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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

ITU-T L.1410 – Case study: A hybrid approach-based comparative analysis of the environmental impact of a baseline data centre and an energy-efficient data centre

ITU-T L-series Recommendations – Supplement 13

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Supplement 13 to ITU-T L-series Recommendations

ITU-T L.1410 – Case study: A hybrid approach-based comparative analysis of the environmental impact of a baseline data centre and an energy-efficient data centre

Summary

Supplement 13 to the ITU-T L-series Recommendations comprises a case study the goal of which is to clarify the greenhouse gas (GHG) emission reduction effect of some new energy saving technologies in a data centre.

The purpose of the study is to assess the production and operation of introducing a more energy-efficient data centre and to compare its impact to a previous set-up. This case study is intended to be open to the public.

In this case study, a hybrid approach was applied. The hybrid approach used in this study includes input-output analysis (IOA) for production and end-of life and process-sum analysis for usage.

History

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* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Introduction

This Supplement has been developed to complement [ITU-T L.1410] for the practical assessment of the production and operation of introducing a more energy-efficient data centre and to compare its impact to a previous set-up. This case study is intended to be open to the public.

In this case study, a hybrid approach was applied. The hybrid approach used in this study includes input-output analysis (IOA) for production and end-of life and process-sum analysis for usage.

Economic input-output (IO) tables developed by Dr. Leontief (b. 1906 in Russia, d. 1999) are widely recognized for their usefulness and importance in the analysis of economic and industrial structures. IO tables systematically present and clarify all the economic activities being performed in a single country, showing how goods and services produced by a certain industry in a given year are distributed among the industry itself, other industries, households, etc., and present the results in a matrix (row and column) format.

For Japan, IO tables have been compiled every five years since 1955 in a joint program involving governmental organizations. The structure of the IO tables is shown in Figure 1-1.

Demand sector (buyer) / Supply sector (seller)		Intermediate demand				Final demand								
		1 Agriculture, forestry and fishery	2 Mining	3 Manufacturing	Total A	Consumption expenditure outside households	Expenditure	Fixed capital formation	Increase in stocks	Exports	Total B	(Less) Import C	Domestic production A+B-C
Intermediate input	1 Agriculture, forestry and fishery												
	2 Mining												
	3 Manufacturing												
	Total D												
Gross value added	Consumption expenditure outside households												
	Compensation of employees												
	Operating surplus												
	Depreciation of fixed capital												
	Indirect taxes												
	(Less) Current subsidies												
	Total E												
Domestic production D+E													

Cost structure for raw materials and gross value added (input)

Composition of sales sector of products (output)

Figure 1-1 – Structure of an IO table

For environmentally extended IOA, conventional economic IO tables are accompanied by another set of tables, called "Tables of values and quantities" that describe the input to each sector in the form of quantities of key materials, including energy products such as petrochemical products and electricity. Fuel consumption data in particular is used for estimating air emissions by multiplying them by emission coefficients. IO tables provide comprehensive input and output data for the situation of the targeted country that could be used without modification or with minimal processing.

In this case study, environmentally extended IOA was performed based on embodied energy and emission intensity data for Japan using input-output tables (3EID) from the National Institute for Environmental Studies (NIES) in Japan. 3EID contains the embodied environmental burden intensities on a sector level which were calculated using the Japanese IO tables. The embodied environmental burden intensities of 3EID represent energy consumption and GHG emissions generated directly and indirectly by the related production activity of a sector. The tables define economic relationships among sectors using a matrix representation based on annual transactions among sectors. These embodied intensities were calculated using an environmental IOA with Japanese IO tables, which consist of about 400 commodity sectors. These tables are among the most prominent IO tables worldwide and have a high sector resolution.

In a life cycle assessment (LCA) the process-sum analysis method requires detailed input and output data for individual processes, while IO tables include all processes or industry sectors relevant to economic activities, indicating that the required environmental data have been prepared beforehand and is readily available.

The data from IO tables is a useful data source, when satisfactory inventory data acquired by the process-sum method has not yet been prepared and published. If well-founded they are comprehensive and include all cradle-to-gate processes. An advantage is that all data is available and easily accessible. The principal drawback is that price levels depend not only on the resource use but also on other parameters which means that price level changes could occur without changes in resource use. However, for domestic data the effect of this is expected to be limited. The environmental loads are estimated by multiplying their price with the corresponding embodied intensities obtained from input-output analysis. The IOA makes comparison possible for material substitutions or design changes to a product, which fits in with the intended purpose of LCAs. The IOA approach may be easily combined with a process-sum analysis for major contributions. Combining detailed data for the most significant items obtained via the process-sum method and extended data obtained as necessary from IOA will make inventory analysis much easier.

In the Japanese environmentally extended IO tables, data are available at different levels such as for specific materials, specific parts, specific products and specific services, etc. This study was based on data for specific products.

In general IOA data is considered to be comprehensive. As an example, the IOA data of the server cover the domestic part of the activities cradle-to-gate including raw material acquisition and processing and all production activities also including the assembly of the server, transports and all industrial processes. However, the distribution of the server is not included in the IOA data.

Supplement 13 to ITU-T L-series Recommendations

ITU-T L.1410 – Case study: A hybrid approach-based comparative analysis of the environmental impact of a baseline data centre and an energy-efficient data centre

1 Scope

1.1 Purpose and goal of the study

The goal of this case study is to clarify the greenhouse gas (GHG) emission reduction effect of some new energy saving technologies in a data centre.

The purpose of this case study is to assess the production and operation of introducing a more energy-efficient data centre and to compare its impact to a previous set-up. This case study is intended to be open to the public.

In this case study, a hybrid approach was applied. The hybrid approach used in this study includes input-output analysis (IOA) for production and end-of life and process-sum analysis for usage.

To achieve the goal and purpose mentioned above, a comparative analysis was performed for the full life cycles of a data centre with energy-saving cooling and power supply solutions and of a data centre with conventional solutions. The energy saving solutions used are listed in Table 1-1.

Table 1-1 – Introduced energy-saving technique

Category	Energy-saving technique	Technical summary
Air-conditioning	High-efficiency air cooled packaged air-conditioner	A packaged air-conditioner which achieves a high cooling efficiency by enhancing the performance of the inverter.
	Free cooling-type packaged air-conditioner	An air-conditioner which introduces cold outdoor air using a heat exchanger.
	Rack-type air-conditioner	An air-conditioner which locally and efficiently cools a housing rack group generating a large amount of heat.
	Direct-use of geothermal energy	A technique that cools using cold water provided by a heat collecting pipe in the ground.
	Airflow design	A technique which avoids a mixing the air intake (cold air) and the exhaust (hot air) of the server to improve the cooling efficiency of the data centre.
Power supply	HVDC (Note)	A power feeding system which provides DC380V to ICT equipment and realizes higher efficiency and reliability.
Exhaust heat	Use of exhaust server heat	A technique to improve energy efficiency by reusing the exhaust heat of servers for heating.
NOTE – Compliant with [ITU-T L.1200], *Direct current power feeding interface up to 400 V at the input to telecommunication and ICT equipment*.		

1.2 ICT product systems to compare

The ICT product systems studied in the comparative analysis are as follows.

- **Target ICT product system**: An NTTFACILITIES [b-1] data centre that introduces some new energy-saving technologies for air conditioning, power supply and reuse of exhaust heat in offices. The data centre houses 74 servers offering thin client service. The floor space of the data centre is 139 m^2.
- **Reference ICT product** system: A data centre with conventional facilities for air conditioning and power supply. Capacity and floor space of the data centre is similar to that of target ICT product system.

Figures 1-2 to 1-4 give an overview of the two systems.

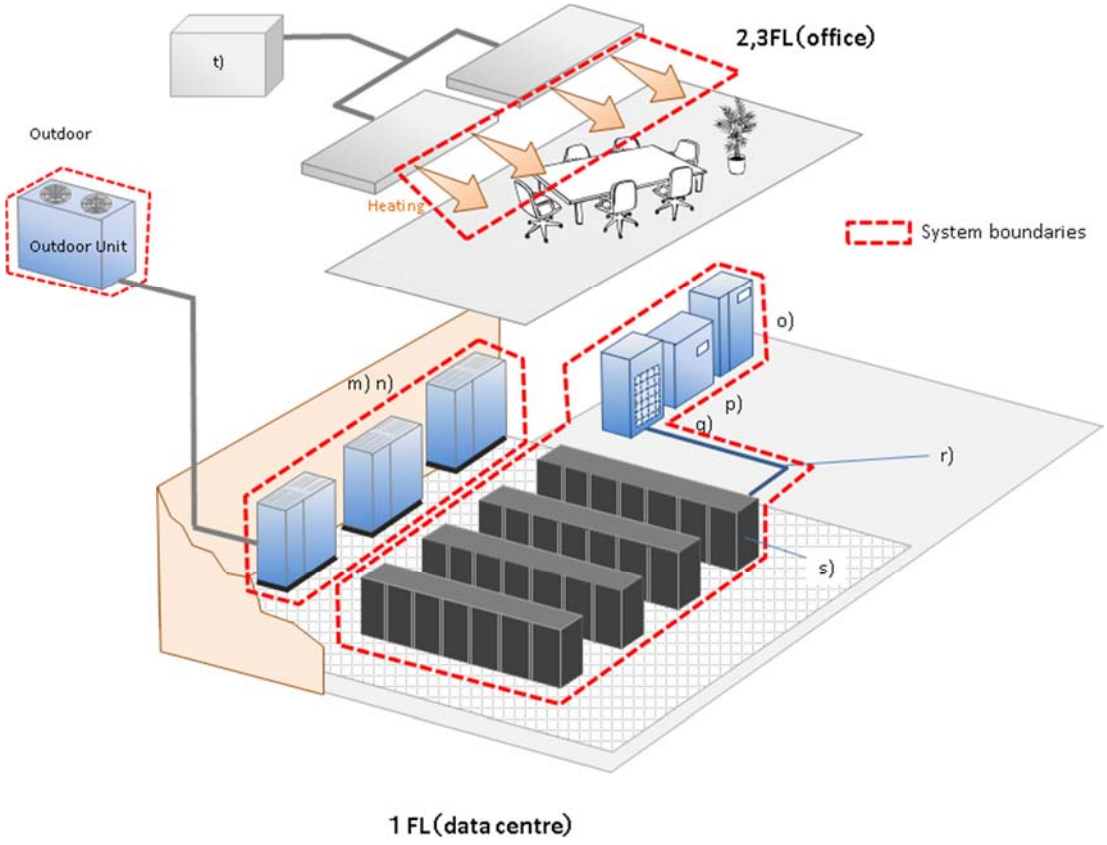


Figure 1-2 – Reference ICT product system

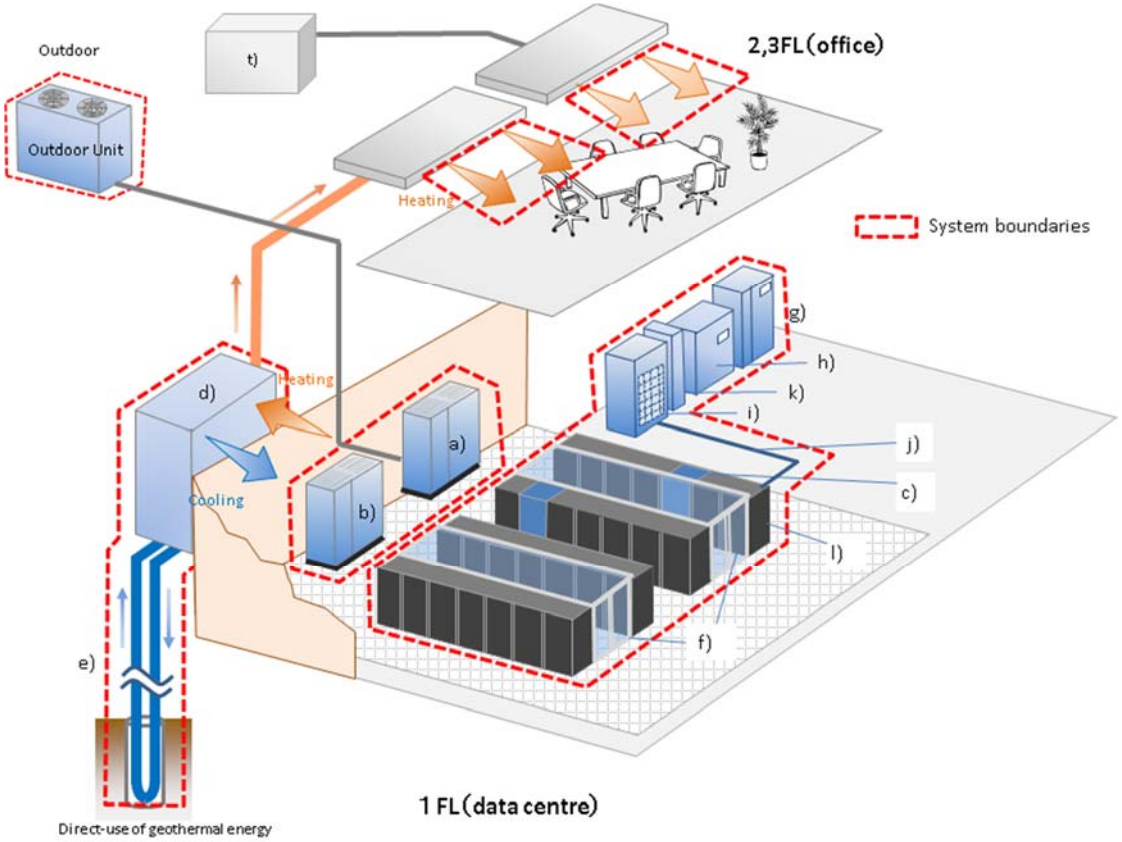


Figure 1-3 – Target ICT product system

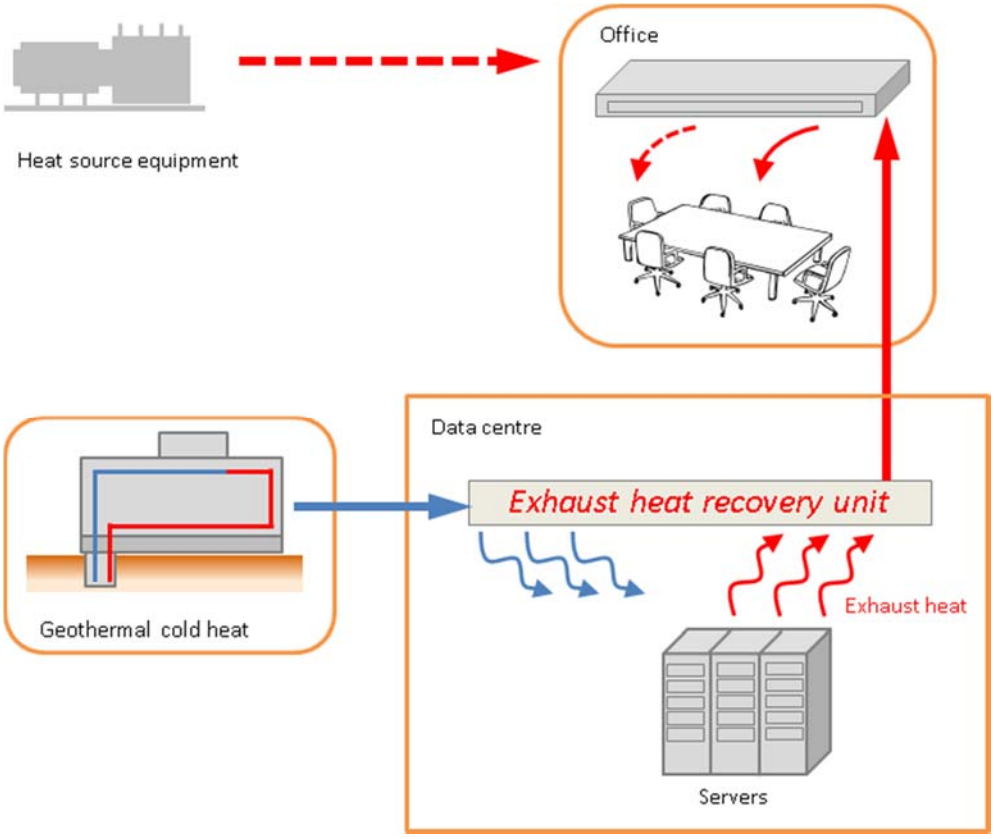


Figure 1-4 – Server room cooling by direct-use of geothermal energy and office room heating by server exhaust heat (Target ICT product system)

The building blocks of each system are shown in Table 1-2.

Table 1-2 – Evaluated system
(1) Data centre

Category		Target ICT product system			Reference ICT product system		
		Items	Unit	Spec.	Items	Unit	Spec.
Air conditioning	High-efficiency air cooled packaged air-conditioner for data centres	a) Outdoor air cooling-type air-cooled package air conditioner for data centres [b-2][b-3]	1	Rated cooling capacity: 45 kW COP: 4.8	m) Air-conditioner	2	Rated cooling capacity: 40 kW COP: 2.6
		b) High-efficiency air cooled packaged air-conditioner for data centres [b-4]	1	Rated cooling capacity: 45 kW COP: 4.4			
	Outdoor air cooling-type local air-conditioner	c) Rack-type local air-conditioner [b-5]	2	Rated cooling capacity: 28.3 kW COP: 5.2	n) Air-conditioner	1	Rated cooling capacity: 56 kW COP: 2.6
	Direct-use of geothermal energy	d) Exhaust heat recovery unit*1	1	capacity: 17.4 kW	–	–	–
		e) Heat collecting pipe	1		–	–	–
	Airflow design	f) Cold aisle-capping [b-6]	2		–	–	–
Power supply		HVDC rectifier system		DC380V	Uninterruptible power supply (UPS)		AC200V
		g) Rectifier unit	1		o) Converter/inverter unit	1	
		h) Battery cell	91	Li-ion batteries battery capacity: 33.7 kWh	p) Battery cell	168	VRLA batteries battery capacity: 168 kWh
		i) HVDC power distribution frame	1	DC380V	q) AC power distribution frame	1	AC200V
		j) Power distribution cables			r) Power distribution cables		
		200 mm^2-CED	4 m		200 mm^2-CET	4 m	
		14 mm^2-CED	868 m		3core14C VVS	868 m	

Table 1-2 – Evaluated system
(1) Data centre

Category	Target ICT product system			Reference ICT product system		
	Items	**Unit**	**Spec.**	**Items**	**Unit**	**Spec.**
	k) Cable protective board	1		–	–	–
Server*2	l) DC servers	74		s) AC servers	74	
*1: Commonly used with the office heating system using the exhaust heat of ICT equipment from December to March. *2: The difference is only a power supply circuit.						

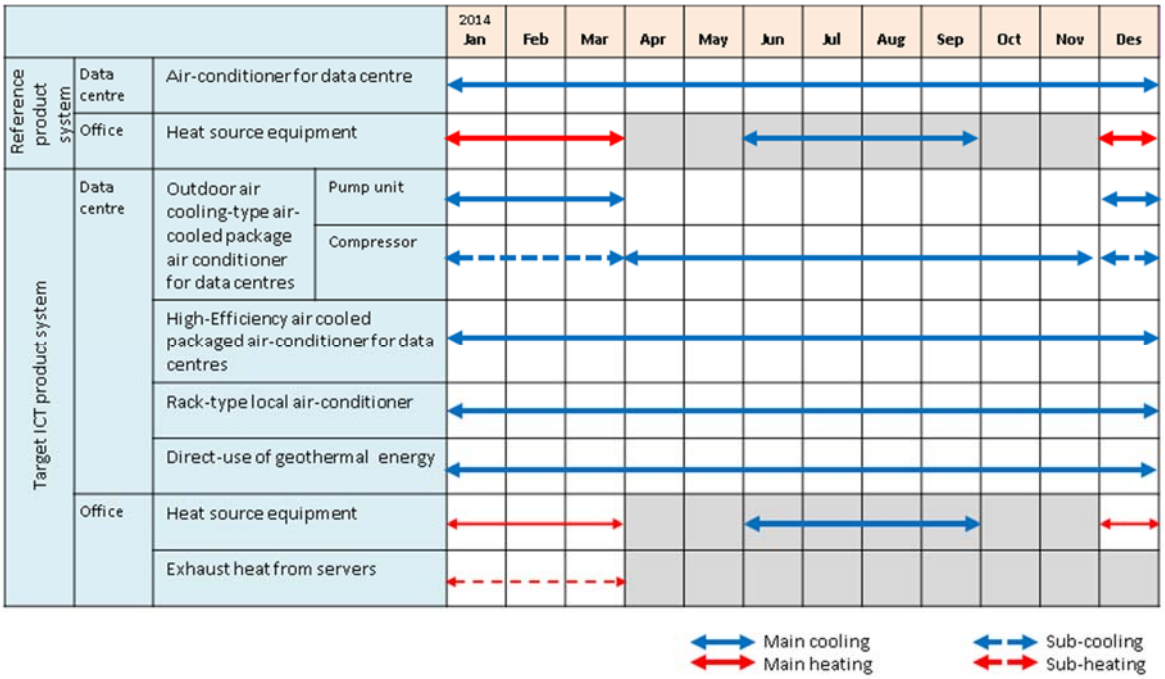
Table 1-2 – Evaluated system
(2) Office

Category		Target ICT product system			Reference ICT product system		
		Items	**Unit**	**Spec.**	**Items**	**Unit**	**Spec.**
Air conditioning	Air-conditioner	t) Heat source equipment	1		t) Heat source equipment	1	
	Exhaust heat use	d) Exhaust heat recovery unit*3	1	capacity: 17.4 kw	–	–	–
*3: Commonly used with the direct-use of geothermal energy system in the data centre and operated from December to March.							

1.3 Operation model of air conditioning

Table 1-3 shows a use scenario for each air conditioner used in this case study and for the usage in offices of the exhaust heat recovered from the data centres.

Table 1-3 – Operative schedule



Energy consumption of the cooling equipment is specified by measurements over several months and extrapolation of those as explained in clause 6.1.

1.4 Functional unit

The functional unit was defined as one-year operation of servers, air conditioning equipment and power supply equipment of the data centre and the office air conditioning.

For a user profile, according to Table 1-3.

1.5 System boundaries

1.5.1 General principles

In order to achieve the goal and purpose of this case study, comparative analysis was carried out according to the following principles:

- In principle only life cycle stages that differ between the two systems were calculated. This means that the overall footprint would be only partially calculated. However some major elements such as the servers were included in the study although they were not relevant for the comparative assessment.
- For the data centre, servers, air conditioning and the power supply were taken into account, whereas the network to which the data centre belonged and the services that it supported were excluded as they were considered to be the same in both systems. For the office, only the use stage of the air conditioning system was taken into account because all other items were considered to be the same in both systems.
- GHG emissions were evaluated using the economic input-output approach for the domestic part of the raw material acquisition and production. Due to restrictions in the IOA data used, non-domestic raw material and production activities were excluded. Furthermore, the results for raw materials acquisition and production could not be separated
- Both the data centre cooling system and the office heating system were considered since the target ICT product system includes heat recovery in offices as well as in the data centre cooling.

1.5.2 Mapping of "eight items to consider" on life cycle stages used in the comparative assessment, and the data list

The items considered and the life cycle stages evaluated in this case study are shown below.

The equipment letters (a, b, c, etc.) used in the reference and in the target parts of Table 1-4 and in the reference and target parts of Table 1-5 correspond to those used in Table 1-2.

Table 1-4 – Mapping of checklist items on life cycle stages in the comparative assessment: data centre part

(1) Reference ICT product system

Category			Raw material acquisition and production	Use	End-of-life treatment
	Sub-category	**Equipment**			
ICT hardware			√	√	√
ICT software			*	*	*
Consumables and other supportive products			*	*	*
Site infrastructure	Air conditioning	m), n)	√	√	√
	Power supply	o), p), q)	√	√	√
		r)	√	√	√
	Buildings	m), n), o), p), q)	√	√	√
Transport (movement of goods)			*	*	*
Travel (movement of people)			*	*	*
Storage of goods			*	*	*
Working environment	Operation and maintenance activities	m), n)	√	√	√
* Common building blocks that are not considered in the comparative assessment.					

Table 1-4 – Mapping of checklist items on life cycle stages in the comparative assessment: data centre part

(2) Target ICT product system

Category			Raw material acquisition and production	Use	End-of-life treatment
	Sub-category	**Equipment**			
ICT hardware (server)			√	√	√
ICT software			*	*	*
Consumables and other supportive products			*	*	*
Site infrastructure	Air conditioning	a), c), d)	√	√	√
		e), f)	√	**	√
	Power supply	g), h), i), k)	√	√	√
		j)	√	√	√
	Buildings	a), b), c), d), g), h), i), k)	√	√	√
Transport (movement of goods)			*	*	*
Travel (movement of people)			*	*	*
Storage of goods			*	*	*
Working environment	Operation and maintenance activities	a), b), c)	√	√	√

* Common building blocks that are not considered in the comparative assessment.

** No energy consumption exists.

Table 1-5 – Mapping of checklist items on life cycle stages in the comparative assessment: office

(1) Reference ICT product system

Category			ICT product system		
	Sub-category	Equipment	Raw material acquisition and production	Use	End-of-life treatment
ICT hardware			*	*	*
ICT software			*	*	*
Consumables and other supportive products			*	*	*
Site infrastructure	Air conditioning	t)	*	√	*
Transport (movement of goods)			*	*	*
Travel (movement of people)			*	*	*
Storage of goods			*	*	*
Working environment			*	*	*
* Common building blocks that are not considered in the comparative assessment.					

Table 1-5 – Mapping of checklist items on life cycle stages in the comparative assessment: office

(2) Target ICT product system

Category			ICT product system		
	Sub-category	Equipment	Raw material acquisition and production	Use	End-of-life treatment
ICT hardware			*	*	*
ICT software			*	*	*
Consumables and other supportive products			*	*	*
Site infrastructure	Air conditioning	d)	√	√	√
		t)	*	√	*
Transport (movement of goods)			*	*	*
Travel (movement of people)			*	*	*
Storage of goods			*	*	*
Working environment			*	*	*
* Common building blocks that are not considered in the comparative assessment.					

1.5.3 Cut-off

The study made the following cut-offs:

- The Japanese input-output (IO) data are based on domestic activities only. For this reason all non-domestic activities related to the raw materials acquisition and production were cut-off. However this cut-off is only partial as import and export are considered in the IO data to some extent. Due to lack of data the impact from this cut-off could not be estimated.
- Servers were included in the results although they do not impact the comparative analysis. However, final distribution of servers was cut-off. This did not impact on the results of the comparison.
- Similarly the final distribution of the power supply (including batteries) and the air conditioners and the exhaust heat recovery unit were cut-off. This did not impact the result of the comparison for power supply as it affects both the assessed systems equally. However, for the air conditioners, the batteries as well as for the exhaust heat recovery unit, the heat collecting pipe and the cold aisle-capping of a number of goods there were differences between the assessed systems but the impact of these differences on the results is considered limited.

1.5.4 Operating lifetime

This study assumes that each item of equipment was used during the statutory useful life defined in Table 1-6 in accordance with the user profile set up in Table 1-3.

Table 1-6 – Statutory useful life time used in this case study [b-7]

Target ICT product system		**Reference ICT product system**	
Equipment	**Useful life time (year)**	**Equipment**	**Useful life time (year)**
a) Outdoor air cooling-type air-cooled package air conditioner for data centres	13	m) Air-conditioner	13
b) High-efficiency air cooled packaged air-conditioner for data centres	13	–	–
c) Rack-type local air-conditioner	13	n) Air-conditioner	15
d) Exhaust heat recovery unit	13	–	–
e) Heat collecting pipe	13	–	–
f) Cold aisle-capping	15	–	–
g) Rectifier unit	15	o) Converter/inverter unit	15
h) Battery cell(Li-ion)	6	p) Battery cell	6
i) HVDC power distribution frame	15	q) AC power distribution frame	15
j) Power distribution cables	30	r) Power distribution cables	30
k) Cable protective board	15	–	–
l) DC servers	5	s) AC servers	5

2 References

[ITU-T L.1410] Recommendation ITU-T L.1410 (2014), *Methodology for environmental life cycle assessments of information and communication technology goods, networks and services*.

[ITU-T L.1200] Recommendation ITU-T L.1200 (2012), *Direct current power feeding interface up to 400 V at the input to* telecommunication *and ICT equipment*.

[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

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

3EID Embodied Energy and Emission Intensity Data

COP Coefficient of Performance

EoLT End-of-Life Treatment

GHG Greenhouse Gas

HVDC High-Voltage Direct Current

ICT Information and Communication Technology

IDEA Inventory Database for Lifecycle Analysis

IO Input-Output

IOA Input-Output Analysis

LCA Life Cycle Assessment

PDF Power Distribution Frame

RMA Raw Material Acquisition

RMA&P Raw Material Acquisition and Production

5 Conventions

None.

6 Life cycle inventory

6.1 Data collection

The collected data items for evaluating the greenhouse gas (GHG) emissions of the target ICT product system are shown in Table 6-1 and Table 6-2 for the data centre and the office, respectively.

Table 6-1 – Data items acquired in this case study: Target ICT product system
(1) Data centre

Necessary information			Primary data items
Category	**Sub-category**	**Items**	
ICT hardware	Servers	Body	Price, weight, power consumption (see Note 1), unit number, installation area
		Power supply unit	Price, weight, unit number
Site infrastructure	Air-conditioner	Outdoor air cooling-type air-cooled package air conditioner for data centre	Price, weight, power consumption (see Note 2), unit number, installation area
		High-efficiency air cooled packaged air-conditioner for data centre	Price, weight, power consumption (see Note 2), unit number, installation area
		Local air-conditioner	Price, weight, power consumption (see Note 2), unit number, installation area
		Exhaust heat recovery unit	Price, weight, power consumption (see Note 2), unit number
		Heat collecting pipe	Price, weight, material, length
		Cold aisle-capping	Price, weight, unit number
	Power supply	HVDC rectifier	Price, weight, power consumption (see Note 3), unit number, installation area
		Lithium ion storage batteries	Price, weight, unit number, installation area
		HVDC power distribution frame（PDF）	Price, weight, power consumption (see Note 4), unit number, installation area
		Power distribution cables	Price, weight, diameter, length
		Cable protective board	Price, weight, power consumption (see Note 4), unit number, installation area
Working environment	Operation and maintenance activities	Air-conditioner for data centre	Man-day of operation and maintenance, lifetime of the compressor, unit number
		Power supply	Man-day reduction ratio (See Note 3), unit number, number of cells

NOTE 1 – The total consumption of the ICT equipment in the data centre was measured and it was assumed that the power consumption of the server is 40% of this power consumption based on Japanese average conditions. http://www.env.go.jp/air/tech/model/heat_aeh-wg2-20_02/ref01.pdf

NOTE 2 – August 2014 - December 2014: measured
January 2014 - July 2014: estimated based on the measured value for August-December modified according to the capacity profile of coefficient of performance (COP) vs outdoor temperature.
http://www.jma.go.jp/jma/menu/report.html

NOTE 3 – Heating

NOTE 4 – Estimated based on the efficiency of the power-supply unit and total power supplied to the data centre.

Table 6-2 – Data items acquired in this case study: Target ICT product system (2) Office

Necessary information			Data items
Category	**Sub-category**	**Items**	
Site infrastructure	Air-conditioner	Heat source equipment	Power consumption (see Note 1)
	Exhaust heat use	Exhaust heat recovery unit	Price, weight, power consumption (see Note 2), unit number, installation area
NOTE 1 – Calculated according to the Japanese average COP (=2.6) according to experts' estimation for the present air conditioner by the following equation: P[kW] = power consumption of ICT equipment/COP of the air conditioner for data centre = 22.0 kW/2.6 NOTE 2 – August 2014 - December 2014: measured January 2014 - July 2014: estimated based on the measured value for August-December modified according to the capacity profile of COP vs outdoor temperature. http://www.jma.go.jp/jma/menu/report.html			

The collected data items for evaluating the GHG emissions of the reference ICT product system are shown in Table 6-3 and Table 6-4 for the data centre and the office, respectively.

Table 6-3 – Data items acquired in this case study: Reference ICT product system (1) Data centre

Necessary information			Data items
Category	**Sub-category**	**Items**	
ICT hardware	Servers	Body	Price, weight, power consumption (see Note 1), unit number, installation area
		Power supply unit	Price, weight, unit number
Site infrastructure	Air-conditioner	Air-conditioner for data centre	Price, weight, power consumption (see Note 2), unit number, installation area, rated cooling capacity, COP
	Power supply	Converter/inverter unit	Price, weight, power consumption (see Note 3) unit number, installation area
		Lead Storage batteries	Price, weight, power consumption (see Note 3), capacity, unit number, installation area
		AC power distribution frame (PDF)	Price, weight, power consumption (see Note 3), unit number, installation area
		Power distribution cables	Price, weight, diameter, length
Working environment	Operation and maintenance activities	Air-conditioner for data centre	Man-day/maintenance, lifetime of the compressor, unit number
		Power supply	Man-day/maintenance, unit number, number of cells

Table 6-3 – Data items acquired in this case study: Reference ICT product system
(1) Data centre

Necessary information			Data items
Category	**Sub-category**	**Items**	
NOTE 1 – Assumed to be the same value as for the target ICT product system. NOTE 2 – Calculated according to the Japanese average COP (= 2.6) according to experts' estimation for the present air conditioner by the following equation: P[kW] = power consumption of ICT equipment/COP of the air conditioner for data centre = 22.0 kW/2.6 NOTE 3 – Estimated from the power consumption of ICT equipment and the efficiency of the power-supply unit.			

Table 6-4 – The primary data items acquired in this case study: Reference ICT product system
(2) Office

Necessary information			Primary data acquisition items
Category	**Sub-category**	**Items**	
Site infrastructure	Air-conditioner	Heat source equipment	Power consumption

6.2 Data calculation

The data calculation was conducted based on the conditions required by [ISO 14040], [ISO 14044] and [ITU-T L.1410].

[ITU-T L.1410] requires the calculation of seven types of GHGs, but only CO_2 emissions were calculated in this study, mainly because of the difficulty in acquiring adequate high quality data.

The calculation equations of GHG emissions (CO_2 emissions only in this study) and the collected data are shown in Table 6-5.

Table 6-5 – How to calculate the GHG emissions from collected data

Category	How to calculate the CO_2 emissions	Collected data and sources
ICT hardware	Server	
	<Raw material acquisition and production> Prices of the hardware[yen](*1) × emission factor [kg-CO2/yen] (*2) ÷ life time[year](*3)	*1: Prices of the hardware (source: statistics of Japan Electronics and information Technology Industries Association, 2009) *2: Emissions factor of hardware for raw material acquisition and production and end-of-life treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
	<Use> Power consumption[kW](*1) ×annual operating time of the hardware[hour/year](*2) × emission factor [kg-CO2/kWh](*3)	*1: Measurements of electric power consumption *2: 8,765H/year(= 24H*365days) *3: Emissions factor of electric power (source: FEPC, 2013)

Table 6-5 – How to calculate the GHG emissions from collected data

Category	How to calculate the CO_2 emissions	Collected data and sources
	<End-of-life treatment> Weight of the hardware[kg](*1)× emission factor [kg-CO2/kg](*2) ÷ life time[year](*3)	*1: Weight of the hardware (source: catalogue) *2: emission factor of waste disposal treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
Site infrastructure	Air conditioning, Power supply.	
	<Raw material acquisition and production> Prices of the hardware[yen] (*1) × emission factor [kg-CO2/yen] (*2) ÷ life time[year](*3)	*1(Air conditioning): Prices of the hardware (source: hearing from the vendor) *1(Power supply): Prices of the hardware (source: The Japan Machinery Federation, 2004) *2: Emissions factor of hardware for raw material acquisition and production and end-of-life treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
	<Use> Power consumption[kW](*1) × annual operating time of the hardware[hour/year] (*2) × emission factor [kg-CO2/kWh](*3)	*1: Measurements of electric power consumption *2: 8,765H/year(=24H*365days) *3: Emissions factor of electric power (source: FEPC, 2013)
	<End-of-life treatment> Weight of the hardware[kg](*1) × emission factor [kg-CO2/kg] (*2) ÷ life time[year](*3)	*1: Weight of the hardware (source: hearing from the vendor) *2: emission factor of waste disposal treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
	Cold Aisle-capping	
	<Raw material acquisition and production> Prices of the hardware[yen](*1) × emission factor [kg-CO2/yen](*2) ÷ life time[year](*3)	*1: Prices of the hardware (source: hearing from the vendor) *2: Emissions factor of hardware for raw material acquisition and production and end-of-life treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
	<End-of-life treatment> Weight of the hardware[kg](*1) × emission factor [kg-CO2/kg](*2) ÷ life time[year](*3)	*1: Weight of the hardware (source: hearing from the vendor) *2: emission factor of waste disposal treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)

Table 6-5 – How to calculate the GHG emissions from collected data

Category	How to calculate the CO_2 emissions	Collected data and sources
	Battery	
	<Raw material acquisition and production> Prices of the hardware[yen](*1) × emission factor [kg-CO2/yen](*2) ÷ life time[year](*3)	*1: Prices of the hardware (source: statistics of Economic Research Association, 2015) *2: Emissions factor of hardware for raw material acquisition and production and end-of-life treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
	<Use> Annual power loss[kWh/year](*1) × emission factor[kg-CO2/kWh](*2)	*1: Measurements of power loss *2: Emissions factor of electric power (source: FEPC, 2013)
	<End-of-life treatment> Weight of the hardware[kg](*1) × emission factor [kg-CO2/kg](*2) ÷ life time[year](*3)	*1: Weight of the hardware (source: catalogue) *2: emission factor of waste disposal treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
	Power cable	
	<Raw material acquisition and production> Prices of the hardware[yen](*1) × emission factor [kg-CO2/yen](*2) ÷ life time[year](*3)	*1: Prices of the hardware (source: statistics of Economic Research Association, 2015) *2: Emissions factor of hardware for raw material acquisition and production (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
	<End-of-life treatment> Weight of the hardware[kg] (*1) × emission factor [kg-CO2/kg](*2) ÷ life time[year](*3)	*1: Weight of the hardware (source: hearing from the vendor) *2: emission factor of waste disposal treatment (source: Japanese Input-Output Table, 2005) *3: Statutory useful life in Japan (source: national tax agency)
	Buildings	
	<Raw material acquisition and production> Site infrastructure installation area[m2](*1) × annual emission factor allocated considering expected lifetime[kg-CO2/m2/year](*2)	*1: Site infrastructure installation area (source: hearing from NTT FACILITIES, the operator of the data centre) *2: emission factor of the office building for each life cycle stage (source: 3rd seminar of Life Cycle Assessment Society of Japan, 2004 (in Japanese) http://lca-forum.org/seminar/pdf/69.pdf
	<Use> Site infrastructure installation area[m2](*1) × annual emission factor [kg-CO2/m2/year](*2)	
	<End-of-life treatment> Site infrastructure installation	

Table 6-5 – How to calculate the GHG emissions from collected data

Category	How to calculate the CO_2 emissions	Collected data and sources
	area[m2](*1) × annual emission factor allocated considering expected lifetime[kg-CO2/m2/year](*2)	
Working environment	Maintenance and operation of air conditioning equipment.	
	<Raw material acquisition and production and end-of-life treatment>,<Use>,<End-of-life treatment> Annual number of work steps[person×day/year](*1) × working area per office worker[m2/person](*2) × daily emission factor [kg-CO2/day/m2](*3)	*1: Number of work steps (source: hearing from NTT FACILITIES, the operator of the data centre) *2: The working area per office worker (source: Japan Building Owners and Managers Association, 2013) *3: Emission factor of the office building (source: Architectural Institute of Japan, 2011)

LCA-DB and statistics used in this case study are shown in Table 6-6.

Table 6-6 – LCA-DB and statistics used in this case study

		Source	Reference
Emissions factor	Electric power	FEPCO: The Federation of Electric Power Companies of Japan CO_2 emissions intensity user end electricity averaged over 12 electric power companies, including distribution loss in and the electricity supply chain for year 2013	http://www.fepc.or.jp/environment/warming/environment/pdf/2014.pdf
	Hardware for raw material acquisition and production and end-of-life treatment	3EID: Embodied Energy and Emission Intensity Data for Japan using input-output tables	http://www.cger.nies.go.jp/publications/report/d031/eng/index_e.htm
Price of ICT equipment	Server, storage	JEITA: Japan Electronics and Information Technology Industries Association	http://home.jeita.or.jp/is/statistics/server/h21/kakaku1.html http://www.jeita.or.jp/japanese/stat/electronic/2008/product/pro_12.pdf (in Japanese)
	Battery, power cable	Economic Research Association	https://www.e-sekisan.jp/ER/topmenu.jsf (in Japanese, toll information)

Table 6-6 – LCA-DB and statistics used in this case study

		Source	Reference
Power consumption/ efficiency	Server, storage	Green ICT committee, DPPE: Holistic Framework for Data Centre Energy Efficiency	http://home.jeita.or.jp/greenit-pc/topics/release/pdf/dppe_e_20120824.pdf
	UPS	JEITA: Japan Electronics and Information Technology Industries Association	http://www.jema-net.or.jp/jema/data/06-ups02.pdf (in Japanese)
Operation and maintenance activities	Power supply	Ministry of Land, Infrastructure, Transport and Tourism Japan	http://www.mlit.go.jp/common/001031666.pdf (in Japanese)

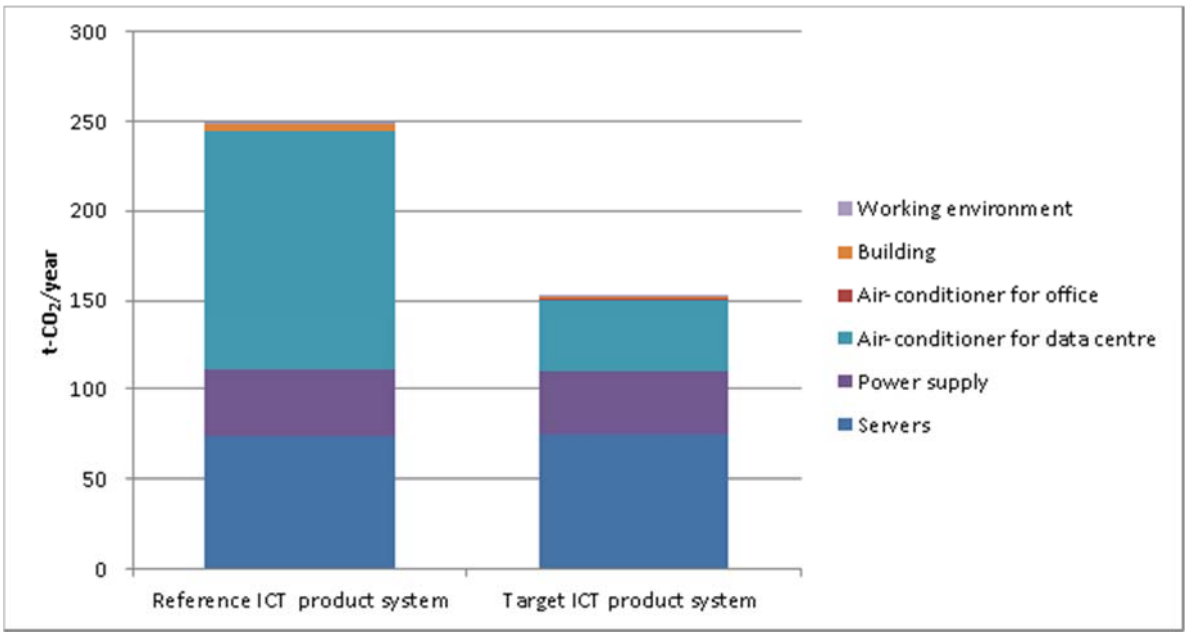
7 Results and conclusion of the evaluation

Clause 7 presents the overall results of the assessment. Detailed results are available in Appendix I.

7.1 Results

The assessment results showing the different parts of the systems are shown in the figures and tables below.

Figure 7-1 and Table 7-1 show the assessment results by category.



NOTE – This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal.

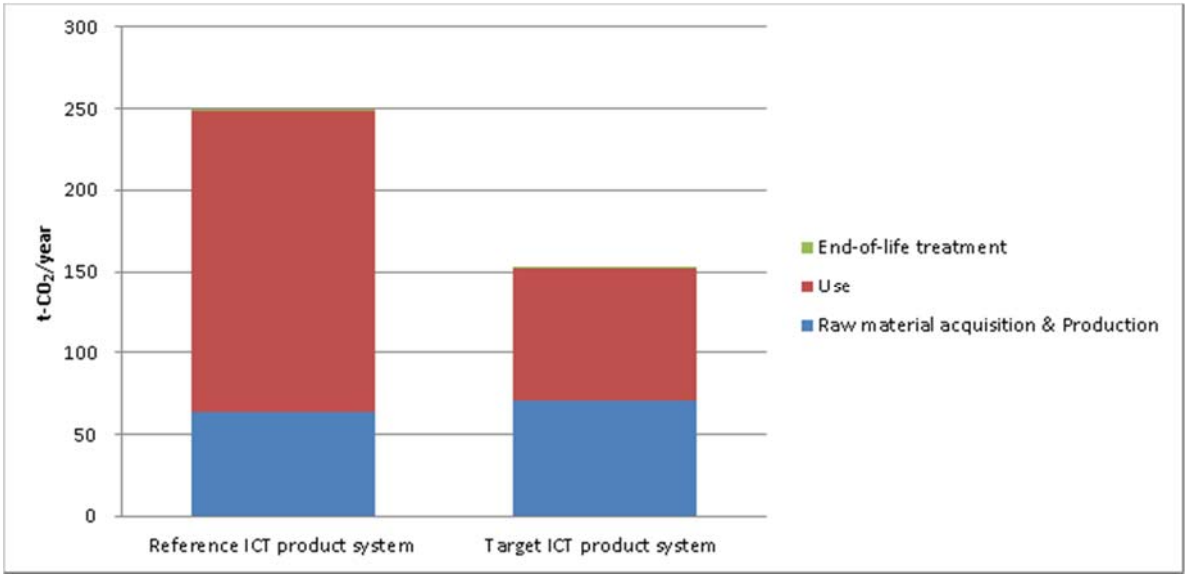
Figure 7-1 – Assessment results by category

Table 7-1 – Assessment results by category

	ICT hardware	Site infrastructure				Working environment
	Servers	Power supply	Air-conditioner for data centre	Air-conditioner for office	Building	
	t-CO_2/year	t-CO_2/year	t-CO_2/year	t-CO_2/year	t-CO_2/year	t-CO_2/year
Reference ICT product system	74.0	36.5	133.7	0.4	4.1	0.1
Target ICT product system	74.7	35.5	40.3	0.4	1.6	0.1

	Total	Reduction amount	Reduction rate
	t-CO_2/year	t-CO_2/year	%
Reference ICT product system	248.9	–	
Target ICT product system	152.5	96.3	39%

Figure 7-2 and Table 7-2 show the results for the different life cycle stages of the reference and the target ICT product systems:



NOTE – This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal

Figure 7-2 – Assessment results by life cycle analysis

Table 7-2 – Assessment results by life cycle analysis

	Raw material acquisition and production	**Use**	**End-of-life treatment**	**Total**	**Reduction amount**	**Reduction rate**
	t-CO_2 /year	t-CO_2 /year	t-CO_2 /year	t-CO_2 /year	t-CO_2 /year	%
Reference ICT product system	63.4	184.7	0.7	248.9	–	
Target ICT product system	70.6	81.5	0.4	152.5	96.3	39%

7.2 Sensitivity analysis

Sensitivity analysis was conducted to analyse the impact of differences of COP and the price of batteries on LCA results because these data were based on general statistics in contrast to other data which were based on the existing data centre.

7.2.1 COP of air conditioner

In the comparative analysis of air-conditioners, 2.6 was used as the COP value of the reference ICT product system. As the result changes greatly according to the COP value of the reference ICT product system, the COP range of conventional air conditioners was also tested as follows and a sensitivity analysis was carried out.

Min COP = 1.5

Max COP = 3.4

The results of sensitivity analysis of COP are shown in Figure 7-3 while with the results based on the COP of 2.6 of the reference ICT product system are shown in Table 7-3. As can be seen in Table 7-3, the CO_2 reduction induced by the applied energy saving technique of the air-conditioner

in the target ICT system was around 190, 90 and 60 t-CO_2/year when the COP of the reference ICT product system was assumed as 1.5, 2.6 and 3.4 respectively. This result suggests that the assumed COP of air conditioners in the reference ICT product system makes a significant difference in the CO_2 emission reduction by using energy-saving technology in the target ICT product system especially when the assumed COP was low.

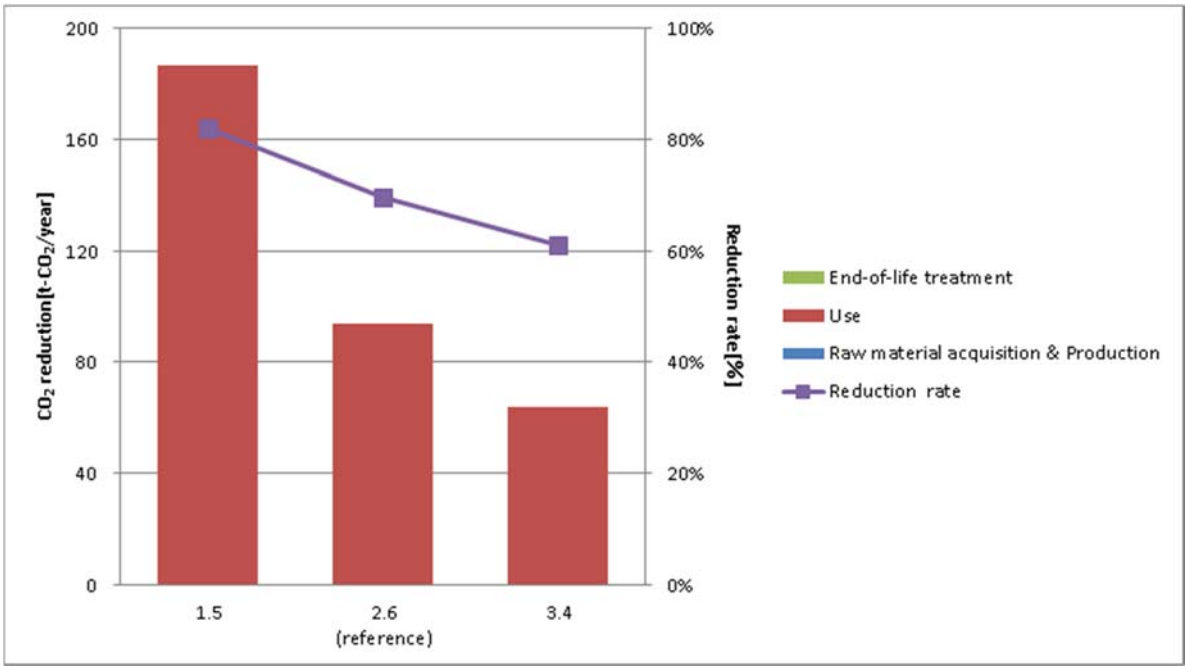


Figure 7-3 – Results of sensitivity analysis of COP

Table 7-3 – Results of sensitivity analysis of COP

COP in reference ICT product system	Air conditioner					Overall result	
	Raw material acquisition and production	Use	End-of-life treatment	Total	Reduction rate	Total	Reduction rate
	t-CO_2 /year	t-CO_2 /year	t-CO_2 /year	t-CO_2 /year		t-CO_2 /year	
1.5	-0.5	186.8	0.0	186.3	82%	189.3	55%
2.6 (reference)	-0.5	93.9	0.0	93.4	70%	96.3	39%
3.4	-0.5	64.1	0.0	63.6	61%	66.5	30%

7.2.2 Raw material acquisition and production of Li-ion battery

In general, the input-output (IO) approach means that the results are sensitive to price levels. This is a general effect and the impact of that was tested for batteries as described below. Similar sensitivity analysis could have been performed also for other IO based data points.

More specifically, in the comparative analysis of the power supply systems, the CO_2 emissions in the raw material acquisition and production stage of Li-ion batteries and lead storage batteries were evaluated by the economic input-output approach. Therefore CO_2 emissions in the raw material acquisition and production stage depend on those prices. According to the latest statistical data of battery production representing the time period 2009-2013 [b-9], the price of Li-ion batteries decreases.

We estimated the future price of Li-ion batteries assuming a linear decrease using the data of capacity and price of battery production during 2009-2013 from the latest statistics on the price and carried out sensitivity analysis. The price per capacity of Li-ion battery and lead battery was estimated to be 85% and 104%, 63% and 104% and 41% and 106% in 2015, 2020 and 2025 compared to 2013 respectively.

The results are shown in Figure 7-4 and in Table 7-4. The assessment result of CO_2 emission reduction was estimated to be larger in both 2020 and 2025 than that in 2015 applying input-output assessment (IOA). Considering the overall results of his study, the CO_2 emission reduction rate was estimated to be 39%, 42% and 44% in 2015, 2020 and 2025 respectively, to be compared with the main result of 39% representing 2013 data (see clause 7.1).

This result suggests that the price change in batteries does not have significant impact on the results of this case study.

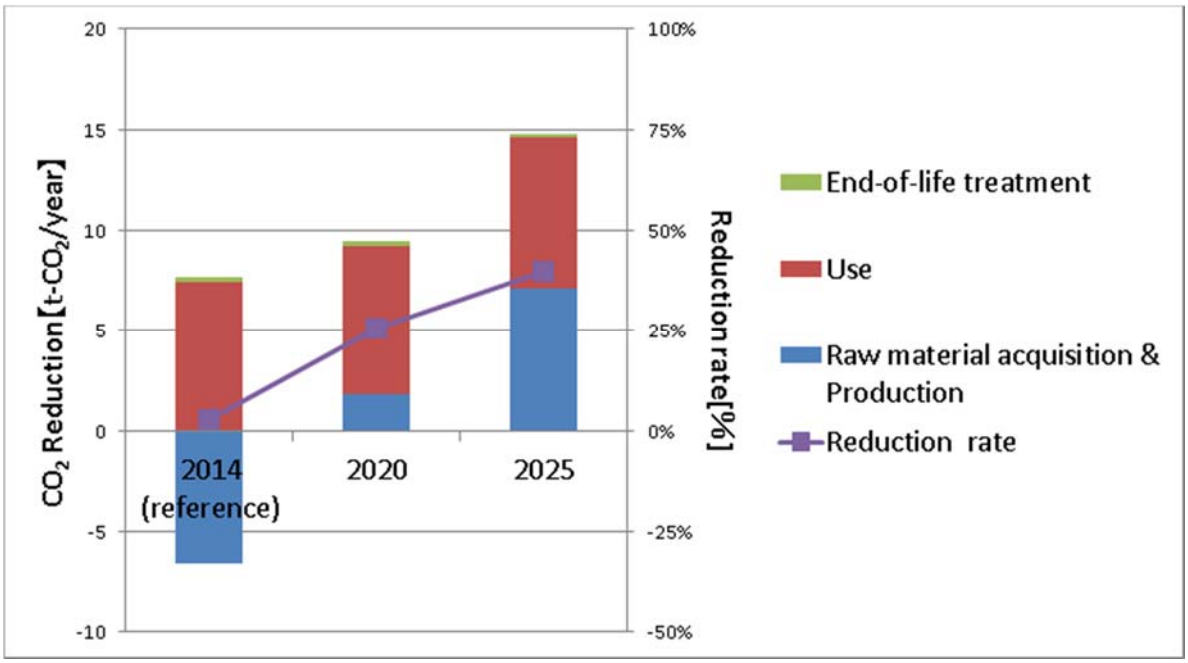


Figure 7-4 – Results of sensitivity analysis of raw material acquisition and production of Li-ion battery

Table 7-4 – Results of sensitivity analysis of raw material acquisition and production of Li-ion battery

Year	Power supply					Overall result	
	Raw material acquisition and production	Use	End-of-life treatment	Total	Reduction rate	Total	Reduction rate
	$t\text{-}CO_2$ / year	$t\text{-}CO_2$ / year	$t\text{-}CO_2$ / year	$t\text{-}CO_2$ / year		$t\text{-}CO_2$ / year	
2014 (reference)	-6.6	7.5	0.2	1.0	3%	96.3	39%
2020	1.8	7.5	0.2	9.4	26%	104.7	42%
2025	7.1	7.5	0.2	14.8	40%	110.1	44%

7.3 Potential second order effects

The potential second order effects are a possible reduction of the installation area of the air conditioner and power supply equipment and a possible reduction of the office area (working environment) for maintenance workers. Potential second-order effects are shown in Table 7-5.

Table 7-5 – Potential second-order effects

Potential	Field test and results ($t\text{-}CO_2$/year)		
	(1) Reference ICT product system	(2) Target ICT product system	Difference (1)-(2)
Travel (movement of people)	–	–	–
Transport (movement of goods)	–	–	–
Site infrastructure	Space for air conditioning equipment, power supply equipment 4.1	Space for air conditioning equipment, power supply equipment 1.6	Space for air conditioning equipment, power supply equipment 2.5
Storage of goods	–	–	–
Working environment	Office space for maintenance workers 0.12	Office space for maintenance workers 0.09	Office space for maintenance workers 0.03

7.4 Conclusion

The power saving technologies evaluated in this case study were found to be very effective for reducing CO_2 emissions of the assessed data centre especially for use stage of air-conditioners. The results seem promising and future studies could investigate if these results could be generalized.

Due to restrictions in the IOA data used, non-domestic raw material and production activities were excluded and the effect of this could not be analysed due to lack of data.

This case study shows that IOA is an interesting approach for environmental assessment of ICT product systems.

For compliance towards [ITU-T L.1410] refer to the compliance table in Appendix II of this Supplement.

8 Critical review

An internal critical review was conducted and a discussion was carried out in the Telecommunication Technology Committee (TTC) in Japan to ensure the objectivity of the assessment.

Appendix I

Reporting according to the tables in Annex L of [ITU-T L.1410]

Table L.1 as presented in Annex L of [ITU-T L.1410] shows a cover page completed here to report the results of the case study assessment described in this Supplement.

Table L.1 of ITU-T L.1410 – Cover page

REPORTING			
	Yes	No	Description/references to page
General information			
Company name and contact information	Yes		Nippon Telegraph and Telephone Corporation, Japan hara.minako@lab.ntt.co.jp
Project name	Yes		A hybrid approach based comparative analysis of the environmental impact of a baseline data centre and an energy-efficient data centre
Product system	Yes		1.3 ICT product systems to compare
Product system related information	Yes		
Product system function	Yes		
Product system description	Yes		
Product picture (optional)		No	
Date of completion of assessment (DD/MM/YYYY)	Yes		10/09/2015
Compliant with ITU-T L.1410 most recent version	Yes		ITU-T L.1410 (2014) http://handle.itu.int/11.1002/1000/12207-en
LCA tool used	Yes		Inventory database for lifecycle analysis (IDEA) : Table 2-8 http://www.ghgprotocol.org/third-party-databases/IDEA Embodied energy and emission intensity data (3EID) for Japan Using Input-Output Tables: Table 2-8 http://www.cger.nies.go.jp/publications/report/d031/eng/index_e.htm
External review (yes/no)	Yes		Telecommunication Technology Committee (TTC) in Japan
Reviewers	Yes		
Goal definition			
Reason for carrying out the study	Yes		1.1 Purpose and goal of the study
Target audience(s)	Yes		Open to the public
Comparative assessment	Yes		1.3 ICT product systems to compare
Scope definition			
Functional unit			1.5 Functional unit
Reference flow			1.3 ICT product systems to compare
System boundaries			1.6 System boundaries
Environmental impact categories			GHG emissions only

Table L.1 of ITU-T L.1410 – Cover page

REPORTING			
	Yes	No	Description/references to page
List of optional and recommended stages considered			Not applicable
Cut-off criteria	Yes		1.6.3 Cut off
Resource used and emission profile			
Secondary data sources	Yes		2.2 Data calculation Table 2-8
Data collection procedure	Yes		2.1 Data collection
Technical process flow diagram		No	These are judged unnecessary from the purpose and goal of this case study.
Unit process description		No	
Calculation procedure	Yes		1.2 The input-output analysis approach 2.2 Data calculation
Allocation procedure including the handling of multi functionality			Not applicable
Data quality			2.1 Data collection GHG emissions in use stage were evaluated with the following power consumption in a year. August 2014 – December 2014: measured January 2014 – July 2014: estimated with capacity profile (Characteristic curve of outside temperature and COP), etc.
Data gap			Not applicable within the studied system boundary
Environmental impact assessment			
Assessment results	Yes		3.1 Results
Normalization (optional)			Not applicable
Weighting (optional)			Not applicable
Interpretation			
Uncertainty aspects including results from sensitivity analyses	Yes		3.2 Sensitivity analysis
Conclusion including identification of hot spots	Yes		3 Results and conclusion of the evaluation

Table L.2 shows the reporting format as presented in [ITU-T L.1410] for included life cycle stages, activities and generic processes. Table L.2 to Table L.9 have been completed from the viewpoint of the hybrid approach employed in this case study.

Table L.2 of ITU-T L.1410 – Reporting format for included life cycle stages, activities and generic processes

Tag	Life cycle stage/ Process	Unit process	Included (Yes/No)	Electricity mix (specific/ country/ world average)	Support activities included (Yes/No)	Transport activities included (Yes/No) G1	Other generic activities included (Yes/No) G2-7	Motiva-tion/ Comment
A	Goods Raw Material Acquisition							
A1	Raw material extraction		Yes (IOA based)					
A2	Raw material processing							
B	Production							
B1	ICT goods production		Yes (IOA based)					
B1.1		Parts produc-tion (for further details refer to Annex E)						
B1.2		Assembly						
B1.3		ICT manufac-turer support activities						
B2	Support goods production		No, because this is common item which will not impact the comparative analysis					
B2.1		Support goods manufacturing	No, because this is common item which will not impact the comparative analysis					
B3	ICT-specific site construction		Yes (secon-dary process-sum data)	CO2 emissions intensity user end electricity averaged 12 electric power companies including distribution loss in FY 2013	Yes	Partially yes (Min transports included but not mainte-nance transports)		
C	Use							
C1	ICT goods use		Yes	CO2 emissions intensity user end electricity averaged 12 electric power companies, including distribution loss in FY 2013	Yes	No, because this is common item which does not impact the compara-tive analysis	No, because this is common item which does not impact the compara-tive analysis	
C2	Support goods		No, because this is common item which does not impact the comparative					

Table L.2 of ITU-T L.1410 – Reporting format for included life cycle stages, activities and generic processes

Tag	Life cycle stage/ Process	Unit process	Included (Yes/No)	Electricity mix (specific/ country/ world average)	Support activities included (Yes/No)	Transport activities included (Yes/No) G1	Other generic activities included (Yes/No) G2-7	Motiva-tion/ Comment
	use		analysis					
C3	Operator support activities		Yes	Not used	No	No	No	
C4	Service provider support activities		No, because this is common item which does not impact the comparative analysis					
D	Goods end-of-life treatment							
D1	Preparation of ICT goods for reuse		No, because this is common item which does not impact the comparative analysis					
D2	ICT-specific EoLT							
D2.1		Storage/ Disassembly/D ismantling/ Shredding	IOA based					
D2.2		Recycling						
D3	Other EoLT		IOA based					

Table L.3 shows the reporting format completed for generic processes for LCAs of ICT goods.

Table L.3 of ITU-T L.1410 – Reporting format for generic processes for LCAs of ICT goods

Generic process	Generic process categories included	Unit processes included (for each generic process category)	Important issues
G1. Transport and travel	IOA based		
G2. Electricity	Japan electricity mix	Including distribution losses and fuel supply chain as well as direct emissions	
G3. Fuels	IOA based		
G4. Other energy	Not applicable		
G5. Raw material acquisition	IOA based		
G6. End-of-life treatment	IOA based		
G7. Raw material recycling	IOA based		

Table L.4 shows the reporting format completed for transport/travel.

Table L.4 of ITU-T L.1410 – Reporting format for transport/travel

Mode	**CO_2e emission factor (see Note 4)**	**Raw material acquisition transport**		**Production stage transport excluding final transport**		**Final transport (see Note 1) (production to use stage)**		**Use stage transport**		**EoLT transport**		**Total transport**		**Total travel (see Note 6)**	
		Transport work (see Note 2) {tonne× km}	GWP100 {kg CO_2e} (see Note 7)	Transport work {tonne× km}	GWP100 {kg CO_2e}	Transport work {tonne× km}	GWP100 {kg CO_2e}	Transport work {tonne× km}	GWP 100 {kg CO_2e}	Transport work {tonne× km}	GWP 100 {kg CO_2e}	Transport distance (see Note 3) {km}	GWP100 {kg CO_2e}	Travel distance {km}	GWP100 {kg CO_2e}
IOA based – all transports except for final distribution and maintenance intended to be included. See cut-off clause 1.5.4 for details.															
NOTE 1 – The final transport of ICT goods from assembly to operator, including pre- and post-transport connected to the main transport. NOTE 2 – Average in terms of distance, transport mode, load factor, chargeable mass, etc. NOTE 3 – Average in terms of distance, transport mode, load factor, chargeable mass, etc. NOTE 4 – This includes direct fuel consumption and also fuel supply chain. NOTE 5 – Specify used transport mode. NOTE 6 – Includes all kinds of travel throughout life cycles, e.g., commuting, business travel and maintenance travel when applicable. Specify travels taken into account. NOTE 7 – Other impact categories to be added as applicable.															

Table L.5 shows the reporting format completed for raw materials.

Table L.5 of ITU-T L.1410 – Reporting format for raw materials

	Total input (g, kg, tonne)	**Content in product (see Note 1) (%)**	**Recycled raw material used (see Note 2) (%)**	**Recycling of total input (see Note 3) (%)**	**Reference**
Iron/Steel alloys	Included (IOA based) NOTE – Non-domestic part is quite significant				
Aluminium alloys					
Copper alloys					
Silver					
Gold					
NOTE 1 – Percentage of total input material present in the product after the production process, i.e., total input minus the related production waste. NOTE 2 – The amount of recycled raw material used in the production process, this include the raw material contained in the product and the related production waste. NOTE 3 – Total recycling of all input materials, i.e., recycling of manufacturing waste and recycling of total content in final product during EOL.					

Table L.6 shows the reporting format completed for parts production.

Table L.6 of ITU-T L.1410 – Reporting format for parts production

	Part categories included (see Note 1)	**Part unit processes included (see Note 1)**	**Handling of special issues (see Note 2)**
B1.1.1 Batteries	Included (IOA based)		
B1.1.2 Cables			
B1.1.3 Electro-mechanics			
B1.1.4 Integrated circuits (ICs)			
B1.1.5 Mechanics / materials			
B1.1.6 Displays			
B1.1.7 Printed circuit boards (PCBs)			
B1.1.8 Other PBA components			
B1.1.9 Packaging materials			
B1.1.10 Black box modules			
NOTE 1 – Annex E of [ITU-T L.1410] gives a list of part categories and part unit processes which shall be included when applicable. NOTE 2 – Include description of data source and data set for each part category, e.g., from commercial databases.			

Table L.7 shows the reporting format completed for use stage energy consumption.

Table L.7 of ITU-T L.1410 – Reporting format for use stage energy consumption

	Energy consumption {kWh/year}	Source {long term average/ standardized measurement/ modelled}	Motivation/comment
Reference ICT product system	324,068.7	Standardized measurement. (Partially estimated with the capacity profile.) The details are shown in the footnotes in Table 2-3.	The emission factor for the used electricity mix is 0.57 $kgCO_2e/kWh$. It is based on the report of the Federation of Electric Power Companies of Japan. http://www.fepc.or.jp/english/index.html
Target ICT product system	143,060.8	Modelled with average COP etc. The details are shown in the footnotes in Tables 2-1 and 2-2.	

Table L.8 shows the reporting format completed for the end-of-life treatment (EoLT) stage.

Table L.8 of ITU-T L.1410 – Reporting format for EoLT stage

	Process categories included	Process unit processes included	Handling of special issues
D1. Preparation for reuse of ICT goods	Not included		
D2. ICT-specific EoLT	IOA based		
D3. Other EoLT			
NOTE – Annex F of [ITU-T L.1410] gives a list of process categories and unit processes which shall be included when applicable.			

Table L.9 shows the reporting format completed for LCI results.

Table L.9 of ITU-T L.1410 – Reporting format for LCI results

		TOTAL	Raw materials acquisition and production	Use	EoLT
Primary energy use (see Note 1)	Reference ICT product system	Not separative	IOA based	Not considered because the item is common and does not impact the comparative analysis	IOA based
	Target ICT product system	Not separative	IOA based	Not considered because the item is common and does not impact the comparative analysis	IOA based
Total electricity use (see Note 2)	Reference ICT product system	Not separative	IOA based	324,068.7 {kWh/year}	IOA based
	Target ICT product system	Not separative	IOA based	143,060.8 {kWh/year}	IOA based

Table L.9 of ITU-T L.1410 – Reporting format for LCI results

		TOTAL	Raw materials acquisition and production	Use	EoLT
NOTE 1 – The comparative analysis was performed by hybrid LCA method with 3EID (Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables)*1. Therefore the impact of primary energy use in raw material acquisition and production (RMA&P) and EoLT stages is included in the results, but they cannot be separated. The primary energy in use stage is only electricity and shown in Total electricity use. NOTE 2 – The electricity in use stage was measured. The impact of electricity use in RMA&P and EoLT stages is included in the results, but they cannot be separated. *1 http://www.cger.nies.go.jp/publications/report/d031/eng/page/what_is_3eid.htm					

Table L.10 of ITU-T L.1410 (Impact category indicators) is not applicable because only CO_2 emission is considered in this case study.

Tables L.11 (Reporting format for network description), L.12 (Reporting format for network energy consumption) and L.13 (Reporting format for service hardware allocation) of ITU-T L.1410 are not applicable because the network is outside the boundary in this case study.

Appendix II

Compliance towards [ITU-T L.1410]

Table XII.1 as presented in Appendix XII of [ITU-T L.1410] has been completed from the viewpoint of the hybrid approach employed in this case study.

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
Introduction	Deviation(s) from the requirements shall be clearly motivated and reported.	YES		
5.2	Full compliance to this Recommendation can be claimed if all mandatory requirements are fulfilled.		NO	The hybrid approach allows for partial compliance only
5.3	A third-party review is also needed if the comparison result is to be externally communicated.	YES		
5.3	In case of comparative assessment between ICT goods LCAs the operating lifetime shall be set to equal			Lifetime of each equipment is set according to the "Statutory useful life time in Japan"
6.1	The requirements of this Recommendation shall apply as well as those of [ISO 14040] and [ISO 14044].	YES		
6.1.1	The following four high-level life cycle stages (RMA, P, U, EOLT) shall apply to ICT goods, networks and services and shall be assessed as applicable in LCAs based on this Recommendation in accordance with the goal and scope.	YES		
6.1.1	Table 2 in clause 6.2.3.1 defines the detailed life cycle stages which further defines the system boundary and which are to be considered when assessing the life cycle impact of ICT goods, networks and services. In particular, it is important to cover all processes whose relevance is marked as mandatory in that table.	YES		Tables 1-4 and 1-5
6.1.1	The data collected shall be structured in such a way that the GHG emissions and energy consumption/environmental impact arising from the transport processes could be reported transparently as far as possible.		NO	Not possible when using IOA data
6.1	Transport and energy supplies shall be included in all life cycle stages.	YES		
6.1	At the time of publication, to collect appropriate data related to raw materials transport and to separate data related to raw material acquisition stage and production stage is considered challenging due to LCA tool limitations, lack of data, limitations in data granularity and the nature of ICT supply chains. Deviation(s) from this requirement shall be clearly motivated and reported.		YES	IOA based
6.1	Instances of transport of goods between production and use stages shall be taken into account.	YES		IOA based
6.1.2	The ICT goods, networks and services product system to be	YES		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
	assessed shall be clearly described as well as relevant functions and characteristics.			
6.1.2.1	For the ICT good under study, applicable types of parts, as well as amounts of these, shall be defined.	YES		IOA based
6.1.2.2	In the goal and scope phase it shall be outlined which network building blocks are covered.	NA		Network is out of boundary
6.1.2.2	For the ICT network under study, applicable types of nodes and infrastructure, as well as amounts of these, shall be defined.	NA		Network is out of boundary
6.1.2.3	For the ICT service under study, applicable types of ICT network elements and infrastructure, as well as amounts of these, shall be defined.	NA		Service is out of boundary
6.1.3.1	Software shall be considered as well as hardware.	YES		IOA based – software included to some extent but software is not differing between the systems
6.1.3.1	For specific software applications, such as music distribution applications, the software is to be seen as an ICT service and shall be assessed according to the requirements outlined for services.	NA		Service is out of boundary
6.1.3.1	In these cases the hardware needed to operate the software shall be considered as well.	NA		Out of boundary because of common item
6.1.3.1	For users of generic operating systems embedded in products, the life cycle impact of usage of this software may be considered as negligible. However, for the developer of this software the impact of the usage of this software shall be taken into account.	NA		
6.1.3	Operating lifetime is critical for the interpretation of the results of LCAs and shall therefore always be reported when presenting LCA results.	YES		
6.1.3	Operating lifetime estimates and assumptions shall also be clearly described in the reporting.	YES		
6.2.1	During the LCA scoping phase the building blocks of the ICT goods, networks or services shall be identified.	YES		
6.2.2.1	The functional unit shall be chosen in accordance with the goal and scope of the LCA.	YES		
6.2.2.1	The functional unit requires inclusion of the relevant quantifiable properties and the technical/functional performance of the system. This means that the operating lifetime of all included ICT goods shall be specified.	YES		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
6.2.2.1	The number of users/subscribers supported by the network and the traffic profile shall be included where applicable.	NA		Network is out of boundary and these parameters do not differ between the systems.
6.2.2.1	The functional unit shall be clearly defined and measurable.	YES		
6.2.2.1	The reference flow shall reflect the functional unit chosen.	YES		
6.2.2.2	The functional unit shall be chosen in the context of goal and scope of the LCA and shall be further clarified by system boundary and cut-off rules.	YES		
6.2.2.2	To comply with this Recommendation, the following functional unit shall be applied where applicable. annual ICT goods use (per one year of ICT good use), or total ICT good use per lifetime of ICT good.	YES		
6.2.2.2	For relevant LCA results, realistic use scenarios shall be captured.	YES		
6.2.2.3	ICT networks can be seen as a system composed of different types of ICT goods. For the purposes of this Recommendation, the following functional unit shall be applied where applicable for ICT networks used during at least one year: • annual network use.	NA		Network is out of boundary
6.2.2.3	For relevant LCA results, realistic use scenarios shall be captured.	NA		
6.2.2.4	For the purposes of this Recommendation, the following functional unit shall be applied where applicable. annual service use.	NA		Network is out of boundary
6.2.2.4	For relevant LCA results, realistic use scenarios shall be captured.	YES		
6.2.2.4	Corresponding realistic use scenarios shall be defined.	YES		
6.2.2.4	The annual service use shall be defined with respect to the usage scenario to make it possible to define the reference flow.	YES		
6.2.3.1	The selection of the system boundary shall be consistent with the goal of the study.	YES		
6.2.3.1	Consequently, the system boundaries here define the life cycle stages and the unit processes that shall be taken into account in an LCA of an ICT product system.	YES		
6.2.3.1	Table 2 includes further details of the life cycle stages to be included in LCAs of ICT goods, networks and services. The different life cycle stages are further described in clauses 6.2.3.4.2 to 6.2.3.4.5. Mandatory in Table 2 means that the life cycle stage shall be included.	YES		IOA based
6.2.3.1	Mandatory life cycle stages or unit processes shall not be cut-off before considered for inclusion by using alternative data.	YES		IOA based
6.2.3.1	In Table 2 "Mandatory" means that the life cycle stage, if applicable to the studied product system, shall always be taken into account in an LCA for ICT.	YES		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
6.2.3.3.1	In order to set the system boundary of ICT goods the life cycle stages listed in clause 6.1.1 shall be detailed.	YES		IOA based
6.2.3.3.1	As stated in clause 6.1.3, the environmental impact from both hardware and software shall be considered, if applicable.	YES		
6.2.3.3.1	For the ICT good under study, applicable types of parts, as well as amounts of these, shall be defined.	NA		IOA based
6.2.3.3.2	Annex H (Table H.1) provides a mandatory set of raw materials (both ICT-specific and generic) which shall be included in the LCA of ICT goods.	NA		IOA based
6.2.3.3.3	Annex E lists a mandatory set of parts to be included where applicable to the studied ICT product system, when performing an LCA of ICT goods, as well as mandatory part unit processes which shall be included for each part.	NA		IOA based
6.2.3.3.3	As an example, if batteries are part of the studied ICT goods product system they shall be included within the system boundary, and for every battery the Battery Cell manufacturing and Battery module manufacturing shall be included.	YES		
6.2.3.3.3	Assembly (B1.2) shall include as minimum PCBA module assembly, final assembly, warehousing, and packaging.	YES		IOA based
6.2.3.3.3	In case support goods are part of the studied product system, support goods Production (B2) is mandatory.	NA		Out of boundary because not relevant to the comparison
6.2.3.3.3	Support goods (B2.1) which shall be included if applicable to the studied product system are at least air conditioners, cables, and power supply systems.	YES		
6.2.3.3.3	As stated in Table 2 Construction of ICT-specific site (B3) is mandatory if the ICT-specific site is included in the studied product system.	NA		Out of boundary because not relevant to the comparison
6.2.3.3.3	Site building blocks to be included in B3.1, if they are applicable to the studied product system, are antenna towers, fences and shelters.	NA		Out of boundary because not relevant to the comparison
6.2.3.3.4	Raw material acquisition and Production for the additional PCBAs used during the operating lifetime of the ICT goods are mandatory.	YES		IOA based
6.2.3.3.5	As shown in Figure 11, Preparation of ICT goods for reuse of ICT goods (D1), ICT-specific EoLT (D2) and Other EoLT (D3) are within the mandatory system boundary for EoLT.	YES		IOA based
6.2.3.3.5	Annex F lists a mandatory set of EoLT processes to be included where applicable when performing an LCA of ICT goods which includes the EoLT stage.	YES		IOA based
6.2.3.3.5	It is thus recognized that compliance to all requirements in Annex F may not be possible at the time this Recommendation is published. Deviation(s) from the requirements shall be clearly motivated and reported.	YES		
6.2.3.4	The network shall be defined in terms of ICT goods, Support goods and ICT infrastructure (e.g., cables duct).	NA		Network is out of boundary

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
6.2.3.4	For each included product types, the number of units shall be defined as well as their corresponding lifetimes.	NA		
6.2.3.4	For the assessment of networks, operator activities shall always be included.	NA		Network is out of boundary
6.2.3.5.1	In addition to the use of ICT goods and networks, an ICT service may also have additional impacts associated with application software development, use of consumables, infrastructure for sales and logistics, associated travel and transport (in addition to those already included for the ICT goods and networks) which shall also be included as appropriate.	NA		Service is out of boundary
6.2.3.5.1	The impact of the data centres where the service is operated shall be assessed.	YES		
6.2.3.5.1	The data centre shall be studied and assessed in the same way as other ICT goods.	YES		
6.2.3.5.1	The system boundary of the ICT services provided by the ICT network shall be established based on either the actual use scenario of the ICT services, if available, or on an estimated use scenario,	NA		Service is out of boundary
6.2.3.5.2	Energy consumption, material inputs and environmental releases shall be assessed in accordance with the system boundary.	YES		
6.2.4	Cut-offs shall be avoided as far as possible.	YES		
6.2.4	[ISO 14044], clause 4.2.3.3 recommendations shall be used as closely as possible.	YES		
6.2.4	All cut-off criteria stated by [ISO 14040] and [ISO 14044] are to be considered before cut-off of a certain process – and the process shall be included if significant to at least one criterion.	YES		Not possible to analyse fully for IOA
6.2.4	The intention of the present standard is to include all mandatory activities of Table 2. If these activities are not included such cut-offs shall be clearly motivated.	YES		
6.2.4	Any cut-off made shall be clearly described and documented.	YES		
6.2.5.1	A qualitative description of the data quality and any efforts taken to improve it shall be disclosed while considering the following data quality indicators: Methodological appropriateness and consistency Completeness (total LCA level) Uncertainty Data representativeness Data age (timeliness) Acquisition method Supplier independence Geographical correlation Technological correlation Cut-off rules (rules of inclusion/exclusion)	YES		To the extent possible for IOA approach

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
6.2.5.1	In selecting emission factors for use in calculating GHG emissions under this methodology the following guidance shall be followed: Emission factors used should be the most up to date from publicly available sources.	YES		
6.2.5.1	Where emission factors are sourced from non-public sources, or are not the most up-to-date ones, a justification for their use shall be provided.	YES		
6.2.5.1	The specific GWP values used shall be those taken from the latest UN IPCC reports. For further guidance see Table XI.1.	NA		IOA based (CO_2 only)
6.2.5.2	In general, data age and technology are especially important in LCAs for ICT goods, networks and services due to the fast technology evolution and the growth in network traffic. e.g., for data traffic, up-to-date figures shall always be used.	NA		
6.2.5.2	For support activities (e.g., ICT manufacturer support activities and operator support activities) primary data shall be used for all individual processes under the financial or operational control of the organization undertaking the LCA	NA		IOA based
6.2.5.2	… and data shall be representative of the processes for which they are collected.	YES		IOA based
6.3.1.1	Data shall be collected for each unit process that is included within the system boundary in accordance with Annex B.	YES		IOA based
6.3.1.1	Data shall be collected for all mandatory processes outlined in Table 2.	YES		
6.3.1.1	When data has been collected from public sources, the source shall be referenced.	YES		
6.3.1.2	Data shall be collected at least for the processes marked with mandatory in Table 2, unless these are found negligible in accordance with the cut-off rules.	YES		IOA based
6.3.1.2.1	It should be noted that, for many products (especially end-user goods), periods of idling and power off may be significant and are important to consider when modelling the traffic profile/ model the usage profile and shall be included if applicable.	Partially		Idling and power off of servers are considered whereas end-user goods are outside of boundary because of common item
6.3.1.4	Use time, goods type, data traffic and network access type give important statistical data that needs to be collected in order to quantify the use of ICT systems.	YES		
6.3.1.2.3	When calculating the potential environmental impact the LCA practitioner is encouraged to use the most accurate data for the energy mix that is applicable to the ICT goods under assessment. Particularly the use stage shall use the applicable electricity mix to calculate the potential environmental impact from the use stage more exactly.	YES		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
6.3.2.1	The general requirements for data calculations in [ISO 14040] and [ISO 14044] shall be applied.	YES		
6.3.2.1	All calculation procedures shall be explicitly documented and the assumptions made shall be clearly stated and explained.	YES		
6.3.2.1	The same calculation procedures shall be consistently applied throughout the study.	YES		
6.3.2.1	A check on data validity shall be conducted during the process of data collection to confirm that the data quality requirements for the intended application have been fulfilled.	YES		
6.3.2.3	The evaluation of the environmental load shall consider both a fixed part which is independent of the usage and a variable part which correlates to the usage.	NA		Outside of boundary because of common item
6.3.3.1	The same allocation method shall be used for all environmental loads for all products from a common process.	NA		Outside of boundary because of common item
6.3.3.1	The study shall identify the processes shared with other product systems and deal with them according to the stepwise procedure presented below.	NA		Outside of boundary because of common item
6.3.3.2	Data for generic processes (G1 to G7) shall be allocated as a whole (i.e., for the full life cycle for the generic process) to the associated life cycle stage of the product system.	YES		
6.3.3.2	However all Raw material acquisition (G5) shall be allocated to the life cycle stage Raw material acquisition (A).			IOA based (RMA and P are combined)
6.3.3.3	Data for relevant part of the organization/operation shall be allocated to the relevant part of the project/product system life cycle.	NA		IOA based
6.3.3.3	If no detailed information on organization/operation is available the allocation shall be based on organizational/economic data.	NA		IOA based
6.3.3.8	End-user goods (e.g., PCs, smart phones) which are accessing more than one ICT network (e.g., 3G, WLAN) shall be allocated to these ICT networks based on use time.	NA		Outside of boundary because of common item
6.3.3.8	The assumptions regarding use time for access to different ICT networks and off line work shall be described and motivated.	NA		Outside of boundary because of common item
6.3.3.8	Impact from shared network resources (e.g., transmission goods, core nodes and data centres) shall be allocated to an access network based on data traffic.	NA		Network is outside of boundary

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
6.3.3.8	The assumptions regarding data traffic shall be described and motivated.	NA		Outside of boundary because of common item
6.3.3.9	The impact from each ICT network supporting the service should be allocated to the service based on access use time or data traffic. More specifically, the following allocation principle of ICT network data to an ICT service shall be used: Data for end-users goods: to be allocated based on active use time of the ICT service. etc.	NA		Outside of boundary because of common item
6.3.3.9	Data traffic is also preferred for e.g., mobile access networks as mobile access networks show a large dependency between data traffic and energy consumption and need a traffic model that takes data traffic into account	NA		Network is outside of boundary
6.3.3.9	Data for data centres and service provider activities: The data centre(s) where the ICT service is operated as well as the service provider activities shall be allocated based on number of subscriptions and service users or amount of data/transactions.	YES		
7	ISO states that the selection of impact categories shall reflect a comprehensive set of environmental issues related to the product system being studied, taking the goal and scope into consideration.	YES		
7	In the LCA it shall be ensured that the inventory elementary flows (see Annex G are correctly linked with appropriate LCIA characterization factors.	NA		
7	For climate change, the most recent global warming characterization factors from the Intergovernmental Panel on Climate Change (IPCC) for each GHG shall be used and the timeframe should be 100 years.	NA		CO_2 only
7	The midpoint category Climate change is mandatory.	YES		
7	For other impact categories there is no methodological consensus in the LCA community, thus the practitioner shall decide which impact categories to consider and how to calculate them, based on the studied ICT product system and purpose of the LCA study.	NA		
7	All impact categories and category indicators included shall be disclosed (Table L.10) and justified.	YES		
8.2	The sources of uncertainty and methodological choices made shall be assessed and disclosed.	YES		
8.3	The results of the LCI or LCIA phases shall be interpreted according to the goal and scope of the study.	YES		
8.3	The interpretation shall include a sensitivity check of the significant inputs, outputs and methodological choices, and defined use scenarios, in order to understand the uncertainty of the results.	YES		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
9.1	The reporting of ICT product systems shall fulfil the reporting rules as defined by [ISO 14040] and [ISO 14044].	YES		
9.1	In the case of reporting, a public GHG inventory report, the key accounting principles (relevance, accuracy, completeness, consistency, and transparency) shall be met.	YES		
9.1	In addition to the reporting obligations outlined by [ISO 14040] and [ISO 14044], the report shall include the following information: • contact information • studied goods, networks and services product system name and description • type of inventory (i.e., final product cradle-to-grave or intermediate product cradle-to-gate inventory) • goals of the study. The reporting of results shall include: • total GHG emissions reported as amount of CO2e per functional unit for ICT good, network and service that have been assessed • percentage for each life cycle stage contributing to the total results • electricity (with use stage separated from the other stages) • primary energy[1] • fuels • value and sources of emission factors for CO2 and CO2e, and Global Warming Potential (GWP) metric used in the report • other data, justifications and explanations as stated throughout this report.	YES		
9.1	In addition the rules outlined in this clause and what is stated in Annex L shall be followed for reporting of studies claiming compliance with this Recommendation.	YES		
9.1	The report shall contain a compliance statement saying either that the LCA fully complies with this Recommendation (in case of full compliance) or that the LCA partially complies with this Recommendation with the exceptions transparently listed and justified (partial compliance).	YES		
9.1	The extent to which support activities and other optional/recommended activities are excluded for different parts of the life cycle shall be clearly described and for recommendations also motivated in the study report.	NA		

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

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
9.1	For each product system (including ICT goods, networks and services) the following aspects, being of special importance to ICT applications, shall be transparently motivated and described in accordance with the principles defined in this clause: Operating lifetime: All lifetime assumptions shall be stated and motivated.	YES		
9.1	Cut-off: Any cut-off made shall be clearly stated and motivated.	YES		
9.1	Allocations: Basis for allocations made shall be described, especially for recycling, use of recycled materials, distribution of facility data and support activities.	NA		
9.1	Data sources: Data sources (i.e., specific/generic) shall be clearly stated, and deviations from Table 2 shall be motivated.	YES		
9.1	For each product system (including ICT goods, networks and services) an additional diagram shall be presented whenever optional activities in Table 2 have been included.	NA		
9.1	The emission factors used shall be clearly stated. The source used and the year they represent shall be clearly stated.	YES		
9.1	In the case of emission factors for grid electricity the source, year and location (specific, country, global average) shall be clearly stated.	YES		
9.1	Where emission factors are sourced from non-public sources, or are not the most up-to-date ones, a justification for their use shall be provided.	NA		
9.2.1	For each impact category studied, diagrams corresponding to Figures 14a and 14b shall be reported for the corresponding category indicator result.	YES		
9.2.1	Due to the importance of operating lifetime to results, information regarding this shall always be present in the diagram, together with some other basic modelling statements including total result for the indicator, LCA study year operating lifetime, etc. as shown below.	YES		
9.2.1	Figure 14b shall be presented whenever optional activities/processes from Table 2 have been included in the studied product system.	YES		
9.2.1	For transport, the total result including all transport throughout the life cycle (Table L.4) shall be stated in the immediate proximity of the diagram (Figures 14a and 14b).	NO		Not possible with the IOA approach
9.2.1	If used data sets do not report transport separately any missing transport shall be listed and motivated.	YES		
9.2.1	Figure 16 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal".	YES		
9.2.1	A diagram summarizing distribution of selected environmental impact category indicators between life cycle stages shall be prepared together with absolute figures as shown in the Annex L (Table L.10).	YES		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
9.2.1	A diagram summarizing distribution of selected environmental impact category indicators between life cycle stages shall be prepared together with absolute figures as shown in the Annex L (Table L.10).	YES		
9.2.1	Figure 18 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal". See further explanation in the scope.	NA		
9.2.2.1	Any deviation from Table 2 and clause 6.2.3 with respect to mandatory life cycle stages/unit processes shall be clearly stated and motivated.	YES		
9.2.2.1	Additionally, inclusion of generic processes for the different life cycle stages shall be clearly stated and reported.	YES		IOA based
9.2.2.1	Deviations for Generic processes shall be reported according to Table L.3.	YES		IOA based
9.2.2.2	The use of raw materials shall be transparently reported as outlined below.	YES		IOA based
9.2.2.2	The most important metals from recycling point of view shall always be included. For an appropriate reporting format refer to Annex L (Table L.5.)	YES		
9.2.2.2	Deviation(s) from the requirements shall be clearly motivated and reported.	YES		
9.2.2.3.1	Compliance to Annex E (Table E.1) shall be reported and any deviation shall be described and motivated. For an appropriate reporting format refer to Table L.6.	YES		
9.2.2.4.1	Compliance to Annex E (Table E.1) shall be reported and any deviation shall be described and motivated. For an appropriate reporting format refer to Table L.6.	YES		
9.2.2.4.1	The model of distribution over time of different usage modes including power off and idle and the rationale for those shall be transparently reported. For an appropriate reporting format refer to Annex L (Table L.7.)	NA		
9.2.2.4.2	The rationale for the energy consumption values for the support goods use shall be transparently described and motivated. For an appropriate reporting format refer to Annex L (Table L.7.)	YES		
9.2.2.5	If EoLT is included any deviations from Annex F shall be transparently reported and motivated. For an appropriate reporting format refer to Annex L (Table L.3.)	YES		
9.2.3	For LCI the following items shall be reported transparently: total use of primary energy and electricity.	YES		
9.2.3	Additionally, results for elementary flows according to Annex G (Table G.1) could be transparently reported on an optional basis. If such reporting is not made it is mandatory to describe unexpected results, lack of data, and other findings associated with the elementary flows.	NA		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
9.3.1	Operating lifetime is important also for networks, but is associated with the lifetime of the different nodes, which shall be reported.	NA		
9.3.1	It shall be reported following the format of Annex L (Table L.11) which also describes the studied network.	NA		
9.3.1	Figure 18 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal".	NA		
9.3.1	Additionally a diagram summarizing distribution of environmental impact category indicators between life cycle stages shall be prepared together with absolute figures as shown in the Annex L (Table L.10).	YES		
9.3.1	Figure 19 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal".	NA		
9.3.1	Details of network energy consumption shall be reported with a split of different elements of the network. An example of Table for Reporting is provided In Table L.12.	NA		
9.4.1	Operating lifetime is important also for services, but it is associated with the lifetime of the different nodes, which shall be reported.	NA		
9.4.1	Allocation of network data to the service shall be reported. It should be reported according to Annex L (Table L.13).	NA		
9.4.1	Additionally a diagram summarizing distribution of impact category indicators between life cycle stages for the service product system under study shall be presented together with absolute figures as shown in the Table L.10.	YES		
9.4.1	Figure 22 shall be accompanied by the disclaimer "This LCA result cannot be compared to the result of another LCA unless all assumptions and modelling choices are equal".	NA		
10	Any critical review shall be performed according to the requirements of [ISO 14040] and [ISO 14044] and in this Recommendation.	YES		
10	The scope and type of critical review desired shall be defined in accordance with [ISO 14044] clauses 4.2.3.8 and 6.	YES		
11.1	Infrastructure, e.g., highways for transportation, is generally assumed to exist independently of introduction of new services and shall be excluded.	NA		
11.1	The handling of time perspective and scale shall be disclosed and motivated in the report.	YES		
11.1	To be able to quantify the net environmental impact when introducing an ICT based service the environmental impact of both the ICT service itself and of the reference product system need to/shall be assessed from a life cycle perspective.	YES		
11.1	To make sure that the comparative assessment gives a relevant result, the full life cycle of both systems shall always be considered	YES		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
11.1	From an LCA perspective the reference product system and the ICT service based system shall mimic each other as far as possible	YES		
11.1	and the practitioner shall model both systems in an unbiased way.	YES		
11.2	Goods shall be compared with other goods,	YES		
11.2	ICT networks shall be compared between themselves.	NA		
11.2	ICT services shall be compared between themselves.	NA		
11.3.1	In this comparative LCA study, the scope of the LCA study shall be defined in such a way that the two systems can be compared.	YES		
11.3.1	Systems shall be compared using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures and cut-off rules.	YES		
11.3.1	Any differences between systems regarding these parameters shall be identified and reported.	YES		
11.3.2	Also in this case, the scope of the LCA study shall be defined in such a way that the two systems can be compared.	YES		
11.3.2	Both systems shall be assessed using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures and cut-off rules.	YES		
11.3.2	Any differences between systems regarding these parameters shall be identified and reported.	YES		
11.3.3	The assessment of the ICT based system shall be performed in accordance with Part I.	YES		
11.3.3	When making comparisons, it is important to keep in mind that the functional unit used shall be applicable to both the reference product system and the system of ICT goods, networks and services.	YES		
11.3.3	For the reference product system applicable requirements in this Recommendation shall be applied, e.g., requirements regarding data quality, cut-off etc.	YES		
12.2	All the requirements stipulated in Part I for a system boundary definition shall be applied.	YES		
12.2.1	The functional unit shall take into account the general rules outlined in Part I, clause 6.2.2 "Functional unit" and [ISO 14044] clause 4.2.3.2.	YES		
12.2.1	Additionally, the functional unit shall be defined so that it is applicable both to the ICT goods, networks and services product system and the reference product system.	YES		
12.2.1	The reference flow shall be defined to quantify the functional unit.	YES		
12.2.1	In other words, for the functional unit of one meeting, for instance, the reference flow for the systems of ICT goods, networks and services and the reference product system shall be defined.	YES		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
12.2.2	Two different system boundaries shall be defined which are applicable for the ICT goods, networks and services product system and for the reference product systems respectively.	YES		
12.2.2	Considerations shall be made to which electricity is used when assessing the environmental impact of the ICT goods, networks and services product system and the reference product systems.	YES		
12.3	The calculation for the inventory analysis shall be performed in accordance with Part I, clause 6.3.	YES		
12.4	The calculation for the inventory analysis shall be performed in accordance with Part I, clause 6.3.	YES		
13	Any cut-off made during a study shall be clearly stated in the study report, e.g., the exclusion of life cycle processes which are considered insignificant should be justified.	YES		
Annex B	A mandatory list of generic activities (unit processes) that have been found to be of importance for LCA of ICT goods, networks and services can be found in Annex D.	NA		IOA based
Annex B	The following emissions shall be taken into account if applicable to the studied impact category(ies): emissions to air emissions to water emissions to soil.	NA		
Annex B	The following resource objects shall be taken into account if applicable to the studied impact category(ies): material resource use (or material depletion) energy resource use (or energy resources depletion).	NA		IOA based
Annex B	A list of emissions and resource objects that shall be included, if applicable to the studied product system and impact category(ies), can be found in Annex G (Table G.1).	NA		
Annex B	Furthermore, the following inputs shall also be included if applicable to the studied impact category(ies): electricity; other forms of delivered energy (district heating and cooling); fuels (typically indicates the fuels are incinerated on-facility or in a vehicle connected to the facility); primary products (products that are part of the final product in operation); secondary products (products that are not part of the final product in operation) transport, travel, and other services (can be seen as a special non-material secondary product input).	YES		IOA based
Annex B	Finally, the following flows shall also be included if applicable to the studied impact category(ies): water discharge (to municipal sewage or recipient); waste fractions (residual waste fractions or waste fractions that need further treatment, also including material recycling and energy recovery); product output (the main purpose with the unit process or activity).	NA		

Table XII.1 of ITU-T L.1410 – Summary of the requirements of [ITU-T L.1410]

Clause in [ITU-T L.1410]	Requirement	Fulfilled	Not fulfilled	Explanation/ Motivation if not compliant
Annex C	Any support activities included in the LCA scope shall be clearly reported in terms of organization activities considered.	NO		
Annex C	G7….Other material shall be considered	NA		
Annex E	Table E.1 lists the applicable parts and assembly types which shall be taken into account when performing an LCA of ICT goods, if applicable to the ICT good (not ICT network). It also lists the corresponding part and assembly categories and unit processes.	YES		IOA based
Annex G	Table G.1 contains elementary flows which shall be taken into account in LCA analyses for ICT.	YES		IOA based
Annex G	The substance names listed in Table G.1 shall be used in the report.	NA		
Annex G	Deviation(s) from the requirements shall be clearly motivated and reported.	YES		
Annex H	Table H.1 lists the minimum raw materials groups (chemicals, fuels, metals, plastics, packaging materials, and additives) which shall be taken into account in LCAs of ICT goods, if applicable to the studied ICT product system.	YES		IOA based
Annex L	This annex contains tables that shall be used to report the result of the assessment.	YES		
Annex L	Deviation(s) from the requirements shall be clearly motivated and reported.	YES		

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