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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

E-waste and circular economy

Methodology to identify key equipment for environmental impact and e-waste generation assessment of network architectures

Recommendation ITU-T L.1050

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Recommendation ITU-T L.1050

Methodology to identify key equipment for environmental impact and e-waste generation assessment of network architectures

Summary

While a framework for assessing the environmental impacts of the ICT sector exists (developed by the ITU in, for example, Recommendation ITU-T L.1410 on environmental life cycle assessments of information and communication technology goods, networks and services), best practices for equipment identification, developed specifically to assess the environmental impacts of network architecture, are lacking. In this Recommendation, key equipment in networks are identified for smoother life cycle assessment (LCA) calculations.

Different types of network architecture employ different goods which entail differences in terms of energy usage, e-waste generation and environmental footprints. This Recommendation will examine three types of network architectures and will suggest an appropriate set of equipment to be considered for each. This Recommendation will begin to support network designers in determining the environmental and circular performance of different network architectures.

Recommendation ITU-T L.1050 utilizes information compiled from stakeholders which can provide good insights into the specified potential challenges.

History

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Circular economy, energy efficiency, environmental footprint, LCA, networks, waste.

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FOREWORD

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Introduction

In practice, modern networks are highly heterogeneous. An important challenge for energy and the environmental performance optimization of hybrid parallel applications on such platforms is how to accurately estimate the energy consumption (and environmental impact) of application components running on different compute devices of the platform [b-Lastovetsky].

For environmental impact investigations, life cycle assessment (LCA) covers raw material extraction, manufacturing, any transport, use phase, and end-of-life treatment [ITU-T L.1410]. The effects of any specific use modes of the equipment in a given network configuration and concept are usually not considered. Consequently, any effects in other network layers, e.g., layer 2 or layer 3, are often not considered. The main problem here is that network-wide optimization depends on cross-layer optimization, e.g., considering additional Layer-2 and/or Layer-3 equipment and their joint interworking. This goes beyond the usual LCA scope for networks. In theory, network LCA should consider all relevant equipment and its interdependencies. However, since the LCA of almost all ICT network infrastructure equipment is dominated by use-phase energy consumption, it would be simpler to restrict such a network LCA (including cross-layer analysis) to the use stage energy consumption [b-Grobe]. However, the upstream and after-use must also be considered in LCA [ITU-T L.1410].

Nevertheless, it may be immensely difficult to model a complete network infrastructure in detail every time information on the environmental performance is sought. Indeed, if for equipment installed recently, data collection regarding the number of pieces of equipment, their configuration location and their energy consumption during the use phase can be carried out, it is much more difficult for network equipment installed decades ago. A limited list of chosen equipment, ideally comprising >80% of the environmental impact, can potentially be identified for common network types.

The resolution of the equipment scope herein is similar to [b-Griffa] for FTTx, [b-Andrae-1] for off-grid RAN sites and [b-BATS] for satellite networks.

Recommendation ITU-T L.1050

Methodology to identify key equipment for environmental impact and e-waste generation assessment of network architectures

1 Scope

The objective of this Recommendation is to provide best practices for equipment identification for ICT service architecture designers to be able to evaluate the environmental performance of different network architectures.

The Recommendation will specify the necessary requirements for identifying equipment types used in network life cycle assessments (LCAs). The proposed set of equipment can be used to evaluate the following dimensions of network architecture:

– Energy efficiency

– E-waste amounts

– LCA impacts

– Circularity indicators [ITU-T L.1023]

NOTE – Applying [ITU-T L.1023] to a network (in order to achieve a single 0% to 100% score for the network) requires allocation (e.g., based on share of cost, share of environmental impact, share of mass, share of functional performance) of the individual [ITU-T L.1023] scores of the equipment composing the network.

This not an exhaustive list. While it does not give network architect designers environmental impact values for each equipment, for the environmental performance calculation of network architecture, it does provide a solid baseline for the scope and overview of network architectures for later calculation of environmental footprint indicators.

2 References

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

[ITU-T L.1023] Recommendation ITU-T L.1023 (2020), *Assessment method for circular scoring*.

[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*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BAS Broadband Access Server
BBU Baseband Unit
BSC Base Station Controller
BTS Base Transceiver Station
CDN Content Delivery Network
CMTS Cable Modem Termination Systems
DHCP Dynamic Host Configuration Protocol
DSLAM Digital Subscriber Line Access Multiplexer
FTTH Fibre To The Home
FTTx Fibre To The *x*
GPON Gigabit Passive Optical Network
HDD Hard Disk Drive
HLR Home Location Register
HSS Home Subscriber Server
ICT Information Communication Technology
LCA Life Cycle Assessment
MGW Media Gateway
MSC Mobile Switching Centre
NFC Near Field Communication
OLT Optical Line Termination
ONT Optical Network Terminal
PDU Power Distribution Unit
PGW Packet data network Gateway
QoE Quality of Experience
RAN Radio Access Networks
RFID Radio-Frequency Identifier Device
RNC Radio Network Controller
RRH Radio Remote Head
RRU Radio Remote Unit
SBN Satellite Broadband Network
SDD Software Disk Driver
TGBT General Low Voltage Switchboard

TGHT General High Voltage Switchboard

VLR Visitor Location Register

WDM Wavelength Division Multiplexing

5 Conventions

None.

6 Equipment identification

The key equipment required to estimate the environmental impact of network architectures needs to be identified.

Figure 1 shows an illustrative view of a telecom network excluding several RAN aspects [b-EC].

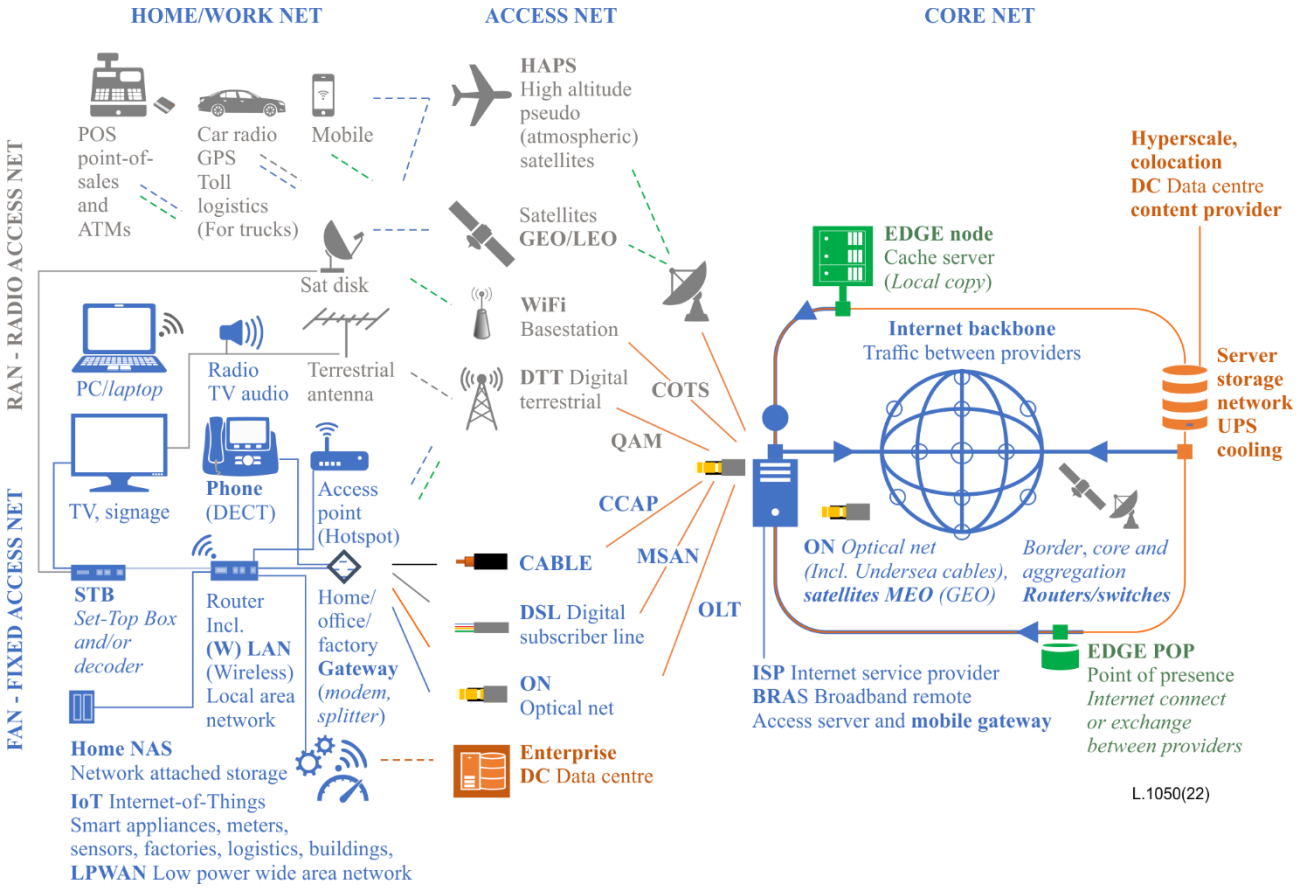

Figure 1 – Illustrative view of a telecom network excluding cellular access

[ITU-T L.1410] contains examples of radio access network (RAN) equipment (and fibre to the *x* (FTTx)) but no exact requirements on which RAN equipment must be included if an LCA of a specific RAN is undertaken.

Table 1 lists 14 equipment types which typically feature within a telecom network architecture system boundary when an LCA is undertaken.

Table 1 – Key equipment used in network architectures

Equipment type	Category
1. Devices and user equipment	Laptop computers
	Tablets
	Mobile phones
	Desktop computers (without screen)
	Desktop screens
	Televisions
	External power units for Laptop computer
	External power units for smartphone & tablet
	External hard disk drive (HDD)
	External software disk driver (SDD)
2. Office equipment	Printers
	Video conference equipment
	Wi-Fi access transmission points
	Video projectors
	Docking stations
	Routers
3. Connected object equipment	Domotics/Home automation devices
	Printers
	Near field communication (NFC) equipment
	Radio-frequency identity devices (RFIDs)
	Bluetooth transmission points
	Wi-Fi Access transmission points
	Batteries
	Displayers
	Sensors
	Control cards
	Flash memory cards
4. Specific devices/equipment	Fixed telephony devices
	Spider conference phone stations
	Connected speakers
	Game consoles
	Printers

Table 1 – Key equipment used in network architectures

Equipment type	Category
5. Data centre site equipment	Site
6. Data centre – Equipment IT	Servers – rack
	Servers – blades
	Servers – mainframes
	Gateways
	Power distribution units (PDUs)
	Load balancers
	Firewalls
	Switches
	Routers
	Racks
	Disk/storage arrays
	Network monitoring devices
	Proxies
7. Data centre – Equipment non-IT	Transformers
	General low voltage switchboards (TGBTs)
	General high voltage switchboards (TGHTs)
	Inverters
	Batteries
	Air conditioners
	Generators
	Cables – Fibre optics
	Cables – copper cable
	Fire safety systems
	Photovoltaic stations
8. Data centre IoT architecture equipment	IoT equipment

Table 1 – Key equipment used in network architectures

Equipment type	Category
9. Access network equipment	Digital subscriber line access multiplexers (DSLAMs)
	Modems
	Gigabit passive optical networks (GPONs)
	User satellite modems
	Earth station gateways
	Intelligent use gateways
	Satellites
	Optical network terminals (ONTs)
	Cable modem termination systems (CMTS)
	Optical line terminations (OLTs)
	Customer premises equipment (CPE)
	Antennas
	Radio transceivers
	Base transceiver stations (BTSs)
	Routers
	Radio remote head (RRH) unit
	ENODE B
	Baseband unit (BBU)
	Radio remote unit (RRU)
	NODE B
10. Network – cables equipment	Optical fibre
	Copper
11. Aggregation/backhaul network equipment	Switches/bridges
	Routers
	Gateways
	Hubs
	Broadband Access Servers (BASs)
	Base station controllers (BSCs)
	Radio network controllers (RNCs)
	Microwave equipment

Table 1 – Key equipment used in network architectures

Equipment type	Category
12. Backbone equipment	Intelligent network gateways
	Wavelength division multiplexing (WDM) routers
	IP routers
	Bridges
	Gateways
	Hub servers
	Content delivery network (CDN) servers
	Mobile switching centres (MSCs), Packet data network gateways (PGWs)…
	Media gateways (MGW)
	Database servers (home location register (HLR), home subscriber server (HSS), visitor location register (VLR) …)
	Dynamic host configuration protocol (DHCP) / domain name system (DNS) servers
13. Network – site equipment	Sites (including masts)
14. Network – technical support equipment	Transformers
	TGBTs
	TGHTs
	Inverters
	Batteries
	Fuel cells
	Air conditioners
	Generators
	Launch vehicles
	Solid fuel booster casings
	Launch fuel, butadiene
	Launch fuel, aluminium
	Launch fuel, hydrogen
	Launch fuel, oxygen
	Launch fuel, chlorine
	Fire safety systems
	Photovoltaic stations

NOTE – [ITU-T L.1410] and [b-ITU-T L.1450] consider user devices, networks and data centres as different categories. Note also that the list of goods above is more inclusive since it considers also products such as printers and game consoles.

6.1 Fibre to the home network architectures

FTTx architectures such as fibre to the home (FTTH) are used to provide broadband subscriptions. For FTTH, LCAs have shown that end user equipment such as CPE is important [b-Griffa] [b-Andrae-2] [b-PWC].

Equipment types 1 to 4 in Table 1 are considered out of scope of FTTH network assessments. That is, types 1 to 4 are not considered and are excluded from the start from an LCA. When carrying out an LCA of the equipment for which "Yes" is noted in the "Include" column of Table 2, it is advised to refer to best practices described in [ITU-T L.1410] to define the scope, functional unit, usage scenario, etc.

Table 2 shows the equipment to be considered for a FTTH network LCA and which cut-offs can be made from the studied defined product system boundary. Here, equipment types 6 to 8 can be cut off. The backbone (i.e., what is set before the local main access point, equipment type 12) and the upstream of the backbone (equipment type 11) are part of the studied product system but can also be cut off. Attempts should be made to quantify the magnitude of the cut-off according to cut-off rules.

Table 2 – Inclusion of key equipment in a studied product system in FTTH network LCA

Equipment type	Category	Include
5. Data centre site equipment	Site	Not considered
6. Data centre – equipment IT	Servers – rack	Not considered
	Servers – blades	Not considered
	Servers – mainframes	Not considered
	Gateways	Not considered
	PDUs	Not considered
	Load balancers	Not considered
	Firewalls	Not considered
	Switches	Not considered
	Routers	Not considered
	Racks	Not considered
	Disk/storage arrays	Not considered
	Network monitoring devices	Not considered
	Proxies	Not considered
7. Data centre – Equipment non-IT	Transformers	Not considered
	TGBTs	Not considered
	TGHTs	Not considered
	Inverters	Not considered
	Batteries	Not considered
	Air conditioning	Not considered
	Generators	Not considered
	Cables – Fibre optics	Not considered
	Cables – copper cable	Not considered
	Fire safety systems	Not considered
	Photovoltaic stations	Not considered

Table 2 – Inclusion of key equipment in a studied product system in FTTH network LCA

Equipment type	Category	Include
8. Data centre IoT architecture equipment	IoT equipment	Not considered
9. Access network equipment	Modems	Yes
	GPONs	Yes
	ONTs	Yes
	CMTSs	Not considered
	OLTs	Yes
	CPE	Yes
	Routers	Yes
10. Network – cables equipment	Optical fibre	Yes
11. Aggregation/backhaul network equipment	Switches/bridges	Not considered
	Routers	Not considered
	Gateways	Not considered
	Hubs	Not considered
	BASs	Not considered
12. Backbone equipment	Intelligent network gateways	Not considered
	WDM routers	Not considered
	IP routers	Not considered
	Bridges	Not considered
	Gateways	Not considered
	Hub servers	Not considered
	CDN servers	Not considered
	MGWs	Not considered
	Database servers (HLR, HSS, VLR …)	Not considered
	DHCP/DNS servers	Not considered
13. Network – site equipment	Site (trenching, civil works…)	Yes
14. Network – technical support equipment	Transformers	Not considered
	TGBTs	Not considered
	TGHTs	Not considered
	Inverters	Not considered
	Batteries	Not considered
	Fuel cells	Not considered
	Air conditioners	Not considered
	Generators	Not considered
	Fire safety systems	Not considered
	Photovoltaic stations	Not considered

6.2 Radio access network architectures

Equipment types 1 to 4 in Table 1 are considered to be out of the scope of RAN assessments.

The necessary key equipment shown in Table 3 may be used by mobile subscription service architecture designers to evaluate the environmental performance of RAN architectures. Table 3 also includes the main equipment types which may be used in 5G RAN. When carrying out an LCA of the equipment denoted "Yes" in column "Include" of Table 2, it is advised to refer to the best practices described in [ITU-T L.1410] to define the scope, functional unit, usage scenario, etc.

Table 3 – Inclusion of key equipment in a studied product system in mobile network LCA

Equipment type	Category	Include
5. Data centre site equipment	Site	Not considered
6. Data centre – equipment IT	Servers – rack	Not considered
	Servers – blades	Not considered
	Servers – mainframes	Not considered
	Gateways	Not considered
	PDUs	Not considered
	Load balancers	Not considered
	Firewalls	Not considered
	Switches	Not considered
	Routers	Not considered
	Racks	Not considered
	Disk/storage arrays	Not considered
	Network monitoring devices	Not considered
	Proxies	Not considered
7. Data centre – Equipment non-IT	Transformers	Not considered
	TGBTs	Not considered
	TGHTs	Not considered
	Inverters	Not considered
	Batteries	Not considered
	Air conditioners	Not considered
	Generators	Not considered
	Cables – Fibre optics	Not considered
	Cables – copper cable	Not considered
	Fire safety systems	Not considered
	Photovoltaic stations	Not considered
8. Data centre IoT architecture	IoT equipment	Not considered

Table 3 – Inclusion of key equipment in a studied product system in mobile network LCA

Equipment type	Category	Include
9. Access network equipment	Modems	Not considered
	Antennas (including active antennas)	Yes
	Radio transceivers	Yes
	BTSs	Yes
	Routers	Not considered
	RRHs	Yes
	ENODE B	Yes
	BBUs (including BBU Hotel)	Yes
	RRUs	Yes
	Small cells	Yes
	NODE B	Yes
10. Network – cables equipment	Optical fibre	Not considered
	Copper	Not considered
11. Aggregation/backhaul network equipment	Switches/bridges	Not considered
	Routers	Not considered
	Gateways	Not considered
	Hubs	Not considered
	BASs	Yes
	BSCs	Yes
	RNCs	Yes
	Microwave equipment	Yes
12. Backbone equipment	Intelligent network gateways	Not considered
	WDM routers	Not considered
	IP routers	Not considered
	Bridges	Not considered
	Gateways	Not considered
	Hub servers	Not considered
	CDN servers	Not considered
	MSCs, PGWs …	Not considered
	MGWs	Not considered
	Database servers (HLR, HSS, VLR …)	Not considered
	DHCP/DNS servers	Not considered
13. Network – site equipment	Sites (including masts)	Yes

Table 3 – Inclusion of key equipment in a studied product system in mobile network LCA

Equipment type	Category	Include
14. Network – technical support equipment	Transformers	Not considered
	TGBTs	Not considered
	TGHTs	Not considered
	Inverters	Yes
	Batteries	Yes
	Fuel cells	Yes
	Air conditioners	Yes
	Generators	Yes
	Fire safety systems	Not considered
	Photovoltaic stations	Yes

6.3 Satellite network architectures

In order to perform an LCA of a satellite broadband network (SBN) – and establish its energy efficiency, e-waste amounts, LCA indicators circularity indicators – the key pieces of equipment listed in Table 4 are required [b-BATS]. Equipment types 1 to 4 in Table 1 are considered to be out of the scope of SBN assessments. When carrying out the LCA of the equipment denoted "Yes" in the "Include" column of Table 2, it is advised to refer to best practices described in [ITU-T L.1410] to define the scope, th functional unit, usage scenario, etc.

In an LCA of an SBN it is possible to employ cut-off rules and approximations to reduce the cost or length of an assessment and still provide useful results.

Key issues include how to compare the energy efficiency of a hybrid broadband satellite network with other methods of broadband delivery, how to accurately assess the carbon embodied during the production of the equipment and how to use low-power modes to reduce energy consumption without affecting the response time or quality of experience (QoE) [b-Dickerson].

Table 4 – Key equipment in studied product system to be included or not in satellite network LCAs

Equipment type	Category	Include
5. Data centre site equipment	Site	Not considered
6. Data centre – equipment IT	Servers – rack	Not considered
	Servers – blades	Not considered
	Servers – mainframes	Not considered
	Gateways	Not considered
	PDUs	Not considered
	Load balancers	Not considered
	Firewalls	Not considered
	Switches	Not considered

Table 4 – Key equipment in studied product system to be included or not in satellite network LCAs

Equipment type	Category	Include
	Routers	Not considered
	Racks	Not considered
	Disk/storage arrays	Not considered
	Network monitoring devices	Not considered
	Proxies	Not considered
7. Data centre – Equipment non-IT	Transformers	Not considered
	TGBTs	Not considered
	TGHTs	Not considered
	Inverters	Not considered
	Batteries	Not considered
	Air conditioners	Not considered
	Generators	Not considered
	Cables – Fibre optics	Not considered
	Cables – Copper cable	Not considered
	Fire safety systems	Not considered
	Photovoltaic stations	Not considered
8. Data centre IoT architecture	IoT equipment	Not considered
9. Access network equipment	User satellite modems	Yes
	Earth station gateways	Yes
	Intelligent use gateways	Yes
	Satellites	Yes
	CPE	Yes
10. Network – cables equipment	Optical fibre	Not considered
	Copper	Not considered
11. Aggregation/backhaul network equipment	Switches/bridges	Not considered
	Routers	Not considered
	Gateway	Not considered
12. Backbone equipment	Intelligent network gateway	Yes
	WDM routers	Not considered
	IP Routers	Not considered
	Bridges	Not considered
	Gateways	Not considered
	Hub servers	Not considered
	CDN server	Not considered
	MSCs, PGWs …	Not considered

Table 4 – Key equipment in studied product system to be included or not in satellite network LCAs

Equipment type	Category	Include
	MGWs	Not considered
	Database servers (HLR, HSS, VLR …)	Not considered
	DHCP/DNS servers	Not considered
13. Network – site equipment	Sites (including masts)	Not considered
14. Network – technical support equipment	Launch vehicles	Yes
	Solid fuel booster casing	Yes
	Launch fuel, butadiene	Yes
	Launch fuel, aluminium	Yes
	Launch fuel, hydrogen	Yes
	Launch fuel, oxygen	Yes
	Launch fuel, chlorine	Yes
	Transformers	Not considered
	TGBTs	Not considered
	TGHTs	Not considered
	Inverters	Not considered
	Batteries	Not considered
	Fuel cells	Not considered
	Air conditioners	Not considered
	Generators	Not considered
	Fire safety systems	Not considered
	Photovoltaic stations	Not considered

7 Outlook

Service LCAs (e.g., provision of virtual meetings) are facilitated by knowing which equipment types are required to assess the total carbon footprint (etc.) of related networks.

An analogy could be drawn between a broadband subscription service and an individual car's mileage service. If the present principle for network architectures scope LCA standard would be used by a car mileage service scope LCA standard, it would specify which equipment types used within the car need to be included in the LCA. That is to say that a car delivers the service 'mobility' and the automotive eco-system is composed of different equipment types of which some are more relevant to the carbon footprint than others. Similarly, this Recommendation defines the minimum list of equipment types which should be considered in a carbon footprint analysis of telecom networks which are in turn used to deliver broadband services.

On a national level it is preferable from a practical and sensitivity standpoint that network operators compile the network environmental footprint indicator scores and then report further for an annual compilation of national footprint evolution. The network equipment manufacturers are best at providing the LCA of manufacturing and distribution (transport) environmental footprints per configuration of equipment types to be included according to Table 2 to Table 4.

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