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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

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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.

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

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

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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: 1 Agriculture, forestry and fishery	2 Mining	3 Manufacturing	Total	Final demand: Consumption expenditure outside households	Expenditure	Fixed capital formation	Increase in stocks	Exports	Total	(Less) Import	Domestic production
					A						B	C	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.

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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.

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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

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*.		

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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.

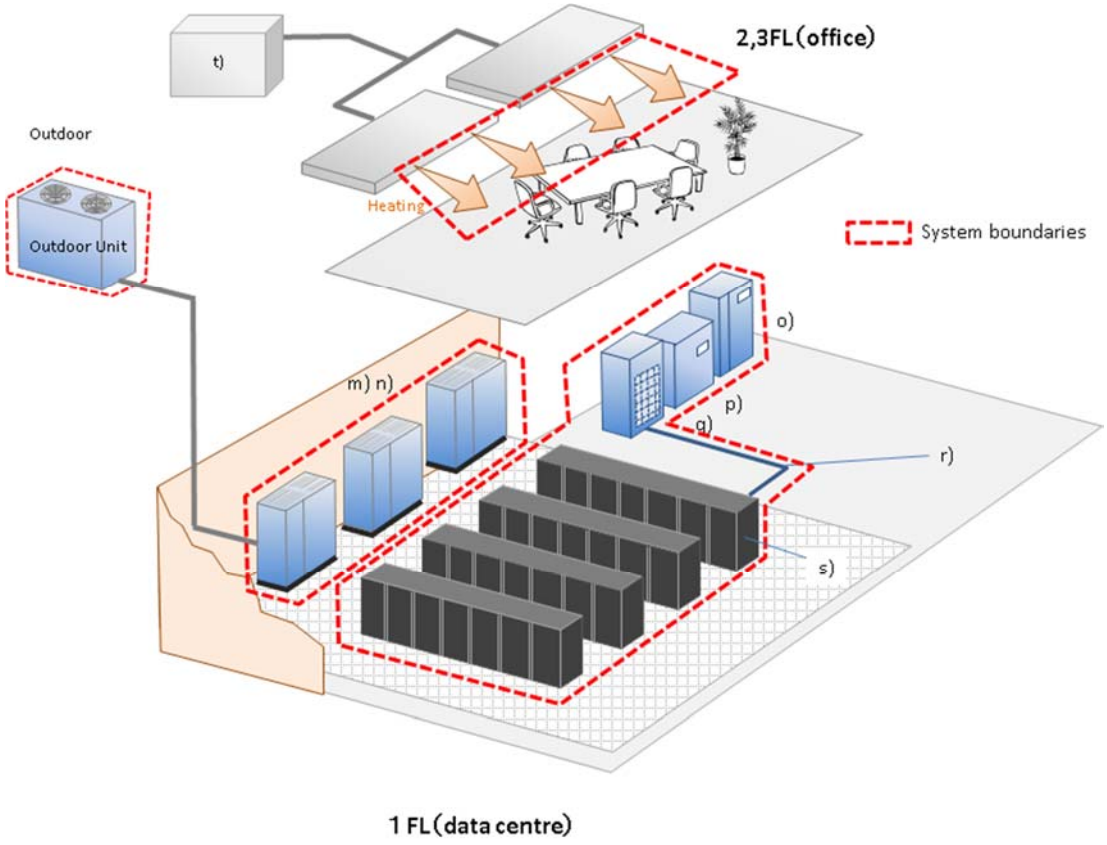

Figure 1-2 – Reference ICT product system

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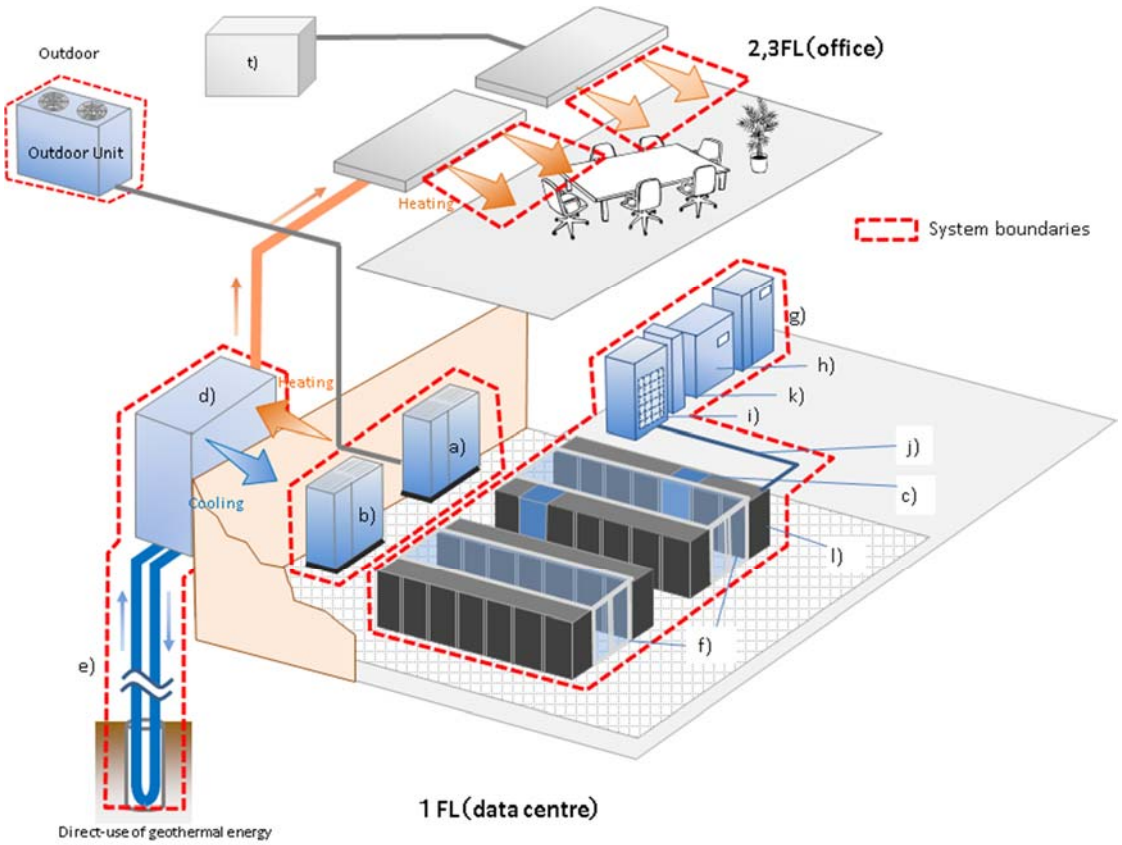

Figure 1-3 – Target ICT product system

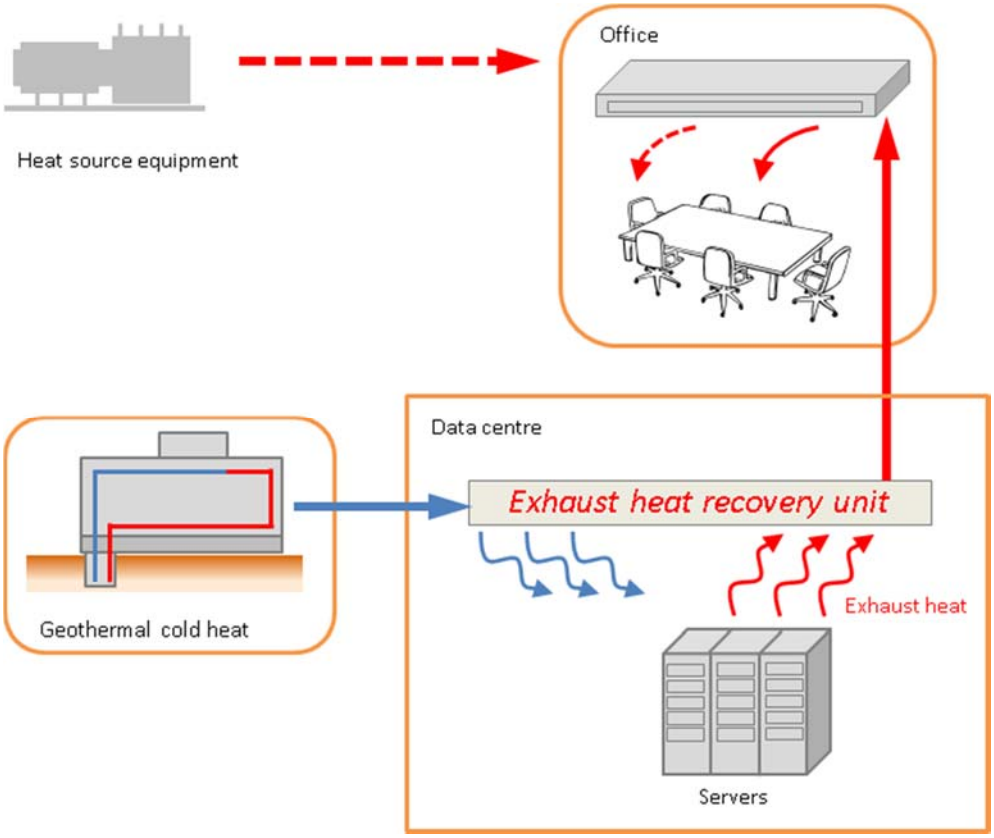

Figure 1-4 – Server room cooling by direct-use of geothermal energy and office room heating by server exhaust heat (Target ICT product system)

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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	

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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.

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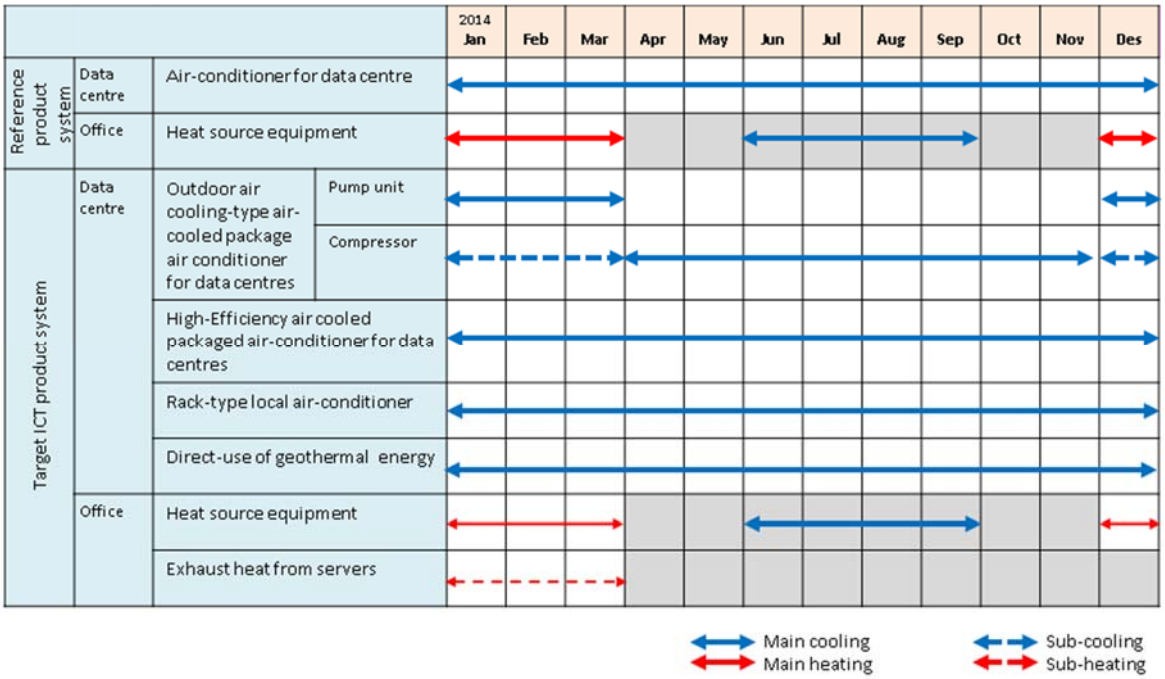
Table 1-3 – Operative schedule



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.

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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.

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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.

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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.					

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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

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