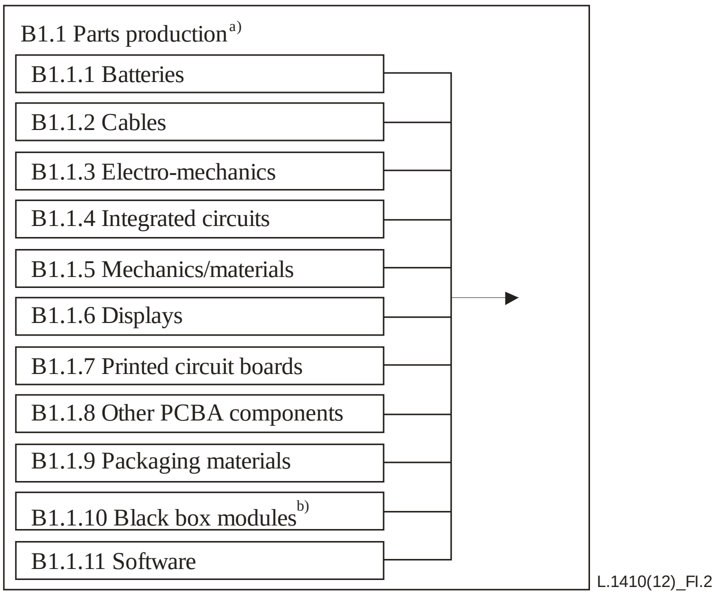


Figure I.1 – Detailed content and connection between life cycle stages



a) Support activities included for each type: offices including ICT use (marketing, sales, research and development), bussiness travel, commuting

b) Modules that are bought as complete products by an ICT manufacturer and for which LCA data distribution is not explicitly accessible for the ICT manufacturer (i.e., it contains its own assembly data)
Examples: mobile broadband module, camera, memory

Figure I.2 – Part production view magnified

Appendix II

Applicable data types per life cycle stage/unit processes

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

Table II.1 – Applicable data types per life cycle stage/unit processes

Tag	Life cycle stage		Unit process	Type of data		
				ICT goods	ICT network	ICT service
A	**Goods raw material acquisition**					
A1		Raw material extraction		Secondary data	Secondary data	Secondary data
A2		Raw material processing		Secondary data	Secondary data	Secondary data
B	**Production**					
B1		ICT goods production				
B1.1			Parts production	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
B1.2			Assembly	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
B1.3			ICT manufacturer support activities	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
B2		Support goods production				
B2.1			Support goods manufacturing	Primary or ICT-specific secondary data: amounts etc. Secondary data: processes	Primary or ICT-specific secondary data: amounts etc. Secondary data: processes	Primary or ICT-specific secondary data: amounts etc. Secondary data: processes
B3		Construction of the ICT-specific site		Primary or ICT-specific secondary data: amounts etc. Secondary data: processes	Primary or ICT-specific secondary data: amounts etc. Secondary data: processes	Primary or ICT-specific secondary data: amounts etc. Secondary data: processes
C	**Use**					
C1		ICT goods use		Primary or ICT specific secondary data	Primary or ICT specific secondary data	Primary or ICT specific secondary data
C2		Support goods use		Primary or ICT specific secondary data	Primary or ICT specific secondary data	Primary or ICT specific secondary data

Table II.1 – Applicable data types per life cycle stage/unit processes

Tag	Life cycle stage		Unit process	Type of data		
				ICT goods	ICT network	ICT service
C3		Operator activities		Primary or ICT-specific secondary data	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
C4		Service provider activities		Not applicable	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
D	**Goods end of life treatment (Note 1)**					
D1		Preparation of ICT goods for re-use		Primary or ICT-specific secondary data	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
D2		ICT specific EoLT		Primary or ICT-specific secondary data	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
D2.1			Disassembly/dismantling/ shredding	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
D2.2			Recycling	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data	Primary or ICT-specific secondary data
D3		Other EoLT		Secondary data	Secondary data	Secondary data

NOTE 1 – For end of life treatment, the term ICT-specific should be interpreted as processes applicable to relevant end of life treatment procedures which may also be used for other electronic goods.

NOTE 2 – Primary data may substitute secondary data.

Appendix III

Uncertainties of life cycle assessments for ICT goods, networks and services

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

Uncertainty is an important aspect of a life cycle assessment of ICT GNS.

The uncertainty of an LCA can be divided into three categories:

- parameter uncertainty
- scenario uncertainty
- model uncertainty

Parameter uncertainty: This is related to uncertainties in input-data and provides a measure of how close the data and calculated emissions are to the real data and emissions. This includes uncertainties in the inventory analysis and uncertainties when translating inventory flows into environmental impact potential. The influence of parameter uncertainty on the final result can be assessed analytically or by simulations. One example of parameter uncertainty is the uncertainty associated with the conversion from the emissions of carbon dioxide (CO_2) and other GHGs into carbon dioxide equivalents (CO_2e).

Scenario uncertainty: This represents a variation of results depending on methodological choices, e.g., LCI modelling principles, allocation procedures and cut-off decisions. The scenario uncertainty can be quantified through sensitivity analysis. Sources of scenario uncertainties include e.g., the allocation method for data for production facilities, overhead activities[12] and vehicle use to the product system studied[13] and also use of old data to represent current activities.

Model uncertainty: This arises from insufficient knowledge of the studied system, leading to omission of data or incorrect assumptions. Model uncertainties are difficult to quantify. Aviation emissions such as NO_X and soot and effects such as land use are examples of emissions/effects usually left out because of a lack of knowledge. One source of model uncertainty much discussed is the possible inclusion of emissions from infrastructure and the supply chain for travel and transportation activities.[14]

Some important uncertainty sources for different life cycle stages

The table below summarizes some important uncertainty sources associated with different life cycle stages. Some of them are described further below Table III.1.

[12] Often based on economic data.

[13] Emission data for a site is typically measured at the site level and not for individual processes and products.

[14] Decisions regarding which activities to include in the life cycle is part of the system boundary setting of a study.

Table III.1 – Important uncertainty sources of the different life cycle stages

Life cycle stage	Activities included	Important uncertainty sources
Raw material acquisition	Raw material extraction Raw material processing	Long supply chain without direct commercial relationship to ICT industry. Variations in geographical location. World market variations beyond the control of ICT.
Production	ICT goods production Support goods production	Large supplier base which changes continuously over product system lifetime based on price, availability etc. Allocation of facility data between product systems and processes.
Use	ICT goods use Support goods use Support activities	Life time, geographical location, traffic scenario model. Large variations between operators regarding site and network design and energy consumption. Electricity production model and power supply variations.
End of life treatment	ICT specific EoLT Other EoLT	Future processes principally unknown. Significant variations between suppliers and regions. Allocation of facility data between product systems and processes.

Within the manufacturing stage it is virtually impossible to collect all product system specific data for the whole upstream supply chain[15]. Raw material acquisition depends on long supply chains related to world market variations beyond the control of the ICT sector and the component 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.[16] 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.

For the use stage estimated, product system lifetimes can generate essential scenario uncertainties. A two-fold increase of the system's lifetime will result in a two-fold increase of emissions from product system operation if lifetime results are presented. Model uncertainties related to product system operation also include assumptions regarding the electricity production and amount of traffic.

End of life treatment (EoLT) and transport typically include model uncertainties related to a lack of comprehensive sub-supplier data. For EoLT there are significant variations between suppliers, especially between regions, and future treatment processes are principally unknown.

15 A magnitude of thousand facilities could be associated with the supply chain of a major ICT company.

16 An LCA study can involve hundred models using thousands of parameters.

Appendix IV

Opportunities and limitations in the use of LCAs for ICT goods, networks and services

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

A life cycle assessment (LCA) is a systematic methodology which gives an understanding of the relative importance of the different life cycle stages/activities. LCAs assist companies in determining where to put their efforts to improve life cycle environmental performance and also to monitor how this performance changes over time. However, it is important to keep in mind that the results of an LCA are always model-based representations of real environmental impact, and the absolute impact of a certain product, network, service or organization is beyond reach. This is true for all kinds of product systems, but especially so for the complex product systems of the ICT sector.

An LCA addresses potential environmental impact; an LCA does not predict absolute or precise environmental impact due to the relative expression of potential impacts to a reference unit, the integration of environmental data over space and time, the inherent uncertainty in modelling environmental impact, and the fact that some possible environmental impacts are clearly future impacts ([ISO 14040], clause 4.3).

In practice, it is virtually impossible to collect enough data for an assessment to give the absolute performance of a product system. Even then, the results would still have model and scenario uncertainty.

Consequently, any LCA result is only valid under the assumptions of the study and is still associated with substantial uncertainty, which needs to be considered so the outcome of the assessment is interpreted in a correct way.

Example 1:

An environmental performance parameter is assessed in two different studies for two goods, A and B. The calculated difference in performance between A and B is 25%. The estimated uncertainty of the parameter is 50%. In this case it is not possible to judge if A or B is a better good with respect to the assessed parameter, although the result value indicates a clear difference.

Example 2:

An environmental performance parameter is assessed for a scenario with an ICT service applied and a scenario without the service applied (business-as-usual scenario). The estimated uncertainty of the parameter is 50% in this case as well, but the calculated improvement in performance when applying the ICT service is a factor of ten. In this case it can be concluded that the scenario with the ICT service clearly has the best performance even though the uncertainty of the performance parameter impacts the absolute value of the performance.

The above examples illustrates that both uncertainty analysis and sensitivity analysis are important tools to understand the results of a study and what conclusions can be made.

Appropriate use of LCAs

LCAs should primarily be used for the following purposes:

- Identification of opportunities to improve the environmental performance of goods, networks, services and organizations.
- Information to decision-makers in industry, government or non-government organizations about typical environmental performance of a product system/organization to assist their policy choices.

- Selection of relevant indicators of environmental performance for monitoring.
- Understanding of the potential impact of new services and solutions.
- Understanding of improvements between generations.

Contrarily, an LCA is less suitable for:

- quantitative benchmarking between studies;
- aggregation[17] of results between studies;
- product system performance legislation (measurable parameters more appropriate); and
- labelling of ICT GNS.

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[17] with sufficient accuracy.

Appendix V

Examples for calculating second order effects

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

Below are examples for calculating second order effects using fictitious values for the difference between the reference product system and the ICT GNS product system. Conversion factors used were from the LCI database.

Equation 6-1 in clause 6.2.5 shows a formula for calculating the secondary effect, $EI_{difference}$:

$$EI_{difference,i} = EI_{reference,i} – EI_{ICT\ GNS,i}$$

(1) Consumption of goods (paper, CDs, DVDs, etc.)

If the consumed good is paper:

$EI_{difference,i=1}$ = (amount of paper consumed$_{reference}$ – amount of paper consumed $_{ICT\ GNS}$) (kg paper/fu) × conversion factor (EI/kg paper)

Where,

fu = functional unit

Conversion factor = factor converting inventory data into impact data, e.g., greenhouse gas emission factor in the case of global warming impact.

Example:

Net amount of paper consumed (difference between the reference and the ICT service)

= 10 kg paper/fu

Conversion factor for paper = 1.3 kg CO_2e/kg paper

$$EI_{difference,i = 1} = 10 \text{ kg paper/fu} × 1.3 \text{ kg } CO_2\text{e/kg} = 13 \text{ kg } CO_2\text{e/fu}$$

(2) Power consumption/energy consumption (electricity, gasoline, kerosene, light oil, heavy oil, town gas, etc.)

If the consumed power is electricity:

$EI_{difference,i=2}$ = (amount of electricity consumed$_{reference}$ – amount of electricity consumed $_{ICT\ GNS}$) (kWh/fu) × conversion factor (EI/kWh)

Example:

Net amount of power consumed (difference between the reference and the ICT service) = –300 kWh/fu

Conversion factor for electricity = 0.49 kg CO_2e/kWh

$$EI_{difference,i=2} = –300 \text{ kWh/fu} × 0.49 \text{ kg } CO_2\text{e/kWh} = –147 \text{ kg } CO_2\text{e/fu}$$

(3) Movement of people (car, bus, railroad, aircraft, etc.)

If the movement of people is done by car:

$EI_{difference,i=3}$ = (number of passengers × distance travelled$_{reference}$ – number of passengers × distance travelled$_{ICT\ GNS}$) (passenger-km/fu) × conversion factor (EI/passenger-km)

Example:

Net passenger-km travelled (difference between the reference and the ICT service) = 2000 passenger-km/fu

Conversion factor for a passenger car = 0.10 kg CO_2e/passenger-km

$EI_{difference,i=3}$ = 2000 passenger-km/fu × 0.10 kg CO_2e/passenger-km = 200 kg CO_2e/fu

(4) Movement and storage of goods (mail, truck, railroad cargo, air cargo, cargo ship, etc.)

If the movement of goods is done using a 10-tonne truck:

$EI_{difference,i=4}$ = (tonnes of goods transported × distance $transported_{reference}$ – tonnes of goods transported × distance $transported_{ICT\ GNS}$) (tonne-km/fu) × conversion factor (EI/tonne-km)

Example:

Net tonne-km transported (difference between the reference and the ICT service) = 1000 tonne-km/fu

Conversion factor for a 10 tonne truck = 0.1 kg CO_2e/tonne-km

$EI_{difference,i=4}$ = 1000 tonne-km/fu × 0.10 kg CO_2e/tonne-km = 100 kg CO_2e/fu

If the storage of goods affects the consumption of electricity

$EI_{difference,i=6}$ = (amount of electricity $consumed_{reference}$ – amount of electricity $consumed_{ICT\ GNS}$)(kWh/fu) × conversion factor (EI/kWh)

Example:

Net amount of power consumed (difference between the reference and the ICT service) = 100 kWh/fu

Conversion factor for electricity = 0.49 kg CO_2e/kWh

$EI_{difference,i=6}$ = 100 kWh/fu × 0.49 kg CO_2e/kWh = 49 kg CO_2e/fu

(5) Improved work efficiency (electricity, office area, etc.)

If improved efficiency occurs in the area of electricity:

$EI_{difference,i=5}$ = (amount of electricity $consumed_{reference}$ – amount of electricity $consumed_{ICT\ GNS}$)(kWh/fu) × conversion factor (EI/kWh)

Example:

Net amount of power consumed (difference between the reference and the ICT service) = 200 kWh/fu

Conversion factor for electricity = 0.49 kg CO_2e/kWh

$EI_{difference,i=5}$ = 200 kWh/fu × 0.49 kg CO_2e/kWh = 98 kg CO_2e/fu

If the improved efficiency affects the area of the office space:

$EI_{difference,i=7}$ = (area of office $space_{reference}$ – area of office space $_{ICT\ GNS}$)(m^2/fu) × conversion factor (EI/m^2)

Example:

Net area of office space reduced (difference between the reference and the ICT service) = 100 m^2/fu

Conversion factor for office space area = 2.0 kg CO_2e/m^2

$EI_{difference,i=7}$ = 100 m^2/fu × 2.0 kg CO_2e/m^2 = 200 kg CO_2e/fu

(6) Waste (wastepaper, garbage, plastic, industrial waste, etc.)

If the concerned waste is waste plastic for incineration:

$EI_{difference,i=8}$ = (amount of waste $plastic_{reference}$ – amount of waste plastic $_{ICT\ GNS}$) (kg waste plastic/fu) × conversion factor (EI/kg waste plastic)

Example:

Net amount of waste plastic (difference between the reference and the ICT service) = 10 kg waste plastic/fu

Conversion factor for waste plastic = 2.8 kg CO_2e/kg waste plastic

$EI_{difference,i=8}$ = 10 kg waste plastic /fu × 2.8 kg CO_2e/kg = 28 kg CO_2e/fu

Summing up the $EI_{difference}$ for the all the comparison categories gives the second order effects of the ICT GNS product system compared with the reference product system. Table V.1 lists second order effects for each comparison category.

Table V.1 – Second order effects for each comparison category

	Comparison category	**Second order effect (kg CO_2e)**
1	Consumption of goods (paper)	13
2	Energy consumption (electricity)	–147
3	Movement of people (passenger car)	200
4	Movement of goods (10-tonne truck) and storage of goods (electricity)	149
5	Improved work efficiency (electricity and work space)	298
6	Waste (waste plastic for incineration)	28
	Total	541

Thus, the second order effects of the ICT GNS product system are 541 kg CO_2e/fu. The EI difference can also be calculated and presented with respect to life cycle stages and components of the systems of ICT GNS as shown in Figures 13 and 14 in clause 6.3.

Appendix VI

Energy mix

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

One of the main environmental impacts of ICTs affecting climate change is GHG emissions from electric power consumption. These GHG emissions depend on sources of electric power generations such as coal, oil, natural gas and nuclear. Conditions of electric power generation are quite different among countries. Also, even in the same country or region, annual GHG emission intensity differs due mainly to the amount of nuclear power generation and renewable energy installed. Therefore, environmental impact assessment of ICTs needs to be carried out carefully when the assessment target includes regions or terms in which GHG emission intensity differs. The impacts should be assessed in energy units for the sake of performing objective and fair assessments. However, this requirement to assess ICT impacts in energy units is not intended to permit a comparative assertion for commercial competition.

Appendix VII

Examples

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

NOTE – In this Recommendation, the examples (clauses VII.1 to VII.6) meet particular parts of the methodology but are not fully aligned with the main text and do not describe the full methodology.

For all the results presented in these examples, uncertainties apply and the results do not give a basis for life cycle comparisons.

Other studies on similar ICT goods, networks and services have provided different results.

VII.1 Examples of evaluation methods for a wired network infrastructure

VII.1.1 Objective and targets of evaluations

The main objective of the evaluations of the three types of services, integrated services digital network (ISDN), asymmetric digital subscriber line (ADSL), and fibre to the home (FTTH) is to provide customers with environmental information when they choose broadband Internet connection services. These services are a set of IP-based (Internet-protocol-based) Internet connection services provided in Japan with flat monthly charges.

VII.1.2 Functional unit

The amount of information transferred is used as the evaluation unit because these ICT services are packet data exchange systems. The functional unit is defined in which "A customer uses the IP-based Internet connection service to access the Internet for two hours and transmits/receives 50 MB of data each day throughout one year".

VII.1.3 System boundary

As shown by the evaluation model in Figure VII.1, the evaluation targets include equipment and devices used in providing the services. This model is established based on actual network facilities in the Tokyo metropolitan region. Specifically, three classes of equipment are evaluated:

- Customer premises: the evaluation targets include a personal computer (PC), digital service unit (DSU), ADSL modem, and an optical network unit (ONU). It is assumed that each subscriber uses a PC for two hours a day according to the definition of the functional unit and that the DSU, ADSL modem, and ONU are on (either fully powered or in standby mode) 24 hours a day.
- Access network equipment: the evaluation targets include the metallic cables, optical cables, telephone poles, manholes, conduits, subscriber modules, digital subscriber line access multiplexers (DSLAMs), and optical line terminals (OLTs). The environmental load of facilities is allocated according to the number of subscribers accommodated by each facility and the constant environmental load is then evaluated from the access network equipment in one year per subscriber regardless of the usage state.
- Core network: the evaluation targets include the optical terminating equipment for users, local area network (LAN) switches, routers, power/air-conditioning facilities, and communication buildings. The evaluation determines the environmental load in one year per subscriber transmitting/receiving 50 MB of data per day according to the functional unit.

The equipment used for maintenance and user management is not included because the environmental load per subscriber is very small.

The assessed life cycle stages include production (including construction of facilities), use and disposal/recycling (including removal of facilities) in the life cycle of ICT goods and networks and facilities, as shown in Figure VII.2.

"Recovery by recycling" means the indirect effect of recycling on reducing the overall environmental load, which is indicated as a negative quantity in the evaluation. When the metal in a product is recycled as pig iron, for example, the environmental load of the recycling process is added to the "disposal/recycling" stage, while the reduction in the environmental load resulting from the decrease in pig iron production, which is the product of the weight of pig iron obtained from recycling multiplied by the environmental load intensity for the production of pig iron, is expressed as a negative number in the "recovery by recycling" stage.

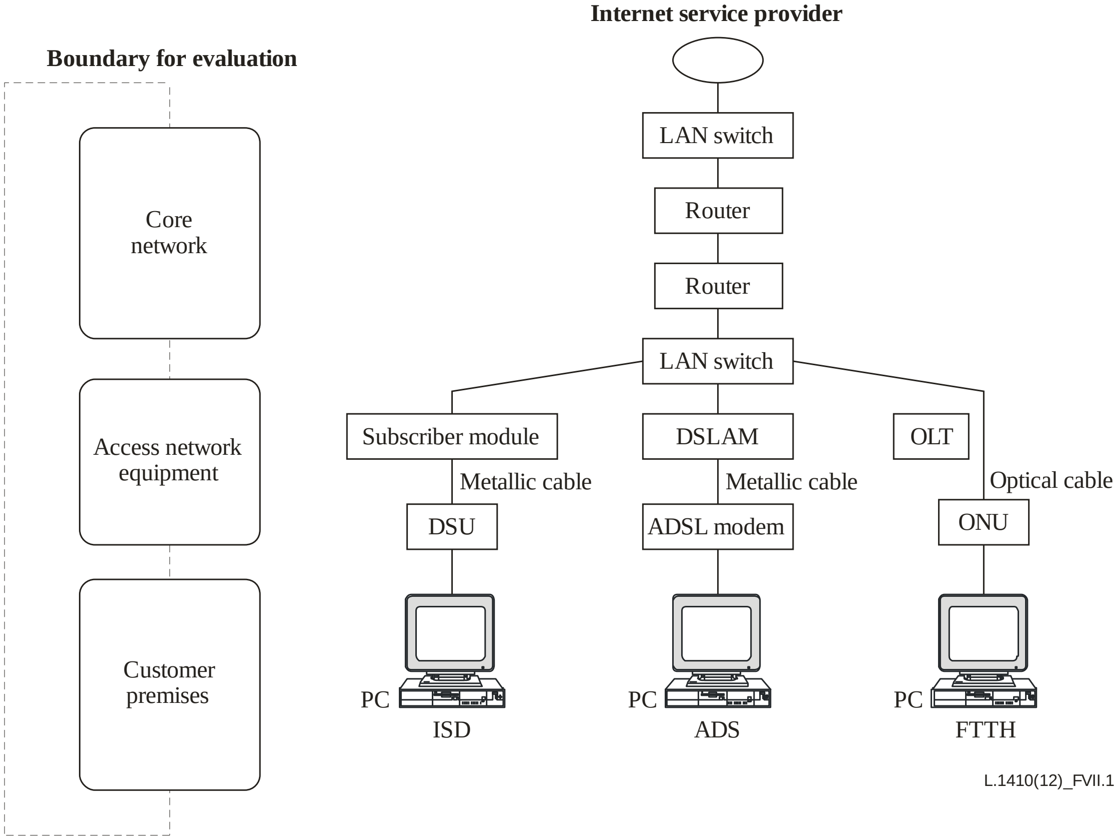

Figure VII.1 – Evaluation model for IP-based Internet connection services

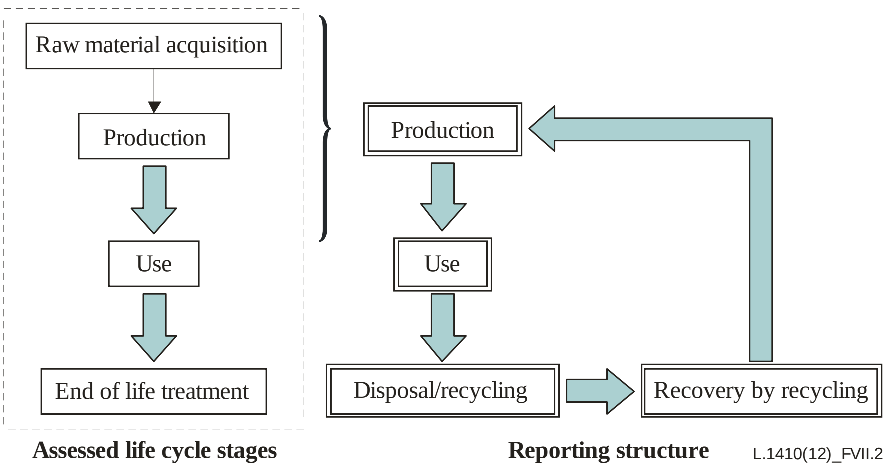

Figure VII.2 – Life cycle stages

VII.1.4 Evaluation procedure

The environmental load is evaluated using the process sum method (bottom-up approach) referring to environmental load intensity of materials composing ICT devices and of facilities composing the network infrastructure.

VII.1.5 Results

The results of our environmental load evaluation of CO_2 emissions and energy consumption from the targeted ICT services based on LCA are shown in Figures VII.3 and VII.4, respectively.

The results of the environmental load evaluation for the targeted ICT services indicate the following.

- CO_2 emissions and energy consumption for an ISDN Internet connection service throughout its life cycle are approximately 83 kg-CO_2/year/subscriber and 0.86 GJ/year/subscriber (including the volume for recovery by recycling), respectively.
- The CO_2 emissions and energy consumption for an ADSL Internet connection service throughout its life cycle are approximately 107 kg-CO_2/year/subscriber and 1.06 GJ/year/subscriber (including the volume for recovery by recycling), respectively.
- The CO_2 emissions and energy consumption for an FTTH Internet connection service throughout its life cycle are approximately 57 kg-CO_2/year/subscriber and 0.66 GJ/year/subscriber (including the volume for recovery by recycling), respectively.

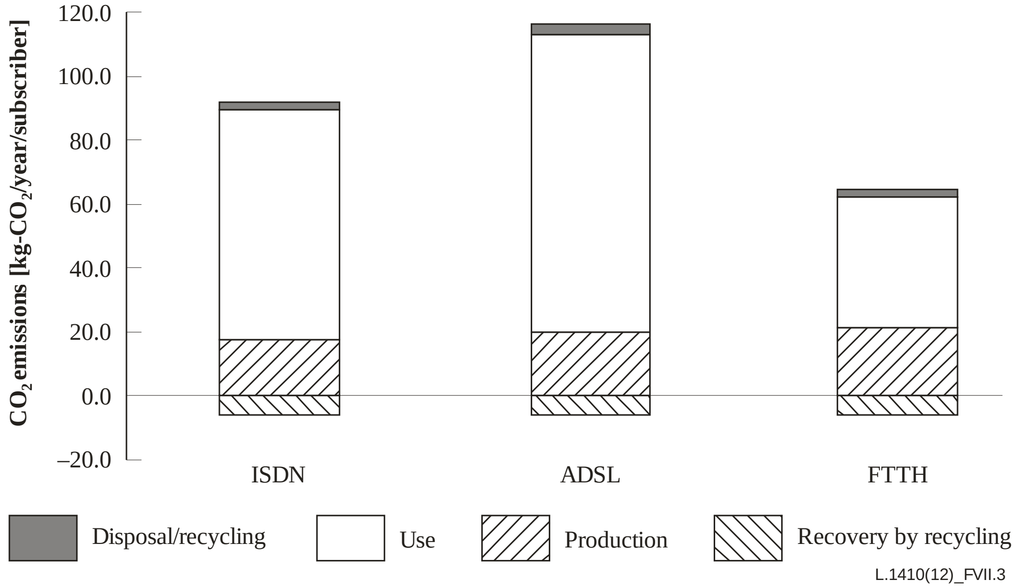

Figure VII.3 – Results of environmental load evaluation for IP-based Internet connection services (CO_2 emissions)

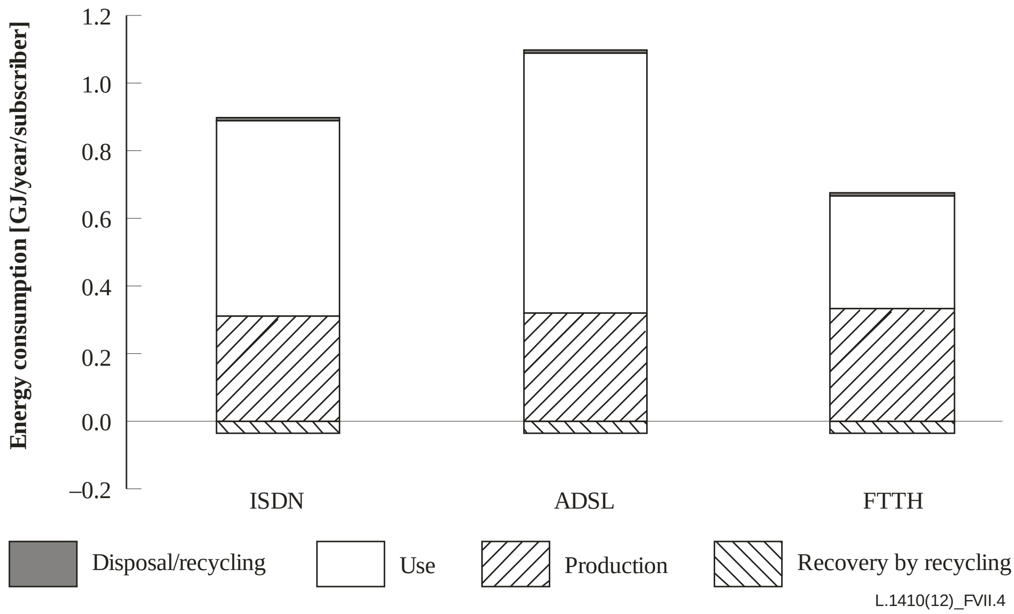

Figure VII.4 – Results of environmental load evaluation for IP-based Internet connection services (energy consumption)

VII.2 Example of an evaluation method for a wireless network infrastructure

VII.2.1 Objective and target of evaluation

The main objective of this evaluation is to provide customers with environmental information when choosing a mobile communication service. In this document, a wideband-code-division-multiple-access-based (W-CDMA-based) service was chosen as the target.

This example is not intended to make a comparative analysis.

VII.2.2 Functional unit

The functional unit of this LCA is defined in which "a customer uses the W-CDMA-based service to make or receive voice calls for 1.6 minutes and videophone calls for 1.6 minutes and to transmit 8.1 email messages and receive 10.6 email messages by packet data communication each day throughout one year". Note that the data used in this functional unit are the average values for mobile users in Japan.

In this example, the W-CDMA-based service provides both circuit-switched and packet data communication. The communication time per customer used for voice and videophone calls in the circuit-switching system, and the amount of information transferred per customer in transmitting and receiving email messages used in the packet data exchange system were the evaluation units.

VII.2.3 System boundary

As shown by the evaluation model in Figure VII.5, evaluation targets include equipment and devices used for providing the services. This model was established based on actual network facilities on the telecommunication route between Tokyo and Niigata.

The evaluation targets for MSs were cellular phones. Cellular phones are assumed to be on (either fully powered or in standby mode) 24 hours a day, and the time for composing email messages is 14.1 minutes per day, which was calculated from a Japanese study report. The time for reading email messages is 10.6 minutes per day, assuming a reading time of one minute per email. The lifetime of the usage stage of an LCA for cellular phones is 550 days, from study report data.

The evaluation targets for the core network were local switch (LS), gateway switch (GS), toll switch (TS), gateway (GW), and mail server. These include devices, cables, and power/air-conditioning facilities. Equipment used for maintenance and user management was not included because the environmental load per subscriber is very small.

The assessed life cycle stages include production (including construction), use and disposal/recycling (including removal of facilities) for each facility, as shown in Figure VII.6. "Disposal/recycling" includes the indirect effect of recycling on reducing the overall environmental load, which is indicated as a negative quantity in the evaluation. When the metal in a product is recycled as pig iron, for example, the environmental load reduction resulting from the decrease in pig iron production is added as a negative number to the "disposal/recycling" stage, which is the product of the weight of pig iron obtained from recycling multiplied by the environmental load intensity for the production of pig iron.

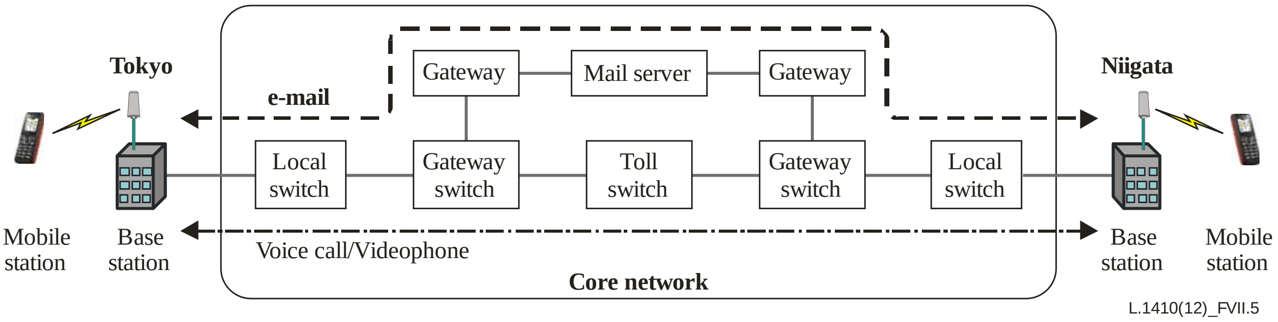

Figure VII.5 – Evaluation model for a W-CDMA-based service in Japan

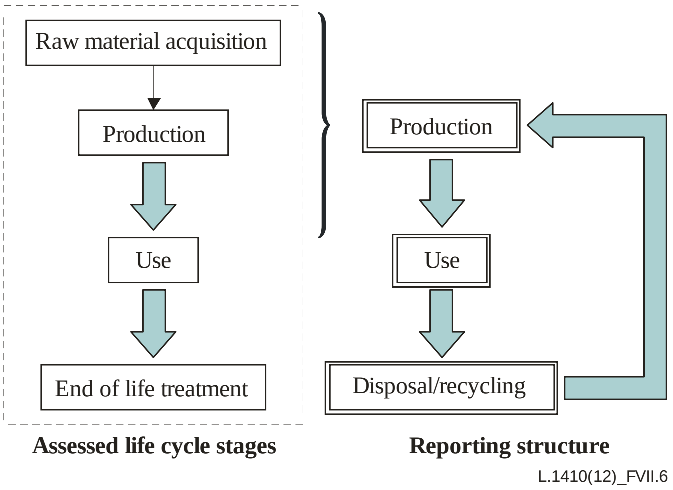

Figure VII.6 – Life cycle stages

VII.2.4 Evaluation procedure

The environmental load is evaluated using the process sum method (bottom-up approach) referring to environmental load intensity of materials composing ICT devices and of facilities composing the network infrastructure.

VII.2.5 Results

The results of the environmental load evaluation of CO_2 emissions and energy consumption for a W-CDMA-based service in Japan are shown in Figures VII.7 and VII.8, respectively.

CO_2 emissions and energy consumption from a W-CDMA-based service throughout its life cycle are approximately 53 kg-CO_2/year/subscriber and 0.57 GJ/year/subscriber (including the volume for recovery by recycling), respectively. These environmental loads from a W-CDMA-based service mainly came from MSs and BSs. The environmental loads from MSs mainly occurred in the production stage. The environmental loads from BSs mainly occurred in the usage stage.

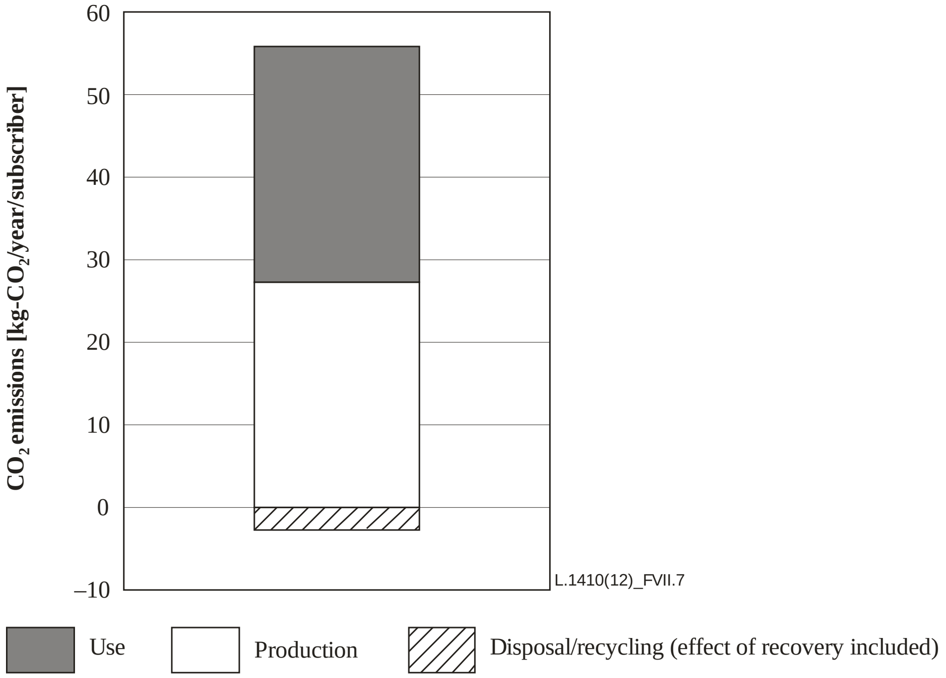

Figure VII.7 – Results of environmental load evaluation for a W-CDMA-based service (CO_2 emissions)

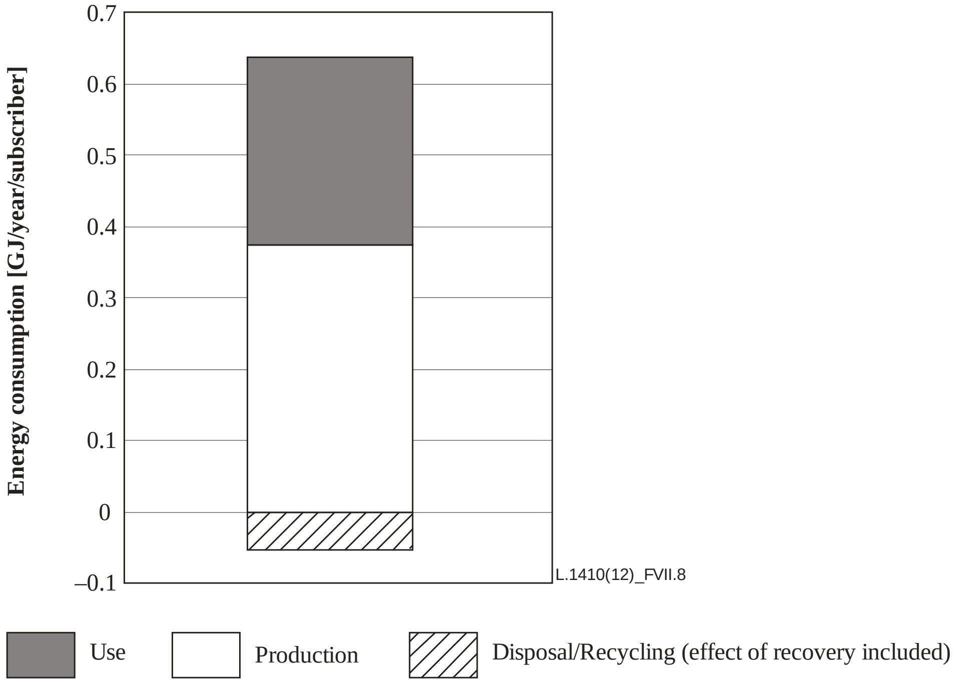

Figure VII.8 – Results of environmental load evaluation for a W-CDMA-based service (energy consumption)

VII.3 Example of evaluation results (video conference and conference on location)

Case 1 (on the left): a video conference held between Tokyo and Yokohama, once a week (48 times/year), one hour each time, with two participants.

Case 2 (on the right): a video conference held between Tokyo and Yokohama, every working day (240 times/year), eight hours each time, with two participants.

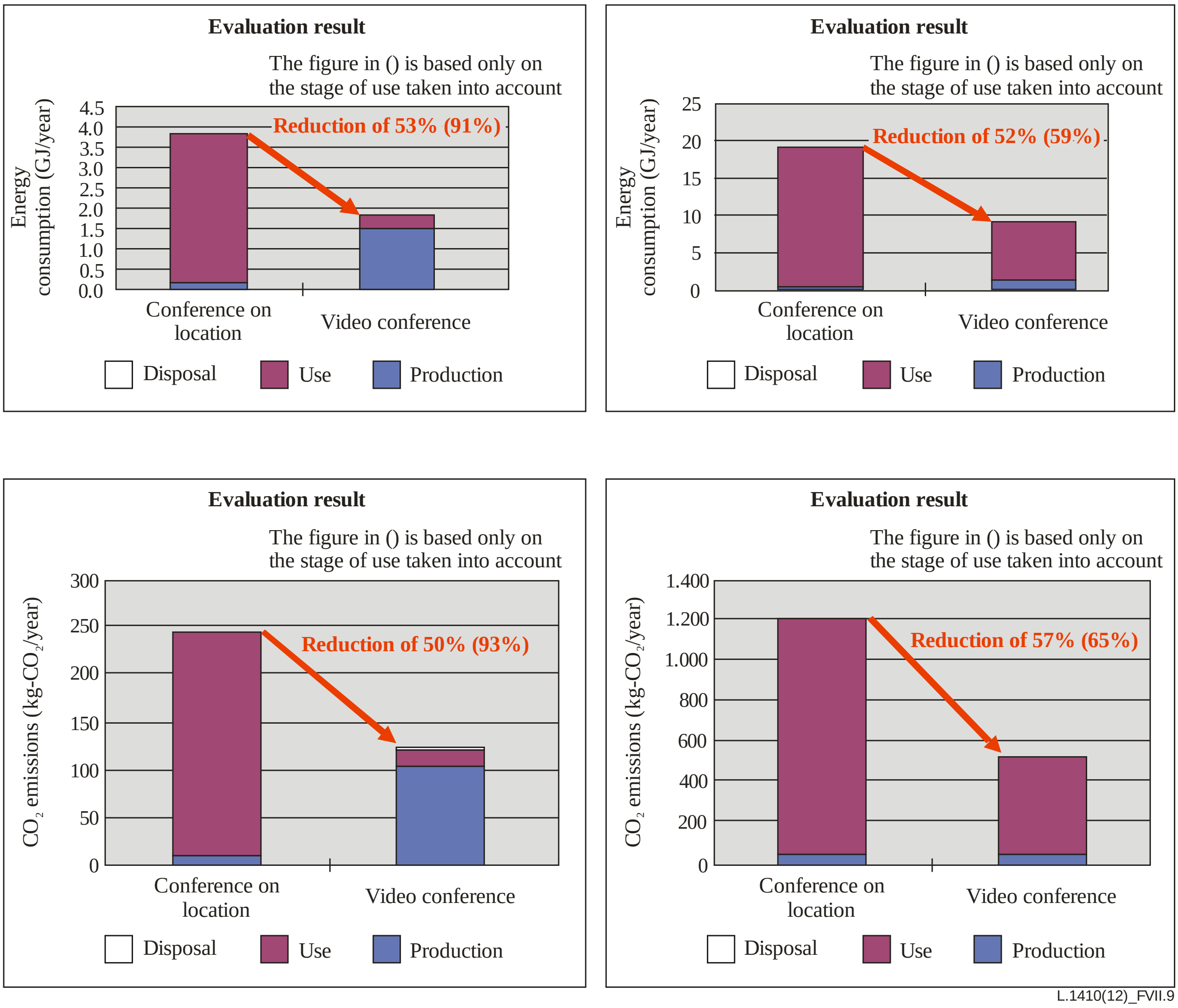

Figure VII.9 – Example of evaluation results for cases 1 and 2

In Case 1, the proportion of energy consumption in the production stage of video conference devices is high; therefore, it will be essential to take the production stage into account. In contrast, in Case 2, a high frequency of use significantly increases energy consumption through on-location and video conferences (in the use stage); therefore, the production stage is less influential, and energy consumption and its reduction significantly vary depending on the video conference devices and their use.

VII.4 Example of the evaluation of the environmental impact of the use stage for the working environment

VII.4.1 Objective of evaluation

The main objective of this evaluation is to provide an example of environmental impact intensity at the use stage for working environments in both Japan and USA. The impact has been calculated from energy consumption in the office such as air-conditioning, heating, lighting and elevators.

VII.4.2 Functional unit

The functional unit of this evaluation is defined as "provision of working space and environment for one year."

VII.4.3 System boundary

This example focuses on the use stage of the working environment as shown in Figure VII.10. The environmental impact from working is derived from air-conditioning, heating, lighting and elevators. The power consumption of ICT goods is excluded from the evaluation to avoid the double counting of any other checklist items. Office working hours are 2040 hours per year.

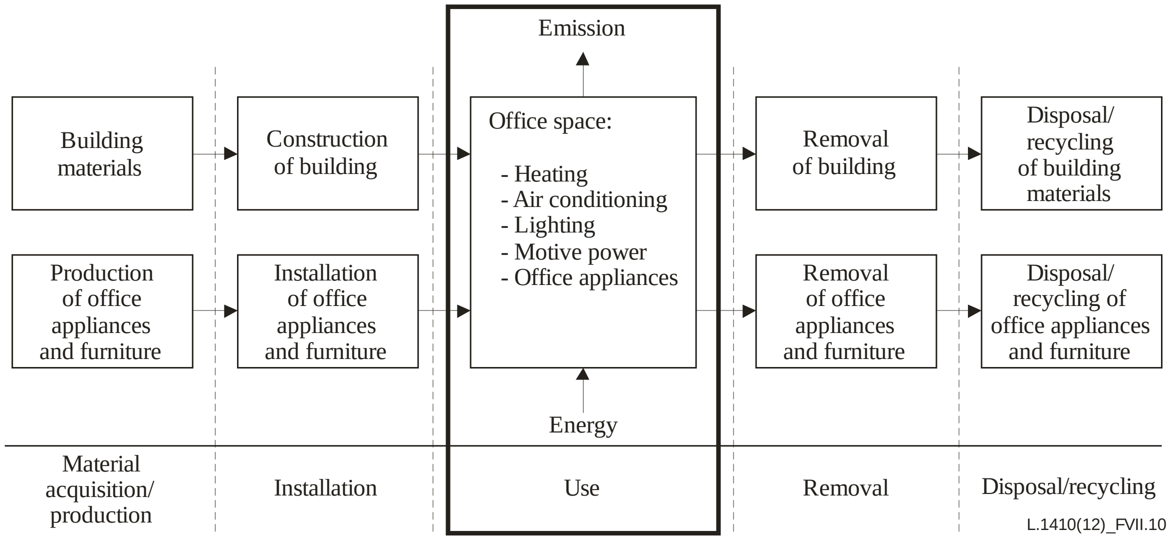

Figure VII.10 – System boundary of this evaluation for the working environment

VII.4.4 Example of the evaluation of environmental impact of conventional office work

VII.4.4.1 Evaluation results for the case in Japan

According to the fact-finding survey on energy in domestic operations departments, electricity, urban gas, and other energy sources are used for example, for air-conditioning, lighting and elevators, and the amount of consumed energy is 870 MJ/m^2/year in office space. The amount of CO_2 emitted from office space can be calculated by multiplying the above value by the CO_2 emission intensity for each kind of energy source, and the result is 79.2 kg-CO_2/m^2/year. Meanwhile, the space occupied by a worker is 13.6 m^2/person according to data by the "Building Owners and Managers Association Japan". Then CO_2 emission intensity per person annually is 1.078 kg-CO_2/person/year as shown in Figure VII.11. If the annual working hours are 2040 hours (170 hour × 12 month) /year, CO_2 emissions are estimated to be 0.528 kg-CO_2/person/hour in Japan.

Table VII.1 – CO_2 emissions per unit area of conventional office space (in Japan)

	Energy consumption [MJ/m²/year] A	CO_2 emission intensity [kg-CO_2/MJ] B	CO_2 emission [kg-CO_2/m²/year] A×B
Electricity	569	0.1054	59.8
Urban gas	184	0.0566	10.4
Heavy oil A	38	0.0739	2.8
Kerosene	8	0.0715	0.6
District heat and cooling	71	0.0774	5.5
Total	870		79.2

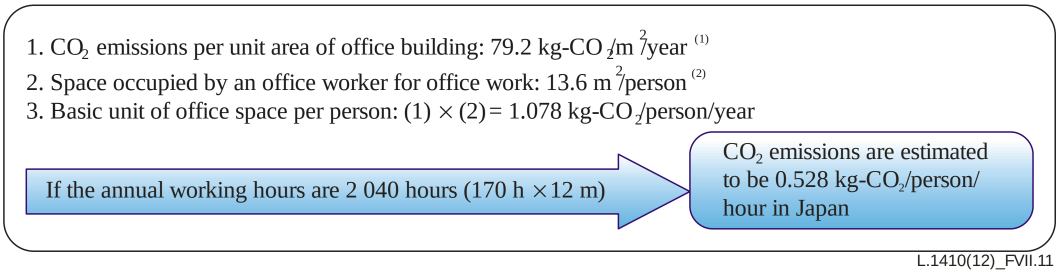

Figure VII.11 – Calculation of CO_2 emission intensity for conventional office space in Japan

VII.4.4.2 Evaluation results for the case in USA

According to a survey on the 2003 energy consumption in commercial buildings (conducted by the Energy Information Administration), a total 1 029 MJ/m^2/year from electricity, gas, heavy oil, and other energy sources are used. If this is multiplied by the CO_2 emission intensity of each kind of energy source, the annual amount of CO_2 emissions is 115.4 kg-CO_2/m^2/year. Office space occupied by a worker is 21.4 m^2/person according to the General Service Administration. Then CO_2 emission intensity per person annually is 2 470 kg-CO_2/person/year as shown in Figure VII.12. If the annual working hours are 2040 hours (170 hour x 12 month) /year, CO_2 emissions are estimated to be 1.21 kg-CO_2/person/hour in the USA.

Table VII.2 – CO_2 emissions per unit area of conventional office space (in USA)

	Energy consumption [MJ/m²/year] A	CO_2 emission intensity [kg-CO_2/MJ] B	CO_2 emission [kg-CO_2/m²/year] A×B
Electricity	561	0.1577	88.8
Natural gas	331	0.0502	16.6
Fuel oil	38	0.0693	2.5
District heat	100	0.0741	7.5
Total	1 029		115.4

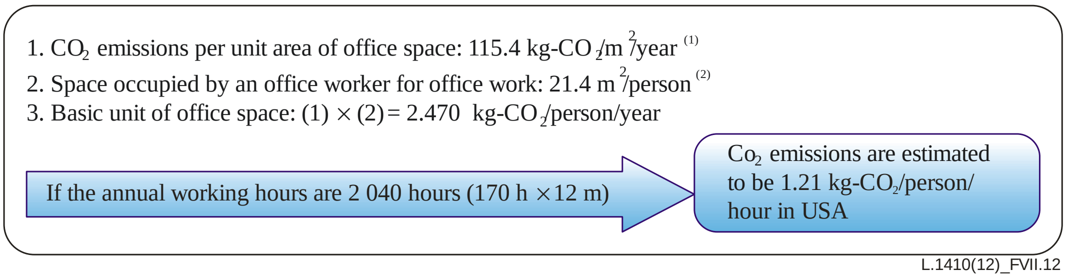

Figure VII.12 – Calculation of CO_2 emission intensity for conventional office space in USA

VII.4.5 Example of the evaluation of environmental impact of home office work

VII.4.5.1 Evaluation results for the case in Japan

As shown in Table VII.3, according to the data of the Greenhouse Gas Inventory Office of Japan, the total fuel usage is 5 457.4 kg-CO_2/household/year on average.

Table VII.3 – Household fuel uses in Japan (2005)

Fuel use	[kg-CO_2/ household/year]
Coal etc.	0.0
Kerosene	633.0
LPG	275.3
Urban gas	437.0
Electric power	2 112.2
Heat	1.5
Gasoline	1 471.6
Diesel	111.0
Domestic waste	300.8
Water supply	115.0
Total	5 457.4

To obtain the home office CO_2 emission intensity, energy consumption was classified by end use categories in Table VII.4. The energy consumption rate for lighting was 16.1% according to the data of "Summary of the Electric Power demand" (Agency for Natural Resources and Energy, "Estimated Demand and Supply of Electricity", or "FY 2006 Annual Energy Report", P.158 (available in Japanese)). As a result, the total energy consumption for home office was 1 215.1 kg/household/year.

Table VII.4 – Household energy end use in Japan (2005)

Energy end use	[kg-CO_2/ household/year]
Heater	754.9
Air conditioner	117.5
Hot-water supply	747.6
Cooking	220.6
Motive power etc.	1 618.4
(Lighting)	(342.7)
Private car	1 582.6
Domestic waste	300.8
Water supply	115.0
Total	5 457.4
Total for home office	1 215.1

Average floor space per household in Japan was 35.7 m^2 (results of census in Japan, Table 17) in 2005 and CO_2 emission intensity in home office was 34.0 kg-CO_2/m^2/year in Japan. It is less than half the intensity of 79.2 kg-CO_2/m^2/year shown in clause VII.4.4.1, "Evaluation results for the case in Japan", for conventional offices.

VII.4.5.2 Consideration of improved work efficiency in Japan

Improved work efficiency is closely related to improved office space. For a conventional office, the environmental impact intensities is calculated in clause VII.4.4.1.

- 0.53 kg-CO_2/person/hour in Japan

In the case of home offices, it is assumed that:

- one person works at home per household
- energy consumption cannot be divided per person
- 16 hours are spent on household activity per day

According to the "Summary of the results and statistical tables 2005 Population Census in Japan", there are 2.55 persons per household in Japan. If every house had an individual air conditioner, heater and lighting system for each person's space, the energy consumption could be divided into each person. However, some houses have central heating system and the actual situation is very complicated. So, it is assumed that energy consumption cannot be divided per person. The actual household activity hours per day, which are the hours except sleeping hours, are also taken into consideration to calculate the consumption of energy by the home office.

For the home office, the environmental impact intensity was calculated as: 0.21 kg-CO_2/person/hour in Japan.

Although the above-mentioned results do not include the energy consumption of ICT equipment, the home office is more efficient than the conventional office.

VII.4.5.3 Evaluation results for the case in USA

Based on the 2005 U.S Residential Energy Consumption Survey [b-US EIA1], the breakdown of fuel use for each energy end use is shown in Table VII.5. Here, the consumption rate of electricity for fuel was 8.8% [b-US EIA1]. As a result, the total energy consumption for home offices was 4 680.4 kg/household/year.

Table VII.5 – Household energy end use in USA

Energy end use	Fuel used	[kg-CO_2/ household/year]
Space heating	Electricity	420.6
	Natural gas	1 408.9
	Fuel oil	480.6
	Kerosene	13.0
	LPG	181.7
Air conditioning	Electricity (central system)	1 141.6
	Electricity (window/wall unit)	180.3
Water heating	Electricity	630.9
	Natural gas	673.4
	Fuel oil	92.2
	LPG	85.2
Refrigerators	Electricity	766.1
Other appliances and lighting	Electricity	3 394.7
	(lighting)	(853.8)
	Natural gas	205.4
	LPG	28.4
Total		9 702.8
Total for home office		4 680.4

Average floor space per household in the USA was 69.9 m^2 [b-U.S. Census Bureau] in 2005 and CO_2 emission intensity in a home office should be 66.9 kg-CO_2/m^2/year in the USA.

VII.4.5.4 Consideration of improved work efficiency in USA

Improved work efficiency is closely related to improved office space. For the conventional office the environmental impact intensities were:

- 1.21 kg-CO_2/person/hour

In the case of a home office, it is assumed that:

- one person per household works at home
- energy consumption cannot be divided per person
- 16 hours are spent for household activity per day

According to the censuses, there are 2.57 persons per household in the USA [b-U.S. Census Bureau]. If every house had individual air conditioners, heaters and lighting systems for each person's space, then energy consumption could be divided per person. However, some houses have central heating systems and the actual situation is very complicated. So, it was assumed that energy consumption could not be divided per person. Actual household activity hours per day which are the hours except for sleeping [b-US Dept. of Labor] were taken into consideration to calculate the consumption of energy in a home office.

For home offices the environmental impact intensities were calculated as: 0.80 kg-CO_2/person/hour.

Although the above-mentioned results do not include the energy consumption of ICT equipment, a home office is more efficient than a conventional office. In some types of business operations which require face-to-face team working, the decline of work efficiency by tele-working should be taken into account.

VII.5 Example of an evaluation method for ICT services of internal information systems for municipal governments in Japan

A case of the environmental impact assessment of ICT service systems with improved work efficiency is shown below.

VII.5.1 Outline of the assessed ICT service system

The functional unit is for one city office in Japan to manage the administration work with 338 kinds of operations such as accounting, general affairs and personnel affairs during one year.

The comparison is between a reference product system and a new ICT service system which offers an upgrade of administrative management and improvement of work efficiency with electronic account settlement.

VII.5.2 Effect of the introduction of the ICT service systems

The reference product system is the conventional system, which is a client-server system using paper-based account settlement. This required a considerable amount of "hands-on" work and of number of person-hours in the office operation. It also required a wide storage space for the large amount of paper documentation.

After introducing the new ICT service system, which was web-based with an electronic account settlement, improved work efficiency and paperless operations were achieved. Moreover, storage space for the paper documentation was reduced remarkably due to the electronic storage system.

Thus, the web-based electronic paperless account system is the ICT service system for comparison against the reference product system.

VII.5.3 Evaluated items for CO_2 emissions

- We evaluated yearly document processing operations (finance and contract, general affairs, document management) in a city office in Japan.
- We evaluated person-hours of operations by PC and "hands on" work operations, whether or not paper was used, the amount of stored documents, and methods of storage for operations using systems (338 operations).
- The consumed electric energy and occupied space in offices were assessed for all ICT goods involved in the systems.

VII.5.4 Summary of assessment evidence

Table VII.6 shows the assessment evidence for each effect factor.

VII.5.5 Assessment results

Tables VII.7 and VII.8 show the positive and negative effects as a result of introducing the ICT system.

Figure VII.13 shows the total CO_2 emissions before and after the introduction of the ICT system. The environmental load was improved from 149 662 kg-CO_2 to 81 646 kg-CO_2 by ICT system. The reduction of CO_2 emissions was 68 016 kg-CO_2, or 45.4%.

Table VII.6 – Assessment evidence

	Examples of categories for comparison	Basic data	Before introduction (reference product system)	After introduction (ICT service system)
1	Consumption of good	Number of papers	1 898 000	829 100
2	Power consumption (only use stage here)	Servers, PCs, etc.	20 300 kWh	45 500 kWh
3	Movement of people	–	–	–
4a	Movement of goods	–	–	–
4b	Storage of goods	Warehouse space	43 m^2	26 m^2
5a	Improved efficiency of office space	Equipment space	24 m^2	25 m^2
		Document space	16 m^2	5 m^2
5b	Improved work efficiency	Working hours	261 000 h	117 600 h
6	Waste	–	–	–

Table VII.7 – Positive effects

Examples of categories for comparison	CO_2 reduction (kg-CO_2/year)
Consumption of goods (paper)	5 472
Improved efficiency of office space	752
Storage of goods	813
Improved work efficiency	70 140
Total	77 177

Table VII.8 – Negative effects

Effect factor	CO_2 increase (kg-CO_2/year)
Power consumption (ICT system)	9 161
Total	9 161

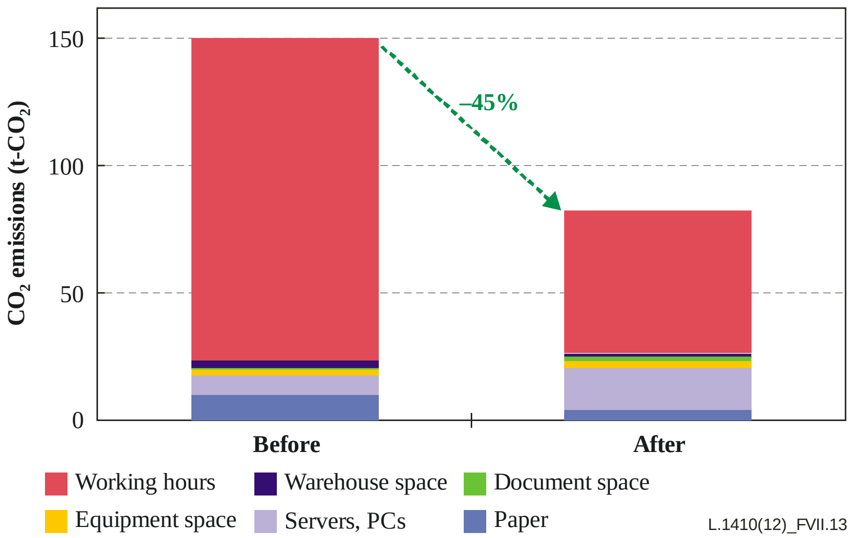

Figure VII.13 – CO_2 reducing effect by introducing an ICT system

VII.6 Example regarding comparative analysis of mobile telecommunication networks

VII.6.1 Introduction

This example, based on the Mobile Energy Efficiency (MEE) Benchmarking service[18] run by the GSM Association (GSMA), shows how energy consumption data collected by mobile network operators (MNOs) can be used for comparative analysis of energy consumption and GHG emissions, when comparing different mobile telecommunication networks.

Currently, the data collection described covers only the use stage but an extension to the full life cycle is targeted in clause VII.6.3.

VII.6.2 Methodology

The data collection and assessment follows a three-step process:

VII.6.2.1 Step 1: Collect data and validate

The data required from MNOs is the following by country or region, annually:

- mobile network electrical energy usage and diesel energy usage, for the radio access and core networks;
- number of physical cell sites and total number of technologies;
- number of mobile connections;
- minutes of mobile voice traffic and bytes of mobile data traffic;
- % mobile coverage (geographic, population); and
- mobile revenues (providing the data is non-confidential).

[18] The MEE Benchmarking service provides information in order to help MNOs reduce energy consumption, carbon emissions and costs by benchmarking their network operation energy consumption externally and internally against key energy efficiency and GHG emissions ratios, using a normalization process. Coverage of the rest of the life cycle will be included at a later date. The MEE use stage assessment has been performed for over 100 networks. The results cannot be disclosed due to confidentiality. [MEE, see http://www.gsma.com/mee].

In the future, MNOs should gather the data following the general rules regarding data collection for the use stage outlined in this Recommendation. MNOs use a detailed list of data and data boundary definitions to collect the information needed. The data submitted is reviewed for inaccuracies, inconsistencies or definitional issues.

Figure VII.14 shows an overview of the radio access and core networks for which MNOs provide data.

VII.6.2.2 Step 2: Calculate energy efficiency and GHG emissions ratios

The targeted comparison is based on the efficiency of mobile networks by country in terms of:

1) mobile network use stage energy consumption/GHG emissions per mobile connection;
2) mobile network use stage energy consumption/GHG emissions per unit mobile traffic;
3) mobile network use stage energy consumption/GHG emissions per cell site;
4) mobile network use stage energy consumption/GHG emissions per unit mobile revenue.

Data is collected as energy consumption values which are converted into GHG emissions based on country grid electricity and diesel conversion factors. This performance is shown graphically.

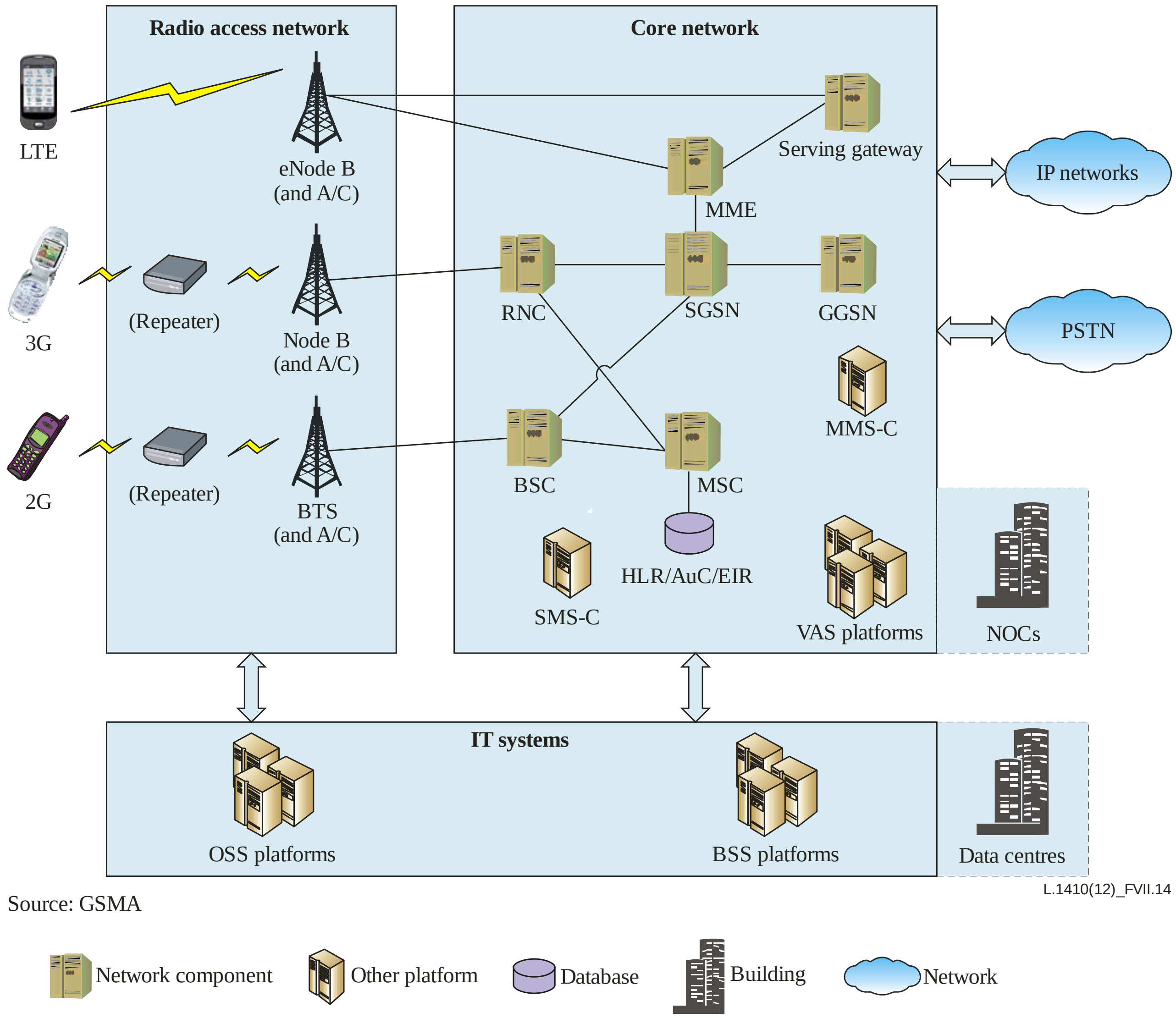

Figure VII.14 – Network overview of radio access and core networks

VII.6.2.3 Step 3: Analyse data using multi-variable regression techniques

MEE normalizes, or adjusts, energy efficiency values for variables outside the MNOs' control, such as country, market and technology factors. After normalization, it is possible to see which networks are over or under-performing on energy usage and where there is potential to reduce costs and emissions.

After the analysis, the benchmarking results are reported anonymously to each participating MNO. MNOs use the results to re-focus energy efficiency improvement initiatives and refine the potential for energy, cost and emissions savings.

VII.6.3 Extension of the comparative assessment to the full life cycle

VII.6.3.1 Objective and target of assessment

The main objective of the assessment is to provide network operators, regulators and other stakeholders with environmental information when assessing a mobile communications service, e.g., in a particular country which corresponds to a single network. In this example, a network with GSM (Global System for Mobile communications) and WCDMA (Wideband Code Division Multiple Access) was chosen as the target, and the network was considered in the LCA but not the MSs (i.e., mobile phones and other mobile devices).

VII.6.3.2 Functional unit

The functional unit of this LCA is defined as "one year of operation of a mobile communication system per subscriber per year".

VII.6.3.3 System boundary

Figure VII.14 above shows that the assessed network comprises the radio access and core network goods used for providing the ICT services.

The assessed goods for the core network are radio network controllers (RNC), base station controllers (BSC), mobile switching centre (MSC) (or mobile switching centre server (MSC-S) and media gateway (MGW)), serving GPRS support node (SGSN), gateway GPRS support node (GGSN), home location register (HLR) (including authentication centre (AuC) and equipment identity register (EIR)), short message service centre (SMS-C), multimedia messaging service centre (MMS-C), mobile switching centre server (MSC-S), mobility management entity (MME) and serving gateway. The data collected includes energy usage from network operations centres (NOCs) and value-added services platforms (e.g., platforms for SMS, MMS and ringtones) and all energy consumption associated with backhaul transport.

The assessed goods for the radio access network are: base transceiver station (BTS), Node B and eNode B. The data collected includes energy usage from repeaters and all energy consumption associated with backhaul transport.

In both the core and radio access networks, devices, cables and all associated infrastructure energy usage such as air-conditioning, inverters and rectifiers are included. Equipment used for maintenance and user management is currently not included due to the variation of this type of equipment between different MNOs.

The assessed life cycle stages include raw material acquisition, production, use and end of life treatment. End of life treatment includes the indirect effect of recycling on reducing the overall environmental load, which is indicated as a negative quantity in the assessment results. The assessment is performed for one country.

VII.6.3.4 Assessment procedure

The environmental load will be assessed using the process-sum method (bottom-up approach) referring to environmental load intensity of materials composing of the ICT devices and of facilities composing the network infrastructure.

The starting point for the analysis is the MEE Benchmarking service. Participating MNOs provide annual electrical and diesel energy consumption for the use stage for radio access and core networks, using agreed data definitions which are part of the MEE methodology. The energy is converted into GHG emissions using standard grid electricity and diesel conversion factors.

The MNO and/or its suppliers provide also the LCI data or LCA results associated with raw material acquisition, production and end of life treatment, both for new and legacy equipment, amortised over the lifetime of the equipment. The results for all life cycle stages will be added together to obtain the total annualised life cycle impact.

VII.6.3.5 Results

The results cannot be disclosed due to confidentiality.

Note that the comparison of LCA results is only possible if comparative conditions are met.

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