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APPENDIX
Research project “Comparability of sustainability standards for telecommunications infrastructure”

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Study by Oeko-Institut Consult GmbH

Authors

Ran Liu, Andreas R. Köhler, Martin Möller
Öko-Institut Consult GmbH

Lars Albus, Hannah Lorösch; Jens Gröger
Öko-Institut e.V.

Öko-Institut Consult GmbH
info@oeko-consult.de
oeko-consult.de
info@oeko-consult.de
oeko-consult.de

Büro Berlin
Borkumstraße 2
13189 Berlin
Telefon +49 30 405085-0
4295 Darmstadt
Phone +49 6151 8191-0

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3GPP	3rd Generation Partnership Project
5GC	5G core network
BRA	Backhauling
BS	Base Station
CAN	Cable Access Network
CAPEX	Capital Expenditure
CCAP	Converged Cable Access Platform
CMTS	Cable Modem Termination System
CoA	Coverage Area
CoC	Code of Conduct
CPE	Customer Premises Equipment
CSRD	Corporate Sustainability Reporting Directive
DCEM	Data processing and Communications Energy Management
DL/UL	Downlink / Uplink
DSLAM	Digital Subscriber Line Access Multiplexer
DP	Data volume
EdgeQAM	Edge Quadrature Amplitude Modulator
EoL	End-of-Life
ESG	Environmental, Social, Governance
ETSI EN	European Standard
ETSI ES	ETSI Standard
ETSI TS	ETSI Technical Specification
E-UTRA	Evolved UMTS Terrestrial Radio Access

FAN	Fixed Access Network
FN	Fiber Nodes
GHG	Greenhouse Gases
GSM	Global System for Mobile communication (2G)
HE	Headend
HFC	Hybrid Fiber/Coax
ICT	Information and Communication Technology
ITE	Information Technology Equipment
KPI	Key performance indicator
KPI	Key Performance Indicator
LCA	Life cycle assessment
LOC	Last Operator Connection point
LTE	Long Term Evolution (4G)
NDC	Network Data Center
NDN	Network Distribution Node
NFV	Network Function Virtualization
NFVI	Network Functions Virtualization Infrastructure
NIU	Network Interface Unit
NTE	Network Telecommunications Equipment
OPEX	Operational Expenditure
OS	Operator Site
OSP	Outside Plant
PDCP-SDU	Packet Data Convergence Protocol Service Data Unit
PNF	Physical Network Functions
RAN	Radio Access Network

RC/RLC	Radio Controller / Radio Link Control
SI	Site Infrastructure
SMF	Session management
UMTS	Universal Mobile Telecommunication Service (3G)
UPF	User Plane Function
VNF	Virtualized Network Functions
WCDMA	Wideband Code Division Multiple Access (3G)
WEEE	Waste Electrical and Electronic Equipment

7 Annex

Annex I. EU taxonomy

Annex I.a. General description

In accordance with Article 9 (European Commission 2020), the EU taxonomy pursues the following six environmental objectives: (a) climate change mitigation, (b) climate change adaptation, (c) the sustainable use and protection of water and marine resources, (d) the transition to a circular economy, (e) pollution prevention and control, and (f) the protection and restoration of biodiversity and ecosystems. One of the aims of the EU taxonomy is to increase market transparency and channel financial flows into investments in sustainable economic activities that make a significant contribution to achieving defined environmental objectives without compromising any of the other environmental objectives.

The EU taxonomy is a classification system for sustainable economic activities, which currently covers 16 sectors of the economy (see Table 7-1). Each sector is assigned economic activities for which technical assessment criteria have been defined.

Table 7-1: 16 defined sectors in the EU taxonomy for which technical assessment criteria for activities have been established

No.	Sector (EN)
1	Forestry
2	Environmental protection and restoration activities
3	Manufacturing
4	Energy
5	Water supply, sewerage, waste management and remediation
6	Transportation
7	Construction and real estate activities
8	Information and communication
9	Professional, scientific and technical activities
10	Financial and insurance activities
11	Human health and social work activities
12	Arts, entertainment and recreation
13	Education
14	Disaster risk management
15	Services
16	Accommodation activities

Source: Own compilation

The EU taxonomy distinguishes between taxonomy-eligible and taxonomy-aligned economic activities. Taxonomy-eligible economic activities are those for which specific sustainability criteria are defined in delegated acts (Climate Delegated Act; Environmental Delegated Act) of the EU taxonomy. Taxonomy-compliant economic activities are those that fully meet the defined sustainability criteria (European Commission 2020; 2021a; 2023c; 2023e).

In accordance with Article 3 (European Commission 2020), taxonomy-compliant economic activities must make a significant contribution to achieving at least one of the environmental objecttives, must not have a significant negative impact on the other environmental objectives ("do no significant

harm"), must meet defined minimum social standards ("minimum safeguards") and the technical assessment criteria.

Financial companies[11] and non-financial companies that fall under the Corporate Sustainability Reporting Directive (CSRD) (see Annex II) must fulfill so-called disclosure requirements as part of the taxonomy (European Commission 2021b). In accordance with Article 5 (European Union 2022c)large companies[12] and capital market-oriented small and medium-sized enterprises[13] are covered. Companies that are not covered by the CSRD, such as micro-enterprises[14], can report voluntarily (European Commission 2024). The disclosure requirements under the EU Taxonomy include the following key performance indicators (KPIs), according to the (European Commission 2021b):

- Turnover KPI: What proportion of net turnover is generated by taxonomy-compliant economic activities?
- Capital Expenditure KPI (CapEx KPI): What proportion of capital expenditure flows into taxonomy-compliant economic activities?
- Operational expenditure KPI (OpEx KPI): What proportion of operating expenditure is spent on taxonomy-compliant economic activities?

[11] e.g. credit institutions = banks, asset managers, (re)insurers

[12] Large companies are those that exceed at least two of the following three size criteria on the balance sheet date Balance sheet total: EUR 25 million; Net turnover: EUR 50 million; Average number of employees during the financial year: 250 ((Artikel 3; European Union 2013; European Commission 2023a)).

[13] Small and medium-sized enterprises are those that **do not** exceed at least two of the following three size criteria on the balance sheet date: Balance sheet total: EUR 25 million; Net turnover: EUR 50 million; Average number of employees during the financial year: 250 and which are not micro-entities (Artikel 3; European Union 2013; European Commission 2023a).

[14] Micro-enterprises are those that do not exceed at least two of the following three size criteria on the balance sheet date Balance sheet total: EUR 450,000; net turnover: EUR 900,000; average number of employees during the financial year: 10 (Artikel 3; European Union 2013; European Commission 2023a).

Table 7-2: Overview of regulations within the framework of the EU taxonomy

Regulation	Abbreviation	Publication date	Remark
Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088	EU Taxonomy Regulation	22.06.2020	EU Taxonomy Regulation
COMMISSION **DELEGATED REGULATION (EU) 2021/2139** of 4 June 2021 **supplementing Regulation (EU) 2020/852** of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives	Climate Delegated Act	09.12.2021	Technical evaluation criteria for environmental objectives (a) climate protection and (b) climate change adaptation are defined
COMMISSION DELEGATED REGULATION (EU) 2021/2178 of 6 July 2021 **supplementing Regulation (EU) 2020/852** of the European Parliament and of the Council by specifying the content and presentation of information to be disclosed by undertakings subject to Articles 19a or 29a of Directive 2013/34/EU concerning environmentally sustainable economic activities, and specifying the methodology to comply with that disclosure obligation	Disclosures Delegated Act	10.12.2021	Requirements are defined for the disclosure of economic activities that are taxonomy-eligible or taxonomy-aligned (see KPIs)
COMMISSION DELEGATED REGULATION (EU) 2022/1214 of 9 March 2022 **amending Delegated Regulation (EU) 2021/2139** as regards economic activities in certain energy sectors and Delegated Regulation (EU) 2021/2178 as regards specific public disclosures for those economic activities	Complementary Climate Delegated Act	15.07.2022	Additions/changes in relation to energy generation from nuclear power plants or gas-fired power plants
Commission **Delegated Regulation (EU) 2023/2486** of 27 June 2023 **supplementing Regulation (EU) 2020/852** of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to the sustainable use and protection of water and marine resources, to the transition to a circular economy, to pollution prevention and control, or to the protection and restoration of biodiversity and ecosystems and for determining whether that economic activity causes no significant harm to any of the other environmental objectives and amending Commission Delegated Regulation (EU) 2021/2178 as regards specific public disclosures for those economic activities	Environmental Delegated Act	21.11.2023	Technical assessment criteria are defined for environmental objectives (c) the sustainable use of water and marine resources, (d) the transition to a circular economy, (e) the prevention and reduction of pollution and (f) the protection and restoration of biodiversity and ecosystems
COMMISSION **DELEGATED REGULATION (EU) 2023/2485** of 27 June 2023 **amending Delegated Regulation (EU) 2021/2139** establishing additional technical screening criteria for determining the conditions under which certain economic activities qualify as contributing substantially to climate change mitigation or climate change adaptation and for determining whether those activities cause no significant harm to any of the other environmental objectives	Amending Climate Delegated Act	21.11.2023	-

Source: Own compilation

Annex I.b. EU taxonomy: Relationship between the EU taxonomy and telecommunication companies

The taxonomy currently includes the "Information and communication" sector (see Table 7-3). In this sector, sustainability criteria are defined for seven (taxonomy-appropriate) activities:

1. Computer programming, consultancy and related activities (Anhang II, 8.2; European Commission 2021a)
2. Data processing, hosting and related activities (Anhang I, 8.1; Anhang II, 8.1; European Commission 2021a)
3. Data-driven solutions for GHG emissions reductions (Anhang I, 8.2; European Commission 2021a)
4. Programming and broadcasting activities (Anhang II; 8.3; European Commission 2021a)
5. Povision of IT/OT data-driven solutions[15] (Anhang II;, 4.1; European Commission 2023c)
6. Provision of IT/OT data-driven solutions for leakage reduction[16] (Povision of IT/OT data-driven solutions for leakage reduction) (Anhang I, 4.1; European Commission 2023c)
7. Software enabling physical climate risk management and adaption (European Commission 2023b)

Telecommunications companies currently engage in several of these activities (see Table 7-3) as well as economic activities from other sectors that are necessary for implementing their business model. These include, for example, "transportation by motorcycles, passenger cars and light commercial vehicles".

However, central business areas of telecommunications companies, such as the "provision and operation of a network infrastructure for telecommunications", are not yet covered by the Taxonomy.

Table 7-3: Economic activities of large telecommunications groups that are only taxonomy-eligible (e) or taxonomy-eligible and taxonomy-compliant (e&c) in the 2023 financial year

Sectors	Activities	Environmental objective in the present study	Source Technical evaluation criterion	Deutsche Telekom AG (Deutsche Telekom AG 2023b)	1&1 AG (1&1 AG 2023)	Telefónica (Telefónica Deutschland Holding AG 2023b)
Transport	Infrastructure enabling low-carbon road transport and public transport	Climate protection	Chapter 6.15, Annex I (European Commission 2021a)	e	n/a	n/a
Transport	Transport by motorbikes, passenger cars and light commercial vehicles	Climate protection	Chapter 6.5, Annex I (European Commission 2021a)	e	e	e

[15] IT = Information technology; OT = Operational technology (including hardware)
[16] Solutions to reduce losses in the water supply system; see environmental goal "(c) the sustainable use of water and marine resources"

Sectors	Activities	Environmental objective in the present study	Source Technical evaluation criterion	Deutsche Telekom AG (Deutsche Telekom AG 2023b)	1&1 AG (1&1 AG 2023)	Telefónica (Telefónica Deutschland Holding AG 2023b)
Construction and real estate activities	Installation, maintenance and repair of energy efficiency equipment	Climate protection	Ch.7.3, Annex I (European Commission 2021a)	n/a	n/a	e&c
Construction and real estate activities	Installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings) .	Climate protection	Ch.7.4, Annex I, (European Commission 2021a)	n/a	n/a	e&c
Construction and real estate activities	Acquisition and ownership of buildings	Climate protection	Ch.7.7, Annex I, (European Commission 2021a)	n/a	e	e
Information and communication	Data processing, hosting and related activities	Climate protection	Chapter 8.1, Annex I, (European Commission 2021a)	e	e	e
Information and communication	Data-driven solutions for GHG emissions reductions	Climate protection	Chapter 8.2, Annex I, (European Commission 2021a)	e&c	n/a	e&c
Services	Sale of second-hand goods	Circular economy	Chapter. 5.4; Annex II, (European Commission 2023c)	n/a	e	e
Services	Product-as-a-service and other circular use- and result-oriented service models	Circular economy	Chapter. 5.5; Annex II, (European Commission 2023c)	e	n/a	e

Source: Own compilation; sorted by environmental goal and sector

Deutsche Telekom AG was active in several taxonomy-compliant activities in 2023 (see Table 7-3). It generated 2.5% of its annual revenue (turnover KPI) with these activities in 2023. Taxonomy conformity was achieved in the activity "Data-driven solutions for GHG emissions reductions ". Deutsche Telekom AG thus achieved a total of 0.2% of its revenue in 2023 (Deutsche Telekom AG 2023b).

1&1 AG was active in several taxonomy-compliant activities in 2023 (see Table 7-3). The technical assessment criteria of the EU taxonomy were not fully met, therefore no taxonomy-compliant activities were reported and the revenue KPI was zero. For investments and operating resources, no sufficient evidence of taxonomy compliance could be provided by the partner companies, therefore CapEx-KPI and OpEx-KPI were zero (1&1 AG 2023).

Telefónica Deutschland Holding AG was active in several taxonomy-compliant activities in 2023 (see Table 7-3). It generated 1% of annual revenue (turnover KPI) with these activities in 2023. Taxonomy conformity was achieved in the activity "Data-driven solutions for GHG emissions reductions".

Telefónica Deutschland Holding AG thus achieved a total of 0.2% of its revenue in 2023. Taxonomy conformity was also achieved for investments (CapEx KPI) in the activities "Installation, maintenance and repair of energy-efficient equipment" and "Installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)" (Telefónica Deutschland Holding AG 2023b).

Deutsche Telekom AG, together with other companies and industry associations such as ETNO (European telecommunications Network Operators' Association), is committed to the inclusion of appropriate criteria for network infrastructure in the EU taxonomy (Deutsche Telekom AG 2023b). According to ETNO (2021), telecommunications companies are investing heavily in the construction and modernization of energy-efficient and fast network infrastructures and data centers.

Telefonica, which operates the O_2 brand among others, also advocates the inclusion of the entire network infrastructure in the EU taxonomy (Barrionuevo 2023).

The delegated acts of the EU Taxonomy Regulation (Climate Delegated Act; Environmental Delegated Act) include economic activities that would be relevant for the indicators in this study but are currently neither operated by the aforementioned telecommunications companies nor communicated as Taxonomy-eligible activities. These include, among others, "repair, refurbishment and remanufacturing" and "preparation for reuse of end-of-life products and product components".

Annex II. EU-CSRD

Annex II.a. EU-CSRD: General description

The Corporate Sustainability Reporting Directive (CSRD), Directive (EU) 2022/2464 requires certain companies to disclose the data prescribed in the European Sustainability Reporting Standards (ESRS). These were developed on the basis of a technical opinion of the European Financial Reporting Advisory Group (EFRAG).

The ESRS comprise the following 12 standards (European Commission 2023d) on ESG (Environmental, Social, Governance) factors:

Table 7-4: European sustainability reporting standards (ESRS)

Category	12 Standards
General standards	ESRS 1: General requirements
	ESRS 2: General disclosures
Environmental standards	ESRS E1: Climate change
	ESRS E2: Pollution
	ESRS E3: Water and marine resources
	ESRS E4: Biodiversity and ecosystems
	ESRS E5: Resource utilization and circular economy
Social standards	ESRS S1: Own workforce
	ESRS S2: Workforce in the value chain
	ESRS S3: Affected communities
	ESRS S4: Consumers and end-users
Governance standards	ESRS G1: Business conduct

Source: (European Commission 2023d)

Since 2017, companies of public interest, which in Germany includes around 500 large, capital market-oriented companies, banks and insurance companies, have had to report on their sustainability as part of the NFRD (Non-Financial Reporting Directive) (BMAS n.d.).): This reporting takes place in a consolidated non-financial statement, which is published in the consolidated management report or a separate report. As a minimum, it includes information on environmental, social and employee matters, respect for human rights and the fight against corruption and bribery (European Union 2014).

The CSRD came into force on 05.01.2023 and was transposed into national law by 06.07.2024. It successively affects the following corporations and commercial partnerships with limited liability only (BMAS n.d.).):

- Public interest entities with more than 500 employees (report 2025 for financial years from 01.01.2024)
- Large corporations[17], credit institutions and insurance companies (report 2026 for financial years from 01.01.2025)

[17] Large companies are those that exceed at least two of the following three size criteria on the balance sheet date Balance sheet total: EUR 25 million; Net turnover: EUR 50 million; Average number of

– Small and medium-sized corporations[18] , credit institutions and insurance companies that are capital market-oriented (report 2027 for financial years from 01.01.2026; if the obligation is lifted: from 01.01.2028)

– Third-country companies with a turnover of more than EUR 150 million in the EU whose subsidiaries meet the above size criteria or whose branches achieve a turnover of more than EUR 40 million. (report 2029 for financial years from 01.01.2028)

The CSRD incorporates the principle of double materiality. According to this principle, companies must report both on the impact of their own business operations on people and the environment and on the financial impact of sustainability aspects on their business activities (BMAS n.d.).

The reported sustainability information must be externally verified by auditors or independent providers of assurance services (e.g. certification bodies or environmental verifiers). Initially, the sustainability information must be confirmed with "limited assurance engagement". This will gradually be expanded to a significantly more comprehensive "reasonable assurance engagement" (European Union 2022b; 2022a).

employees during the financial year: 250 (COMMISSION DELEGATED DIRECTIVE (EU) 2023/2775 of October 17, 2023 amending Directive 2013/34/EU of the European Parliament and of the Council by adapting the size criteria for micro, small, medium-sized and large enterprises or groups (2023); Article 3; Directive 2013/34/EU of the European Parliament and of the Council of 26 June 2013 on the annual financial statements, consolidated financial statements and related reports of certain types of undertakings and amending Directive 2006/43/EC of the European Parliament and of the Council (2023)). June 2013 on the annual financial statements, consolidated financial statements and related reports of certain types of undertakings, amending Directive 2006/43/EC of the European Parliament and of the Council and repealing Council Directives 78/660/EEC and 83/349/EEC (2013)).

[18] Small and medium-sized enterprises are those that do not exceed at least two of the following three size criteria on the balance sheet date: Balance sheet total: EUR 25 million; net turnover: EUR 50 million; average number of employees during the financial year: 250 and which are not micro-entities (COMMISSION DELEGATED DIRECTIVE (EU) 2023/2775 of October 17, 2023 amending Directive 2013/34/EU of the European Parliament and of the Council by adapting the size criteria for micro, small, medium-sized and large enterprises or groups (2023); Article 3; Directive 2013/34/EU of the European Parliament and of the Council of June 2013 on the annual financial statements, consolidated financial statements and related reports of certain types of undertakings, amending Directive 2006/43/EC of the European Parliament and of the Council and repealing Council Directives 78/660/EEC and 83/349/EEC (2013)).

Table 7-5: Overview of the legal acts under the CSRD

Regulation (EN)	Publication date	Remark
DIRECTIVE 2013/34/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013 on the annual financial statements, consolidated financial statements and related reports of certain types of undertakings, amending Directive 2006/43/EC of the European Parliament and of the Council and repealing Council Directives 78/660/EEC and 83/349/EEC	26.06.2013	Accounting Directive
DIRECTIVE 2014/95/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 **amending Directive 2013/34/EU** as regards disclosure of non-financial and diversity information by certain large undertakings and groups	15.11.2014	Non-Financial Reporting Directive (NFRD)
DIRECTIVE (EU) 2022/2464 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2022 **amending** Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive **2013/34/EU**, as regards corporate sustainability reporting	16.12.2022	Corporate Sustainability Reporting Directive - CSRD Directive
COMMISSION **DELEGATED REGULATION (EU) 2023/2772** of July 31, 2023 **supplementing Directive 2013/34/EU** of the European Parliament and of the Council as regards sustainability reporting standards	22.12.2023	European Sustainability Standards (ESRS) are defined and described
COMMISSION **DELEGATED DIRECTIVE (EU) 2023/2775** of 17 October 2023 **amending Directive 2013/34/EU** of the European Parliament and of the Council as regards the adjustments of the size criteria for micro, small, medium-sized and large undertakings or groups	21.12.2023	The size categories for the key figures (total assets, net sales) from Article 3 of Directive 2013/34/EU (Accounting Directive) are adjusted here (inflation adjustment)

Source: own compilation

Annex II.b. EU-CSRD: Relationship between EU-CSRD and telecom companies

Large telecommunications companies such as Deutsche Telekom AG, 1&1 AG and Telefónica Deutschland Holding AG must report for the previous financial year (i.e. for the first time for 2024) as part of the CSRD from 2025. Therefore, the sustainability reports and non-financial reports currently available do not yet meet the requirements of the CSRD. However, companies are preparing for the future requirements of the CSRD.

According to Fantini et al. (2024), selected European telecommunications companies[19] were already prepared in 2022 for some of the requirements they will face as part of the CSRD. For example, 44%-71% of the disclosure requirements from the ESRS were already fulfilled,

[19] According to Figure 3 in Fantini et al. (2024): six companies. However, it is not known exactly which six companies are meant.

including an average of 86% of general disclosures (ESRS 2), 65% of disclosures on corporate policy (ESRS G1), 50% of environmental disclosures (ESRS E1 - E5) and 57% of social disclosures (ESRS S1 - S4).

Table 7-6: Relationship between provisions of the ESRS and the categories of energy management, greenhouse gas emissions and circular economy that are relevant for telecommunications companies

Environmental aspects considered in this study	Disclosure Requirement	Indicators in connection with must-have indicators (see Table 1-1)	Method
Energy management	ESRS E1 E1-5 - Energy consumption and energy mix	Total energy consumption in MWh related to own operations from (a) fossil sources, (b) nuclear sources, (c) renewable sources[20] (paragraph 37)	It only reports energy consumption from processes owned or controlled by the company and applies the same scope as for reporting Scope 1 and Scope 2 emissions (AR 32a) -> **GHG Protocol Corporate Standard (AR39a)**
		disclose separately non-renewable energy production and renewable energy production in MWh (paragraph 39)	• The splitting of energy types[21] between renewable and non-renewable sources is based on the approach applied to calculate market-based Scope 2 GHG emissions. Energy is only recognized as renewable if the origin of the purchased energy is clearly defined in the contractual arrangements with its suppliers (renewable power purchasing agreement, standardised green electricity tariff, market instruments like Guarantee of Origin from renewable sources in Europe(50)or similar instruments like Renewable Energy Certificates in the US and Canada, etc.). (AR32j)
		energy intensity (total energy consumption per net revenue) associated with activities in high climate impact sectors. [22] (paragraph 40)	Total energy consumption in MWh per net revenue[23] in monetary unit (e.g. euros) (AR 36)

[20] Broken down by (i) fuel consumption from renewable sources, (ii) consumption from purchased and acquired energy from renewable sources, (iii) consumption of self-generated non-fuel renewable energy (p. 79., paragraph 37c)

[21] Electricity, steam, heat or cooling

[22] Climate-intensive sectors are the sectors listed in sections A to H and in section L (as defined in Regulation (EU) 2022/1288). Regulation (EU) 2022/1288 defines "climate-intensive sectors" as the sectors listed in Sections A to H and Section L of Annex I to Regulation (EC) No 1893/2006 of the European Parliament and of the Council

[23] Net revenue in accordance with the accounting standards applicable to the financial statements, i.e. IFRS 15 "Revenue from Contracts with Customers" or local accounting requirements. Amounts from the sale of products and services after deduction of sales deductions, VAT and other taxes directly related to sales.

Environmental aspects considered in this study	Disclosure Requirement	Indicators in connection with must-have indicators (see Table 1-1)	Method
GHG emissions	ESRS E1 E1-6 - Gross GHG emissions in Scope 1, 2 and 3 categories and total GHG emissions in metric tons of CO2 equivalent	• Scope 1 GHG gross emissions (paragraph 44 / paragraph 48) • Location-based and market-based Scope 2 GHG gross emissions (paragraph 44/ paragraph 49) • Scope 3 GHG gross emissions (from each significant Scope 3 category that is a priority for the company) (paragraph 44 / paragraph 51) • Total GHG emissions (sum of Scope 1, 2 and 3), differentiated by location-based and market-based methods (paragraph. 44; paragraph. 52)	• Company standard GHG Protocol (2004 version)[24] (AR 39a) • GHG protocol for the corporate value chain (Scope 3) (2011 version) (AR 46a) • Use of the latest values published by the IPCC for GWP100 (AR 39d)
		Greenhouse gas intensity (paragraphs 53 to 55)	Total GHG emissions in metric tons of CO2 equivalent per net revenue broken down by location-based and market-based methods (AR 53)
Circular economy	ESRS E5 E5-4 - Resource inflows	the weight in both absolute value and percentage, of secondary reused or recycled components, secondary intermediary products and secondary materials used to manufacture the company's products and services. (paragraph 31c)	The company shall provide information on the methodologies used to calculate the data. It shall specify whether the data is sourced from direct measurement or estimations, and disclose the key assumptions used. (paragraph 32).

	ESRS E5, E5-5 - Resource outflows	The total amount of waste generated in tons or kilograms:
		• a) the **total amount** of waste generated,
		• (b) the total quantity by weight diverted from disposal, broken down by hazardous and non-hazardous waste and by the following types of recovery operations:
		  • i. Preparation for reuse,
		  • ii. Recycling and
		  • iii. other recovery procedures (paragraph 37a&37b)
			The company shall provide contextual information on the methodologies used to calculate the data and in particular the criteria and assumptions.
			It shall specify whether the data is sourced from direct measurement or estimations; and disclose the key assumptions used. (paragraph 40)

Source: Own compilation based on the (European Commission 2023d): Delegated Regulation (EU) 2023/2772 of July 31, 2023; AR: application requirements

[24] "*The undertaking may consider Commission Recommendation (EU) 2021/2279 or the requirements stipulated by EN ISO 14064-1:2018. If the undertaking already applies the GHG accounting methodology of ISO 14064- 1: 2018, it shall nevertheless comply with the requirements of this standard (e.g., regarding reporting boundaries and the disclosure of market-based Scope 2 GHG emissions);)"* (p. 97, AR 39a, (European Commission 2023d)). (EU) 2021/2279: Product Environmental Footprint and Organization Environmental Footprint Methods ("PEF"/"OEF" method); ISO 14064-1: Greenhouse gases - Part 1: Specification with guidance for quantifying and reporting greenhouse gas emissions and removals at the organization level

Annex III. Summary of identified technically equivalent standards between ETSI, ITU and 3GPP

Table 7-7 provides an overview of the standards of the ETSI and ITU institutes, which are technically equivalent to each other. In the case of equivalence between the institutes, the latest standard is used. The ETSI standards were therefore taken into account in this study, as their publication date is more recent than that of the ITU standards. In addition, the Technical Specifications (TS) "**ETSI TS 128 554"** and "**ETSI TS 128 552"** were created by the ETSI 3rd Generation Partnership Project (3GPP). **ETSI TS 128 552 (3GPP TS 28.552)** defines performance measurements for 5G networks, including network slicing. Must-have indicators are described in **ETSI TS 128 554 (3GPP TS 28.554)** and have been considered in this study. **ETSI TS 128 552** serves as a reference for **ETSI TS 128 554** and has not been explicitly included, but the relevant content referenced in ETSI TS 128 554 has been considered.

Table 7-7: Overview of considered technically equivalent standards between ETSI, ITU and 3GPP

ETSI standard	Title	Technically equivalent ITU/3GPP standard	Title
ETSI ES 203 228 V1.4.1 (2022-04)	Environmental Engineering (EE); Assessment of mobile network energy efficiency	**ITU-T L.1331 (01/2022) / ITU-T L.1330 (03/2015)**	Assessment of mobile network energy efficiency / Energy efficiency measurement and metrics for telecommunication networks
ETSI ES 203 199 V1.2.1 (2024-11)	Methodology for environmental life cycle assessments of information and communication technology goods, networks and services	**ITU-T L.1410 (11/2024)**	Methodology for environmental life cycle assessments of information and communication technology goods, networks and services
ETSI ES 203 539 V1.1.1 (2019-06)	Environmental Engineering (EE); Measurement method for energy efficiency of Network Functions Virtualization (NFV) in laboratory environment	**ITU-T L.1361 (11/2018)**	Measurement method for energy efficiency of network functions virtualization
ETSI TS 128 554 V18.7.0 (2024-10)	5G; Management and orchestration; 5G end to end Key Performance Indicators (KPI)	**3GPP TS 28.554 version 18.7.0 Release 18**	3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Management and orchestration; 5G end to end Key Performance Indicators (KPI)
ETSI TS 128 552 V18.8.0 (2024-10)	5G; Management and orchestration; 5G performance measurements	**3GPP TS 28.552 version 15.7.0 Release 15**	3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Management and orchestration; 5G performance measurements

Source: Own compilation

Annex IV. Completeness check

Annex IV.a. Overview of the reviewed standards in three categories: latest version and technical equivalence (WP1)

Table 7-8: Overview of the reviewed standards in the energy management category

No.	Standards	Check for updates: new versions (status: 18.11.2024)	Technically equivalent
1	ETSI EN 303 215 V1.3.1 (2015-04)	An update is in preparation.	-
2	ETSI EN 303 471 V1.1.1 (2019-01)	-	-
3	ETSI EN 303 472 V1.1.1 (2018-10)	-	-
4	ETSI ES 201 554 V1.2.1 (2014-07)	-	-
5	ETSI ES 202 706-1 V1.8.0 (2024-07)	ETSI ES 202 706-1 V1.8.1 (2024-09)	-
6	ETSI ES 203 136 V1.2.1 (2017-10)	-	-
7	ETSI ES 203 184 V1.1.1 (2013-03)	-	-
8	ETSI ES 203 228 V1.4.1 (2022-04)	An update is in preparation.	**ITU-T L.1331 (01/2022); ITU-T L.1330 (03/2015)**
9	ETSI GS OEU 012 V1.1.1 (2015-10)	-	-
10	ETSI TR 102 530 V1.2.1 (2011-07)	-	-
11	ETSI TR 103 540 V1.1.1 (2018-04)	-	-
12	ETSI TR 103 541 V1.1.1 (2018-05)	-	-
13	ETSI TS 102 533 V1.1.1 (2008-06)	-	-
14	ETSI TS 102 706 V1.3.1 (2013-07)	-	-
15	ETSI TS 102 706-2 V1.7.1 (2024-07)	-	-
16	ETSI TS 103 786 V1.2.1 (2024-02)	ETSI TS 103 786 V1.3.1 (2024-09)	
17	ETSI TS 103 199 V1.1.1 (2011-11)	-	
18	GRI 302	-	-
19	GRI 307	Replaced by GRI 2-27[25]	-
20	GRI 308		-
21	ISO 14001:2015	-	-
22	ISO 14040:2006	DIN EN ISO 14040:2021-02	-
23	ISO 50001:2018	ISO 50001:2018/Amd 1:2024(en) Energy management systems - Requirements with guidance for use - AMENDMENT 1: Climate action changes	-
24	ITU-T L.1410 (12/2014)	ITU-T L.1410 (11/2024), not published	ETSI ES 203 199 V1.4.1_2024
25	ITU-T L.1310 (09/2020)	ITU-T L.1310 (09/2024)	-
26	ITU-T L.1325 (12/2016)	-	-
27	ITU-T L.1330 (03/2015)	-	ETSI ES 203 228 (see no. 8)
28	ITU-T L.1331 (09/2020)	ITU-T L.1331 (01/2022)	ETSI ES 203 228 (see no. 8)
29	ITU-T L.1350 (10/2016)	-	-
30	ITU-T L.1351 (08/18)	-	-
31	ITU-T L.1361 (11/2018)	-	ETSI ES 203 539 V1.1.1 (2019-06)

[25] https://www.globalreporting.org/media/zauil2g3/public-faqs-universal-standards.pdf (Question 34) (accessed 09.04.2025)

No.	Standards	Check for updates: new versions (status: 18.11.2024)	Technically equivalent
32	ITU-T L.1382 (06/2020)	-	-
33	ITU-T L.1390 (08/22)	-	-
34	ITU-T L.1420 (02/2012)	-	-
35	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	-	-
36	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	-	-
37	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	-	-
38	ETSI TS 105 200-2-3 V1.2.1 (2019-12)	-	-
39	ETSI TS 128 554 V18.7.0 (2024-10)	-	3GPP TS 28.554 version 18.7.0 Release 18
40	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	-	-
41	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	-	-
42	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	-	-
43	ITU-T L.1332 (01/2018)	-	-

Note: No 1 – No. 34: the standards specified by the client. Standards from No. 35 onwards were further considered in this study
Source: Own compilation.

Table 7-9: Overview of the reviewed standards in the GHG category

No.	Standards	Check for updates: new versions (status: 18.11.2024)	Technically equivalent
1	ETSI TS 103 199 V1.1.1 (2011-11)	-	-
2	ETSI **TS** 203 199 V1.4.0 (2024-07)	ETSI **ES** 203 199 V1.4.1 (2024-11)	ITU-T L.1410
3	GHG protocol calculation tool for emissions in Scope 1,2 and/or 3	-	-
4	GHG Protocol Corporate Accounting and Reporting Standard (2004), extension with Scope 2 Guidance (2015)	Under Revision / no draft publicly available	-
5	GRI 305-2	-	-
6	GRI 305-5	-	-
7	GRI 306	-	-
8	GRI 307	Replaced by GRI 2-27	-
9	GRI 308	-	-
10	ISO 14001:2015	-	-
11	ISO 14040:2006	DIN EN ISO 14040:2021-02	-
12	ISO 14064-1:2018	-	-
13	ISO 14064-2:2019	-	-
14	ITU-T L.1031 (06/2024)	-	-
15	ITU-T L.1410 (12/2014)	ITU-T L.1410 (11/2024), not published	ETSI ES 203 199 V1.4.1_2024 (see no. 2)
16	ITU-T L.1420 (02/2012)	-	-
17	ITU-T L.1450 (09/2018)	-	-
18	ITU-T L.1470 (01/2020)	-	-
19	ITU-T L.1471 (08/2023)	-	-
20	Product Life Cycle Accounting and Reporting Standard (2011)	-	-
21	Protocol Corporate (Value Chain) Standard (2011)	Under Revision / no draft publicly available	

No.	Standards	Check for updates: new versions (status: 18.11.2024)	Technically equivalent
22	GSMA, GeSI, ITU Scope 3 Guidance for Telecommunication Operators	-	Supplement 57 to ITU-T L.1420: Scope 3 Guidance for Telecommunication Operators (06/2023)

Note: No 1 – No. 21: the standards specified by the client. Nr.22 Standard was further considered in this study
Source: Own compilation.

Table 7-10: Overview of the reviewed standards in the circular economy category

No.	Standards	Check for updates: new versions (status: 18.11.2024)	Technically equivalent
1	ETSI TS 103 199 V1.1.1 (2011-11)	-	
2	GRI 306	-	
3	ISO 14001:2015	-	-
4	ISO 14040:2006	DIN EN ISO 14040:2021-02	-
5	ITU-T L.1031 (06/2024)	-	
6	ITU-T L.1036 (02/2022)	-	
7	ITU-T L.1020 (01/2018)	-	
8	ITU-T L.1410 (12/2014)	ITU-T L.1410 (11/2024), not published	ETSI ES 203 199 V1.4.1_2024
9	ITU-T L.1022 (2019)	-	-
10	ITU-T L.1023 (2023)	-	-
11	ITU-T L.1050 (2022)	-	-
12	ETSI TR 103 476 V1.1.2 (2018-02)	-	-
13	DIN EN 45556	-	-
14	DIN EN 45557	-	-
15	ETSI EN 305 174-8 V1.1.1 (2018-01)	-	-
16	ETSI TS 105 174-8 V1.2.1 (2019-12)	-	-

Note: No 1 – No. 8: the standards specified by the client Standards from No. 9 onwards were further considered in this study
Source: Own compilation.

Two added European standards EN 45556 and EN 45557 originate from ETSI EN 303 808 V1.1.1 (2023-01). ETSI EN 303 808 V1.1.1 (2023-01) examines to what extent the general EN standards, EN 45552 - EN 45559, are applicable to ICT network infrastructures. The conclusion is that the standards EN 45556, EN 45557, EN 45558 and EN 45559 are in principle directly applicable to ICT network infrastructures. EN 45558 and EN 45559 provide general methodological approaches to critical raw materials and material efficiency aspects, but these are not the focus of this study and are therefore not considered further. EN standards 45556 and 45557, which deal with the reuse potential and the recycled content, are analyzed in more detail in phases WP2 and WP3. In addition, an indicator for the recycling and reuse rate is introduced in the EoL based on the calculation methodology of ETSI EN 305 174-8 V1.1.1 (2018-01).

In addition, the ETSI EN 305 174-8 V1.1.1 (2018) standard was introduced in accordance with BEREC (2023) for the "Recycling and reuse rate at end-of-life (EoL)" indicator.

Annex IV.b. Reasons for the exclusion of the standards for WP1

Table 7-11: Reasons for the exclusion of the standards for WP1 in the energy management category

Category Level 1	Category level 2	Standards	Reason for the exclusion of the standards
General standards	Organization / Company (5)	GRI 2-27	a general reporting standard, not specifically relevant for networks. Reporting of material violations of laws and regulations
		GRI 302	Organizational reporting standard offers great flexibility at the methodological level in the choice of calculation method and is not specifically tailored to telecommunications networks. Organizations can calculate their energy consumption or energy efficiency data according to their own preferences. The calculation of energy consumption outside the organization (reference to upstream & downstream chain) is based on **GHG Protocol Corporate Value Chain (Scope 3)**, which is considered in the GHG category.
		GRI 308	concerns Scope 3, where only the reporting is described; there is no concrete methodological approach for assessing the environmental impact
		ISO 14001:2015	The ISO standard is overarching and stipulates that environmental aspects with a significant environmental impact must be identified and corresponding environmental targets set. However, it does not contain any specific methodology or indicators for determining the most significant environmental aspects. This standard is mentioned in several laws[26]
		ISO 50001:2018	is not specifically tailored to telecommunications networks. Companies can calculate their energy consumption or energy efficiency data according to their own preferences. This standard is mentioned in several laws.[27] According to Section 8 (EnEfG), companies with an annual average total final energy consumption within the last three completed calendar years of more than 7.5 gigawatt hours are obliged to introduce an energy or environmental management system (e.g. in accordance with ISO 50001) (BGBl. 2023 I Nr. 309 2023).
	General products and services (1)	DIN EN ISO 14040:2021-02	The life cycle assessment according to ISO 14040/14044 evaluates products and services holistically over their entire life cycle - from raw material extraction, energy and material production to use, waste treatment and disposal. However, it is too granular and methodologically too variable to determine the necessary must-have indicators, which is why it is unsuitable for this purpose.

[26] e.g. a) Environmental Audit Act (UAG) as a reference in the approval as an environmental verifier: Certification certificates according to ISO 14001 may be awarded through the approval; or b) Ordinance on Statistics on the Award of Public Contracts and Concessions (Vergabestatistikverordnung - VergStatVO): ISO 14001 is mentioned as an example of a sustainability criterion in the award procedure; or c) Ordinance on Specialist Waste Management Companies, Technical Inspection Organizations and Waste Management Associations (Ordinance on Specialist Waste Management Companies - EfbV): ISO 14001 as an example of a possible qualification as an expert, consideration of results of the audit of the environmental management system

[27] e.g. definition of an energy management system in accordance with ISO 50001 in a) Act on Energy Services and Other Energy Efficiency Measures (EDL-G); or b) Ordinance on Systems for Improving Energy Efficiency in Connection with Relief from Energy and Electricity Tax in Special Cases (Peak Equalization Efficiency System Ordinance - SpaEfV); or c) Act to Increase Energy Efficiency in Germany (Energy Efficiency Act - EnEfG)

Category Level 1	Category level 2	Standards	Reason for the exclusion of the standards
ICT-specific standards	Organization/ Company (1)	ITU-T L.1420 (02/2012)	ICT-specific organization-related standards. Not network-specific. These standards are considered in the GHG category.
	ICT equipment, networks and services (2)	ETSI ES 203 199 V1.4.1_2024	- This is an ICT-specific life cycle assessment method (life cycle analysis) based on ISO 14040/14044. -Energy-relevant must-have indicators are not defined.
		ETSI TS 103 199 V1.1.1 (2011-11)	This technical specification (TS) 103 199 has been replaced by the ES standard 203 199.
Telecommunications network-specific standards	ICT equipment and devices (5)	• ETSI EN 303 215 V1.3.1 (2015-04) • ETSI ES 203 136 V1.2.1 (2017-10) • ETSI ES 203 184 V1.1.1 (2013-03) • ETSI TS 102 533 V1.1.1 (2008-06) • ITU-T L.1310 (09/2024)	Standards at device level focus on the individual properties and energy consumption of individual devices. not at network level
	Networks / ICT locations (12)	ETSI ES 202 706-1 V1.8.1 (2024-09)	The average power consumption of the base station is based on laboratory measurements under static conditions at low, medium and peak load according to a reference configuration.
		ETSI GS OEU 012 V1.1.1 (2015-10)	on data center
		-ETSI TS 103 786 V1.3.1 (2024-09) -ETSI TS 102 706-2 V1.7.1 (2024-07)	Dynamic measurement method and measurement specification for determining the energy efficiency in relation to the data volume for wired 5G NR and 4G base stations under variable data loads. However, the standards are based on laboratory tests.
		ETSI ES 201 554 V1.2.1 (2014-07)	mobile radio core network devices and the Radio Network Controller (RNC) of the 3G radio access network. It has not been updated since its publication in July 2014. Most of the technologies covered are now obsolete. The standard is based on laboratory tests
		ETSI TR 102 530 V1.2.1 (2011-07)	-General principles and considerations for energy measurement are described, but there is no specific method defined as a standard for electricity measurement. -A proposal for calculating the energy efficiency of fixed broadband devices is based on normalized power consumption in relation to data rate and transmission distance. However, these are not must-have indicators and the underlying technical reporting standard has not been updated since 2011.
		ETSI TR 103 541 V1.1.1 (2018-05)	Best practice for assessing the energy efficiency of radio access networks (RAN). Recommended indicators according to ETSI ES 203 228, which is already being taken into further consideration
		ETSI TS 102 706 V1.3.1 (2013-07)	This technical specification (TS) 102 706 has been superseded by ETSI ES 202 706-1 V1.8.1, ETSI TS 102 706-2 V1.7.1 (2024-07) and ETSI TS 103 786 V1.3.1 (2024-09).

Category Level 1	Category level 2	Standards	Reason for the exclusion of the standards
		ITU-T L.1325 (12/2016)	Green ICT solutions for telecommunications network infrastructures. No indicators are specified.
		ETSI ES 203 539 V1.1.1 (2019-06)/ITU-T L.1361 (11/2018)	Measurement method is for laboratory and pre-deployment tests to evaluate and compare the energy efficiency of VNFs. The measurement method is explicitly excluded for a real operational NFV (Network Function Virtualization) environment.
		ITU-T L.1382 (06/2020)	Smart energy solution for telecommunication rooms. Neither indicators nor a specific methodology for measuring energy are specified.
		ITU-T L.1390 (08/2022)	Energy-saving technologies and best practices for 5G radio access networks (RAN). Neither indicators nor a specific methodology for measuring energy are specified.

Source: Own compilation

Table 7-12: Reasons for the exclusion of the standards for WP1 in the GHG category

Category Level 1	Category level 2	Standards	Reason for the exclusion of the standards
General standards	General and reporting standards (7)	GRI 305-2	• 305-2 regulates the reporting of indirect energy-related GHG emissions (Scope 2). • The requirements for GHG emissions in this standard are based on the requirements of the "GHG Protocol Corporate Accounting and Reporting Standard" ('GHG Protocol Corporate Standard') and "GHG Protocol Scope 2 Guidance". These two standards are examined in more detail in phases WP2 and WP3.
		GRI 305-5	• 305-5 regulated Reduction of greenhouse gas emissions, i.e. reduction of greenhouse gas emissions as a direct result of reduction initiatives, in tons CO2-eq • Does not include its own method for calculating greenhouse gas emissions, but only refers to reporting on a company's emission reduction measures and not to the quantified recording and reporting of greenhouse gas emissions; and no must-have indicators
		GRI 306	• Waste-related indicators (in the circular economy category) • It relates exclusively to waste management/recycling processes (reference to circular economy).
		GRI 2-27	A general reporting standard, not specifically relevant for networks. Reporting of material violations of laws and regulations.
		GRI 308	Concerns Scope 3: Only the reporting is described here; there is no specific methodological approach for assessing the environmental impacts.
		ISO 14001:2015	The ISO standard is overarching and stipulates that environmental aspects with a significant environmental impact must be identified and corresponding environmental targets set. However, it does not contain any specific methodology or indicators for determining the most significant environmental aspects. This standard is mentioned in several laws.
		ISO 14064-1:2018	-regulates the quantification of greenhouse gas emissions and removals -In connection with the CSRD, reference was made to the GHG Protocol Corporate Standard as a mandatory methodology in the regulatory context. The "Disclosure requirement E1-6" in accordance with Delegated

Category Level 1	Category level 2	Standards	Reason for the exclusion of the standards
			Regulation (EU) 2023/2772 also refers to the OEF method (Recommendation (EU) 2021/2279) and ISO 14064-1:2018 as supplementary, voluntary methods. However, the requirements of the GHG Protocol Corporate Standard must be met in all cases. In addition, research into the sustainability reports of telecommunications companies shows that the GHG Protocol Corporate Standard is the preferred basis for organization-related greenhouse gas balances. For this reason, this standard was not discussed in further detail in sections WP2 and WP3.
	General products and services (2)	DIN EN ISO 14040:2021-02	The life cycle assessment according to ISO 14040/14044 evaluates products and services holistically over their entire life cycle - from raw material extraction, energy and material production to use, waste treatment and disposal. However, it is too granular and methodologically too variable to determine the necessary must-have indicators, which is why it is unsuitable for this purpose.
		Product Life Cycle Accounting and Reporting Standard (2011)	The standard provides requirements and guidelines for the quantification and public reporting of greenhouse gas emissions and reductions associated with a specific product. However, an in-depth consideration was excluded, as only organization-related indicators were analyzed in this context.
	Projects (1)	ISO 14064-2:2019	-Specially designed for climate protection projects that aim to reduce greenhouse gas emissions. -Provides a framework for quantifying greenhouse gas reductions at project level. The standard includes, for example, determining the spatial and temporal scope of the project, e.g. determining the spatial and temporal scope of the project, defining the baseline scenario, etc. - However, it does not regulate a fixed method for calculating emission reductions; these should be defined in line with the respective climate protection projects. -Not specific to telecommunications networks or operators.
ICT-specific standards	Organization/Company (1)	ITU-T L.1471 (08/2023)	Although the standard has an organizational focus, it does not contain any helpful information on data collection; for this, reference is made to ITU-T L.1420. ITU-T L.1420 will be examined in more detail in phases WP2 and WP3.
	ICT equipment, networks and services (4)	ETSI TS 103 199 V1.1.1 (2011-11)	This technical specification (TS) 103 199 has been replaced by the ES standard 203 199.
		ETSI ES 203 199 V1.4.1 (2024-11)/ITU-T L.1410	-It is an ICT-specific life cycle assessment method (life cycle analysis) based on ISO 14040/44. -It is not intended for organizational balance
		ITU-T L.1031 (06/2024)	It relates exclusively to waste management/recycling processes (reference to circular economy).
		ITU-T L.1450 (09/2018)	Focus on product or process level (life cycle of a product/process).
	ICT equipment & networks (1)	ITU-T L.1470 (01/2020)	Not useful for calculating organization-related GHGs, as the focus of the standard is on the entire ICT sector and compliance with SBTi target lines.

Source: Own compilation

Table 7-13: Reasons for the exclusion of the standards for WP1 in the circular economy category

Category Level 1	Category level 2	Standards	Reason for the exclusion of the standards
General Standards (2)	Organization / Company (1)	ISO 14001:2015	The ISO standard is overarching and stipulates that environmental aspects with a significant environmental impact must be identified and corresponding environmental targets set. However, it does not contain any specific methodology or indicators for determining the most significant environmental aspects.
	General products and services (1)	DIN EN ISO 14040:2021-02	The life cycle assessment according to ISO 14040/14044 evaluates products and services holistically over their entire life cycle - from raw material extraction, energy and material production to use, waste treatment and disposal. However, it is too granular and methodologically too variable to determine the necessary must-have indicators, which is why it is unsuitable for this purpose.
ICT-specific standards (6)	Organization/Company (1)	ITU-T L.1020 (01/2018)	The standard provides a basis for players in the ICT sector to develop circular business models independently. It does not contain any specific key figures or measurement methods.
	ICT equipment, networks and services (3)	ETSI TS 103 199 V1.1.1 (2011-11)	This technical specification (TS) 103 199 has been replaced by the ES standard 203 199.
		ETSI ES 203 199 V1.4.1 (2024-11) / ITU-T L.1410	-This is an ICT-specific life cycle assessment method (life cycle analysis) based on ISO 14040/14044. -The standard describes a methodical approach for balancing reuse, recycling and refurbishment at material and component level. However, this is too detailed for the must-have indicators examined in this study at product level.
		ITU-T L.1022 (2019)	It is a framework standard or guideline on aspects of the circular economy, but does not specify any specific indicators. The EN 45556 standard is used to assess the proportion of reused components in energy-related products. An in-depth examination of EN 45556 is carried out in phases WP2 and WP3.
	ICT equipment and devices (2)	ITU-T L.1031 (06/2024)	Two different methods (market supply methodology and consumption-based methodology) for compiling an e-waste inventory are explained. However, both methods are for the compilation of an inventory at country level.
		ITU-T L.1023 (2023)	The standard is used to assess the circularity of an individual product, particularly in the product design phase. The overall assessment of the circularity performance of entire organizations is not taken into account - this would be too complex for the objective of this study.
Telecommunications network-specific standards (2)	Base stations (1)	ITU-T L.1036 (02/2022)	The standard provides a framework for the environmentally sound waste management system of e-waste and hazardous waste (SW: scheduled waste[28]) in base stations. There are no specific indicators.

[28] Original definition of SW: "*Any waste that possesses hazardous characteristics and has the potential to adversely affect public health and the environment*" (ITU-T L.1036 (02/2022), page 9).

Category Level 1	Category level 2	Standards	Reason for the exclusion of the standards
	Total networks (1)	ITU-T L.1050 (2022)	Although the standard does not contain any indicators, it identifies relevant telecommunications devices differentiated by network segment. The identified devices are listed in a table. This list can serve as a basis for recording relevant e-waste in the network.

Source: Own compilation

Annex V. Greenhouse Gas Protocol

Annex V.a. 15 Scope 3 categories according to the Greenhouse Gas Protocol Initiative (2011)

Table 7-14 lists the 15 Scope 3 categories according to the GHG Protocol. Scope 3 categories include all indirect emissions that are not already covered by Scope 2. A distinction is made between upstream and downstream activities of an organization.

Table 7-14: Scope 3 categories according to the Greenhouse Gas Protocol Initiative (2011)

Scope 3: categories	Explanation
1. Purchased goods and services	Extraction, production and transportation of goods and services not included in categories 2 - 8.
2. Capital goods	Extraction, production and transportation of capital goods purchased or acquired by the reporting company.
3. Fuel- and energy-related activities (not included in scope 1 or scope 2)	Upstream emissions from extraction, production and transportation of purchased fuels and electricity, transmission and distribution losses
4. Upstream transportation and distribution	• Transportation and distribution of products purchased by the reporting company • Transportation and distribution services purchased by the reporting entity In each case in vehicles and facilities not owned or controlled by the reporting company.
5. Waste generated in operations	Disposal and treatment of waste generated by the operations of the reporting entity, where the treatment takes place externally. takes place externally.
6. Business travel	Transportation of employees for business-related activities (excl. transportation with the company fleet).
7. Employee commuting	Transportation of employees between their homes and workplaces in the reporting year (excl. transportation with the company fleet).
8. Upstream leased assets	Operation of assets leased from the reporting entity (tenant) that are not included in Scope 1 and 2.
9. Downstream transportation and distribution	emissions from the transportation and distribution of products sold by the company, including storage. sold by the company, including storage.
10. Processing of sold products	emissions from the further processing of intermediate products sold by the sold by the company to third parties.
11. Use of sold products	emissions from the use of goods and services sold by the company. sold by the company.
12. End-of-life treatment of sold products	emissions from waste disposal and treatment of products sold. products.
13. Downstream leased assets	emissions from the operation of assets leased from third parties and owned by the company.
14. Franchises	emissions from the operation of franchises controlled by the company.
15. Investments	emissions associated with the company's investments, such as shareholdings in other companies (the company's activities must be taken into account in line with the size of the shareholding).

Source: Greenhouse Gas Protocol Initiative (2011)

Annex V.b. GHG Protocol Tools

The GHG Protocol website[29] provides various tools and associated guidelines to assist with the calculation of greenhouse gas emissions. A basic distinction can be made between the following tools:

- Cross-industry tools
- Country-specific tools
- Sector-specific tools
- Tools for countries and cities

The country-specific tools relate to production processes that are irrelevant for telecommunications companies, such as the production of cement or pulp and paper. In addition, the geographical reference to China, Mexico, India and the USA is not suitable for calculating network-related activities in Germany. The tools for countries and cities are also not suitable for the purposes of telecommunications companies, as they do not have a company or product-related scope.

Furthermore, the sector-specific tools are not considered relevant for the targets discussed in this study. They start at the level of materials or semi-components and indicate selected relevant emissions for this. However, they are too detailed to examine the overall environmental impacts of telecommunications networks (see Table 7-15).

Table 7-15: Overview of the sector-specific tools of the GHG Protocol

Product/raw material	Emissions from the production of products/raw materials
Aluminum	CO_2 and PFC emissions
Adipic acid	N_2O emissions
Ammonia	Ammonia
Cement	Greenhouse gases (GHG)
Iron and steel	CO_2
HCFC-22	HFC-23 emissions
Nitric acid	N_2O emissions
Pulp and paper	CO_2, CH_4 and N_2O emissions
Semiconductors	PFC emissions
Wood	CO_2, CH_4 and N_2O emissions
Lime	CO_2

Source: https://ghgprotocol.org/calculation-tools-and-guidance#sector_specific_tools_id, accessed 15.05.2025

Among the existing tools, there are none that relate specifically to the telecommunications sector. However, there are some cross-sector tools that can be used to calculate organization-related activities, such as GHG emissions from stationary and mobile combustion or the use of purchased electricity. There are also tools that can assist with uncertainty assessment. However, it should be noted that some of the tools are now outdated and cannot be used without first checking the underlying factors. An overview of the tools and an assessment of their relevance for telecommunications companies can be found in Table 7-16. The tools updated in 2024 are highlighted in yellow in the table below.

[29] Available at: https://ghgprotocol.org/calculation-tools-and-guidance, status: 29.04.2025

Table 7-16: Cross-industry tools provided by the GHG Protocol

Title on website	Title of the tool	Version	Current version	Purpose of the tool	Relevance for the present study
Allocation of Emissions from a Combined Heat and Power (CHP) Plant	Allocation of emissions from a combined heat and power (CHP) plant	1.0	September 2006	This Tool is intended to facilitate the allocation of GHG emissions attributable to the purchase or sale of energy from a combined heat and power (CHP) plant.	The efficiency factors stored in the calculation tool need to be updated, but the underlying method for allocating emissions from a CHP plant can be used. However, it is probably not of great significance for telecom network-related activities.
Measurement and Estimation Uncertainty of GHG Emissions	Aggregation of statistical parameter uncertainty in greenhouse gas inventories	n/a	September 2003	This tool is intended to facilitate the aggregation and classification of statistical parameter uncertainties due to random errors in the calculation of greenhouse gas emissions. It uses the first-order propagation method (Gaussian method).	document is outdated, but the general methodological procedure for calculating parameter uncertainty can be used.
Scope 3 Uncertainty Calculation Tool	Uncertainty assessment template for product GHG inventories	n/a	November 2016	This file illustrates a procedure for applying uncertainty assessment to product GHG inventories under the GHG Protocol.	Generally applicable for the product-related calculation of GHG uncertainty. Product-related GHG calculation is partly relevant for Scope 3, e.g. for categories 1, 10, 11, 12.
GHG Emissions from Transport or Mobile Sources	Calculation of GHG emissions from mobile combustion	2.7	September 2024	This tool calculates the CO_2, CH_4 and N_2O emissions of the following vehicles: • Vehicles that are owned or controlled by a person • Public (or outsourced) transportation • Mobile machines, such as construction machinery.	Relevant for the calculation of Scope 1 and 3; the emission factors (EFs) were updated in 2024 for the UK and US, there are no Germany-specific EFs. Telecom networkrelevant activities that can be calculated in this way are, for example, trips for the telecom network maintenance
Refrigeration and Air-Conditioning Equipment	Calculation of HFC and PFC emissions from the manufacture, maintenance and/or disposal of refrigeration and air conditioning systems	1.0	February 2005	This guideline is intended to facilitate the measurement and reporting of direct greenhouse gas emissions of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) generated during the manufacture, maintenance and disposal of refrigeration and air conditioning equipment.	GWP factors of HFCs and PFCs are outdated, this data would need to be reviewed and updated if the tool is to be used.
Emission Factors	Emission factors from the cross-sector tools	2.0	March 2024	This tool contains cross-sectoral emission factors and unit conversions that can be used to estimate emissions from stationary combustion plants, purchased electricity and mobile combustion plants.	High relevance for the calculation of Scope 1. With regard to Scope 2, the GHG Protocol Initiative points out that international emission factors for electricity are no longer provided, but

Title on website	Title of the tool	Version	Current version	Purpose of the tool	Relevance for the present study
					can be purchased from the International Energy Agency.
GHG Emissions from Stationary Combustion	Calculation of GHG emissions from stationary combustion	4.2	August 2024	This tool calculates CO_2, CH_4 and N_2O emissions from the combustion of fuels in boilers, furnaces and other stationary combustion plants. It can be used by organizations from all industries.	High relevance for the calculation of Scope 1 emissions from stationary combustion; data is up-to-date and can be used. However, stationary incineration plants are probably of minor relevance for network -related activities.
Global Warming Potential Values	IPCC values for the global greenhouse gas potential	2.0	August 2024	The document contains global warming potential (GWP) characterisation factors for a period of 100 years. The GWP characterisation factors s are taken from the IPCC assessment report from 2020 (AR6).	The GWP characterisation factors are required for the conversion of emission values, for example from methane to CO_2equivalents.

Source: Own compilationfrom https://ghgprotocol.org/calculation-tools-and-guidance (Status: 29.04.2025)

Annex V.c. Revision and development of the GHG Protocol

Table 7-17: Overview of which standards and guidelines are being revised or developed by the GHG Protocol

Standard	Status
GHG Protocol Corporate Accounting and Reporting Standard (2004)	Revision, finalization 2027
GHG Protocol Scope 2 Guidance (2015)	Revision, finalization 2027
Scope 3: Protocol Corporate (Value Chain) Standard (2011)	Revision, finalization 2027
Land Sector and Removals Guidance	Revision, finalization Q4 2025
GHG Accounting and Reporting on the Impacts of Actions and Market Instruments	Standard development, finalization 2028

Source: Huckins (2025)

Annex VI. Research results on Sustainability Reporting by Telecommunications Network Operators

The following Table 7-18 compares the sustainability reporting of German telecommunications network operators with regard to the presentation and accounting of their GHG emissions. Scope 3 activities with a clear connection to the network are highlighted in blue.

Table 7-18: Sustainability reporting by telecommunications network operators in Germany

Name of the company	Report on sustainability and climate available?	If so, according to which method?	Aspects considered in Scope 1	Aspects considered in Scope 2	Aspects considered in Scope 3: upstream	Aspects considered in Scope 3: downstream	Source
Telekom Deutschland GmbH	Yes	GHG Protocol	• Direct emissions Fuels Fleet • Direct emissions Fossil fuels	Market- and location-based: • Indirect emissions Electricity • Indirect emissions District heating • Indirect emissions Electricity consumption vehicle fleet	• Transportation services, • acquired products and services, • Capital goods, • Production waste, • Energy and fuel supply chains, • Business trips • Way to work • Rented and leased capital goods	• Transportation of sold products to the customer, • Use of sold and rented products • Disposal and recycling of products sold • Investments	**Deutsche Telekom AG (2023a)**
Vodafone GmbH	Yes	GHG Protocol	• Fuels from vehicles owned by Vodafone or leased for six months or longer • Natural gas and other heating fuels used for space heating and water heating • Diesel and gasoline used for generators in off-grid areas or where back-up capacity is required • Volatile releases of coolants or fire extinguishing	Market- and location-based: • Electricity • Heating/cooling • Steam	• Purchased goods and services • Capital goods • Energy and fuel-related activities • Upstream & downstream transportation and distribution (aggregated) • Waste • Business trips • Commuting • Rented or leased property, plant and equipment	• Use/utilization of products sold • End-of-life treatment of products sold • Property, plant and equipment rented or leased • Franchise retail stores • Investments in network operators	Vodafone Group Plc (2024)

Name of the company	Report on sustainability and climate available?	If so, according to which method?	Aspects considered in Scope 1	Aspects considered in Scope 2	Aspects considered in Scope 3: upstream	Aspects considered in Scope 3: downstream	Source
			agents from air conditioning or fire protection systems				
Telefónica Germany GmbH & Co. OHG	Yes	GHG Protocol, ISO 14064, ITU-T L. 1420	Direct emissions • from fuel consumption • from fossil fuels (natural gas) • from refrigerants	Market- and location-based: • Electricity • Heat	• Purchased goods and services (aggregated with upstream and downstream transportation) • Capital goods • Fuel and energy-related activities	• Use of products sold (aggregated with disposal of products sold)	Telefónica Deutschland Holding AG (2023a)
Freenet AG	Yes	GHG Protocol	• Fleet fuels (petrol, diesel) • Heating consumption • Refrigerants were not taken into account for reasons of materiality	Market- and location-based: • Electricity • District heating	• Employee vehicle model • Travel activities • Payment Services • Standard contract documents in customer communication	• Parcel shipping	freenet AG (2023)
United Internet AG	Yes	GHG Protocol; sector-specific guidance of the "Groupe Spéciale Mobile Association" (GSMA) for telecommunications operators	• Thermal energy consumption gas and heating oil • Fuel consumption in data centers & technical locations • Emission of volatile gases (coolants) from refrigeration systems	Market- and location-based: • Electricity • District heating	• Purchased goods and services • Capital goods • Fuel and energy-related emissions • Transportation and distribution (upstream) • Business trips • Commuting of employees	• Waste • Processing of the products sold • Use of the products sold • Dealing with products sold at the end of their life cycle • Investments	United Internet AG (2025)

Name of the company	Report on sustainability and climate available?	If so, according to which method?	Aspects considered in Scope 1	Aspects considered in Scope 2	Aspects considered in Scope 3: upstream	Aspects considered in Scope 3: downstream	Source
					• Rented or leased property, plant and equipment		
NetCologne GmbH	Yes	GHG Protocol	Not specified	Market-based: • Electricity • District heating	n/a	n/a	Stadtwerke Köln GmbH (2022)
Deutsche GigaNetz GmbH	Yes	n/a	n/a According to the ESG report, the GHG emissions from all scopes are calculated, but they are not published	n/a	n/a	n/a	Deutsche GigaNetz GmbH (2023)
Tele Columbus AG	Yes	GHG Protocol	Vehicle fleet Heating energy	Market- and location-based: • Electricity purchasing	• T&D line losses • Business trips • Employee commuting • Electricity home office • Product utilization • Electricity distribution board (NE4)[30] • Material purchasing • Hardware (network) purchasing • Hardware (CPE[31]) Purchasing	• Logistics (parcel shipping) • Mailings (paper)	Tele Columbus AG (2023)

[30] NE4 refers to grid level 4, which is typically the level that supplies end consumers via the low-voltage grid.
[31] CPE (Customer Premises Equipment) refers to the telecommunications or network equipment owned by the end user and installed at their location (e.g. in a home or office).

Name of the company	Report on sustainability and climate available?	If so, according to which method?	Aspects considered in Scope 1	Aspects considered in Scope 2	Aspects considered in Scope 3: upstream	Aspects considered in Scope 3: downstream	Source
					• Underground construction for network expansion (laying cables) • Heating rental properties • Logistics (procurement of goods)		
1&1 AG	Yes	GHG Protocol	Company car Thermal energy consumption (gas, heating oil)	Market- and location-based: Electricity consumption, district heating	• Purchased goods and services • Capital goods • Fuel and energy-related emissions • Transportation and distribution • Waste • Business trips • Commuting of employees • Rented or leased property, plant and equipment	• Use of the products sold • Dealing with products sold at the end of their life cycle	1&1 AG (2023)
M-net Telekommunikations GmbH	Yes	GHG Protocol	Heating oil, natural gas, refrigerants, vehicle fleet	Market- and location-based: Electricity consumption, district heating	-	-	M-net Telekommunikations GmbH (2023)

Source: Own compilation. Scope 3 activities with a clear reference to the network are marked in blue.

Annex VII. Detailed evaluation of the comparative analysis (WP2): Energy management

Annex VII.a. Overview of the selected 15 standards: Energy management

Table 7-19: Overview of the selected 15 standards: Energy management

Abbreviation	Name	Network segment
ETSI EN 303 472 V1.1.1 (2018-10)	Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for RAN equipment	RAN: 2G/3G/4G
ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	Environmental Engineering (EE); Assessment of mobile network energy efficiency	RAN: technology-independent
ETSI TR 103 540 V1.1.1 (2018-04)	Environmental Engineering (EE); Mobile Network (MN) Energy Consumption (EC) estimation method; Energy estimation method based on statistical approach	RAN: technology-independent
ITU-T L.1350 (10/2016)	Energy efficiency metrics of a base station site	RAN: technology-independent
ITU-T L.1351 (08/2018)	Energy efficiency measurement methodology for base station sites	RAN: technology-independent
ETSI EN 305 200-2-3 V1.1.1 (2018-06)	Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 3: Mobile broadband access networks	RAN: technology-independent
ETSI TS 105 200-2-3 V1.2.1 (2019-12)	Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Implementation of Global KPIs; Part 2: Specific requirements; Sub-part 3: Mobile broadband access networks	RAN: technology-independent
ETSI EN 305 200-2-2 V1.2.1 (2018-08)	Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 2: Fixed broadband access networks	FAN: technology-independent
ETSI TS 105 200-2-2 V1.3.1 (2019-12)	Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Implementation of Global KPIs; Part 2: Specific requirements; Sub-part 2: Fixed broadband access networks	FAN: technology-independent
ETSI ES 205 200-2-4 V1.1.1 (2015-06)	Integrated broadband cable telecommunication networks (CABLE); Energy management; Global KPIs; Operational infrastructures; Part 2: Specific requirements; Sub-part 4: Cable Access Networks	CAN: technology-independent
ETSI TS 128 554 V18.7.0 (2024-10)	5G; Management and orchestration; 5G end to end Key Performance Indicators (KPI) (3GPP TS 28.554 version 18.7.0 Release 18)	5G mobile network: RAN, core network, end-to-end, NFV, slicing
ETSI EN 305 200-3-1 V1.1.1 (2018-02)	Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 3: ICT Sites; Sub-part 1: DCEM (Note: DCEM: Data processing and Communications Energy Management)	ICT location: Core network
ETSI TS 105 200-3-1 V1.2.1 (2019-12)	Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Implementation of Global KPIs; Part 3: ICT Sites; Sub-part 1: DCEM	ICT location: Core network
ITU-T L.1332 (01/2018)	Total network infrastructure energy efficiency metrics	ICT location: entire network

Abbreviation	Name	Network segment
ETSI EN 303 471 V1.1.1 (2019-01)	Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for Network Function Virtualization (NFV)	Entire access network: NFV

Source: Own compilation

Annex VII.b. Definition of the three-level model (high, medium, low) for the comparative analysis in the energy management category

Table 7-20: Definition of the three-level model (high, medium, low) for the comparative analysis in the energy management category

Evaluation criteria	No. of the evaluation aspects	Evaluation aspects	Classification of the evaluation criteria: Definition of the three-level model (high, medium, low)
Robustness	**A1.1**	**Method of data collection:** energy consumption	•Low: Estimation based solely on manufacturer information (e.g. technical data sheets) •medium: combination of on-site measurement (e.g. power consumption) and calculation (e.g. measured power consumption × operating time, or extrapolation). •high: exclusive on-site measurement in real operation with electricity meters (grid utility or on-site sources)
Robustness	**A1.2**	**Method of data collection:** the other reference variable, if available	•low: exclusive estimation of the data volume based on e.g. data rates, subscriber numbers •medium: combination of direct measurement and estimation of data volume •high: exclusive direct measurement of the data volume in real operation (Note: the energy efficiency must-have indicator is based on data volume)
Reproducibility	**A2.1**	**Measurement methodology:** On-site measurement: measurement period and measurement frequency	•low: No defined measuring period or measuring frequency •medium: Measurement in fixed periods with/without defined measurement frequency •high: Continuous measurement that realistically reflects annual seasonal fluctuations and load variations. with specified or documented measurement frequency.
Reproducibility	**A2.2**	**Measurement methodology:** On-site measurement: Ambient conditions	•low: No requirements for the recording or consideration of ambient conditions •medium: Ambient conditions are recognized as an influencing factor for energy consumption, but without documentation requirements. •high: Ambient conditions (e.g. temperature, humidity) are clearly defined, recorded and documented during measurements in real operation.
Reproducibility	**A2.3**	**Measurement methodology:** Measurement on site: Measuring instruments	•low: No specific requirements for the quality or calibration of the measuring instruments •medium: Measuring instruments with basic quality and optional calibration •high: Measuring instruments with high quality and mandatory calibration

Evaluation criteria	No. of the evaluation aspects	Evaluation aspects	Classification of the evaluation criteria: Definition of the three-level model (high, medium, low)
Reproducibility	**A2.4**	**Measurement methodology:** On-site measurement: Measuring points	•low: Measuring points are not defined •medium: Measuring points are generally described but not precisely defined •high: Measuring points are precisely defined by a detailed description of the physical position (e.g. input of the transformer) or by reference to diagrams
Reproducibility	**A2.5**	**Methodological definition:** Allocation rules or delimitation of the scope of application	•Low: No defined allocation rules or unclear delimitation of the scope of application •medium: Allocation rules or scope of application are generally described but not precisely defined •high: Allocation rule is precisely defined; or scope of application is clearly defined, e.g. standard is only applicable under common governace → allocation is not necessary
Credibility	**A3.1**	**Assessment of uncertainties / data quality**	•low: No assessment of uncertainties or data quality provided. •medium: Assessment of uncertainties or data quality optional. •high: Assessment of uncertainties or data quality mandatory.
Credibility	**A3.2**	**Validation**	•low: No validation planned, or validation optional •medium: internal validation required as a minimum •high: external validation required
Transparency	**A4**	**Reporting**	•Low: No systematic requirements for reporting on metric results and framework conditions. •Medium: Reporting of metric results and/or basic input parameters. •high: Detailed general information on the test framework conditions (system under test, test conditions, location and equipment) as well as indicator results and basic input parameters in a standardized report template.

Source: Own compilation

Annex VII.c. Results of the assessment aspects and background information on the standards for the comparative analysis in the energy management category

Table 7-21: Overview of the assessment aspects and background information of the standards for the comparative analysis in the category energy management: Mobile access network (RAN) - Part 1

Evaluation criteria	Evaluation aspects	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)
Background	**Assignment of the network segment**	**RAN: 2G/3G/4G**	**RAN: technology-independent**	**RAN: technology-independent**
Background	**Area of application**	•Only applicable to base station sites that support a single operator network. Shared base stations and sites used by two or more operators are not considered. •Primarily **for trend analyses**, not for BS comparisons (except for similar operating conditions)	•Applicable for mobile network operators to enable a better understanding of the energy efficiency of networks, especially taking into account the evolution of networks over different time periods	•Enables the estimation of the total energy consumption of a mobile access network (RAN) based on measurement data from selected sites. •Does not take into account infrastructure such as cooling or power supply units, but only the energy consumption of ICT devices
Background	**Goals**	Energy efficiency of **radio access networks** and/or infrastructures	•Defines indicators for the energy efficiency of mobile access networks and methods for assessing (and measuring) energy efficiency in operational networks. •Enables **extrapolation** of results from small networks to larger networks (e.g. nationwide)	Energy estimation method based on 2 **statistical approaches**: Basic estimation method and stratified estimation method
Background	**Scope**	BS site: 1) ICT equipment (incl. ITE&NTE) 2) Infrastructure	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure	BS locations: ICT equipment only (incl. ITE&NTE)
Background	**Technical representativeness**	•3G: UTRA, WCDMA •4G: E-UTRA, LTE •2G: GSM •NFV: not G10mentioned	Evaluation of energy efficiency in the **mobile access network** (2G/3G/4G/5G) with extrapolation to the overall mobile access network.	•homogeneous and heterogeneous networks, and technologies such as GSM (2G), UMTS (3G) and LTE (4G). •NFV: not mentioned
Background	**Consideration of various energy sources**	Electrical energy from renewable and non-renewable sources, from the grid or through self-supply	Electrical energy from renewable and non-renewable sources, from the grid or through self-supply	energy types are not explicitly mentioned. As the standard only measures the consumption of ICT devices, the energy consumption would be independent of the source (mains power or self-supply) as long as the

Evaluation criteria	Evaluation aspects	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)
				measurement is carried out directly on the device.
Background	**Indicators**	**<u>1) BS site:</u>** **- $KPI_{EE\text{-}capacity}$ =∑data_volume/(E_{SI}+∑E_{BS}) (Mbits/Wh)** E_{BS} is the total energy consumption of each BS of the BS site during the measurement period; E_{SI} is the total energy consumption of the support infrastructure of the BS site during the measurement period **- $KPI_{EE\text{-}coverage}$ and CoA_Qdes $KPI_{EE\text{-}coverage}$=$A_{(coverage)}$ /(E_{SI}+∑E_{BS}) (km²/Wh)** **- $KPI_{EE\text{-}site}$=∑$E_{(BS)}$ / (E_{SI}+∑E_{BS}) (%)** **<u>2) Extended BS Site:</u>** **- $KPI_{REN\text{-}tot}$= ($EL_{renewable\ grid}$+ $EL_{renewable\ on\ site}$) / $EL_{(tot)\ (\%)}$** **- $KPI_{(REN\text{-}onsite)}$ =($EL_{renewable\ on\ site}$) / ($EL_{renewable\ on\ site}$+ $EL_{non\text{-}renewable\ on\ site}$) (%)**	**-Mobile Network (MN) Energy Consumption (EC_{MN}) (Wh)**: the sum of the energy consumption of each equipment included in the MN under investigation. This includes base stations (BS), backhauling (BH), site infrastructure (SI), radio controllers (RC), as well as central cloud (CC) and local cloud (LC) entities **-Mobile Network data Energy Efficiency ($EE_{MN,DV}$) (bit/J)**: the ratio between the data volume (DV_{MN}) and the Energy Consumption (EC_{MN}) when assessed during the same time frame. **-Mobile Network coverage Energy Efficiency ($EE_{MN,CoA}$) (m²/J):** the ratio between the area covered by the MN under investigation and the energy consumption when assessed **during one year**. **-Site Energy Efficiency (SEE) (%)**: the ratio of the energy consumed by ICT equipment (e.g.base stations), to the total energy consumption of the site, which includes both the ICT equipment and the site infrastructure. -Does not explicitly define a metric for renewable energy; however, it requires reporting the percentage of energy derived from renewable sources on site.	Energy consumption of the RAN as an absolute value with the margin of error
Background	**Other reference variable** (only relevant for calculating the energy efficiency indicators.)	•The useful data volume (excluding retransmission) •the designated coverage area (CoA_des); • a coverage quality factor (CoA_Qdes)	•Data volume •Coverage area •Latency •Registered subscribers •Demographics (population density) •Topography (physical structure of the terrain: flat, hilly, mountainous) •Climate zones (climatic conditions: tropical, dry, temperate, cold, very cold)	Not relevant

Evaluation criteria	Evaluation aspects	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)
Background	**Dependencies between standards**	•Power and energy consumption measurement methods: ETSI ES 202 336-12 •Data volume: ETSI ES 203 228	•The measurement of energy efficiency for virtualised devices (virtual network functions, NFV) is based on **ETSI EN 303 471**. •Energy measurement can be carried out in accordance with **ETSI ES 202 336-12**. •Data volume: → 2G/3G/4G: according to **ETSI TS 132 425 and ETSI TS 132 412** →5G: in accordance with **ETSI TS 128 552 / ETSI TS 128 554.**	not mentioned
Background	**Description of the measurement methodology:** Specific measurement steps defined in the standard or alternative standards referenced	•Power and energy consumption measurement methods and accuracy shall meet the requirements of ETSI ES 202 336-12 •The useful data volume (excluding retransmission) [Mbits] shall be collected on Radio Link Control (RLC) Layer 3 as defined as DVMN of ETSI ES 203 228.	•Energy: By means of meter information from electricity supply companies, by integrated measuring systems of the mobile network or by sensors for locations and devices in accordance with ETSI ES 202 336-12 •Data volume (bit) (UL and DL): measured → 2G/3G/4G: By means of network-internal software counters in accordance with ETSI TS 132 425 and ETSI TS 132 412, taking into account the QoS (Quality of Service). → 5G: By measuring the quantity of DL/UL-PDCP-SDU bits (Packet Data Convergence Protocol Service Data Unit) in accordance with ETSI TS 128 552 / ETSI TS 128 554. •Coverage area (m²): Based on network planning area, supplemented by a coverage quality factor from operational statistics, without additional measurements. •Demography / topography / climate zones: Statistics.	1)Basic Estimation Method: • individual choice to select a confidence level •While the sample size is an individual choice, it is recommended that the sample measurement consist of: at least 50 of the network sites, representing at least 5 % of the network; randomly; 2)Stratified Estimation Method •define the mobile network Strata -> individual choice; however guidance and examples are provided.
Robustness	**Method of data collection:** energy consumption	Energy: on-site measurement	•Energy: By means of meter information from electricity supply companies, by integrated measuring systems of the mobile network or by sensors for locations and devices in accordance with ETSI ES 202 336-12	Energy (ICT devices): -Measurements on site, or -Data from the electricity supplier, if: -Consumption is stated in watt hours, -only location-relevant devices are included, -transmission losses (TLAF) are known and removed, and -energy costs are not used for the calculation.

Evaluation criteria	Evaluation aspects	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)
Robustness	**Method of data collection:** the other reference variable, if available	•Data volume: **Measurement** •The coverage area (km²) is estimated by the designated coverage area (CoA_des) and a coverage quality factor (CoA_Qdes)	•The data volume is recorded using internal network software counters. •The coverage area is determined based on the network planning and supplemented by a coverage quality factor. •The extrapolation from the sub-network to the overall network must be based on the demographic classes. The demographic classes (e.g. Rural, Urban) must be selected so that they represent at least 75 % of the area of the overall network. Optionally, it can also be based on topography classes, climate zones or a combination of all three factors.	Not relevant
Reproduci-bility	**Measurement methodology:** On-site measurement: measurement period and measurement frequency	•Measurement period: -Continuous, 365 days as standard; -A shorter measurement period (at least 7 days) is permissible if it realistically reflects annual values and is not seasonally distorted. •Measurement frequency: not fixed and remains flexible, but must be clearly documented in the measurement report.	•Measurement period: flexible; can be weekly (7 days), monthly (30 days) or yearly (365 days). •Measurement frequency: not defined, but should be documented in the report.	The measurement period is freely selectable, but the estimate of the energy consumption is limited to this period and must be stated together with the energy consumption.
Reproduci-bility	**Measurement methodology:** On-site measurement: Ambient conditions	•Temperature: No fixed values are specified, but it is necessary to document the internal and external temperature with the respective minimum, maximum and average values in the measurement report. The environmental class should also be documented. •Other environmental parameters: No direct requirement, indirectly taken into account via the documentation of the site and the site equipment.	•Environmental conditions are implied by capturing demographics, topography and climate zones to assess the energy efficiency of the network under different geographic and population influences. •The minimum, maximum and average temperatures (internal and external) can be documented in the report, but are not mandatory.	No specific requirements for environmental conditions such as temperature. However, the stratified method clearly defines external temperature as a possible criterion for defining strata (see Table 1, 4.3.2)

Evaluation criteria	Evaluation aspects	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)
Reproducibility	**Measurement methodology:** On-site measurement: Measuring instruments	•Energy: Measurement methods/accuracy must comply with ETSI ES 202 336-12.	•Energy: Measurement methods/accuracy must comply with ETSI ES 202 336-12.	No explicit requirement for the measuring instruments
Reproducibility	**Measurement methodology:** On-site measurement: Measuring points	Electrical power from the grid supplied to site infrastructure and telecom equipment. The exact positions are not specified.	The measuring points are focussed at site level and differentiate between ICT and infrastructure consumption. The exact positions are not specified.	No explicit requirement for the measuring points. -In the case of the basic method: the sample comprises at least 50 locations or 5 % of the network -For the strata method: the sample is distributed across the strata in order to better reflect the heterogeneity of the network.
Reproducibility	**Methodological definition:** Allocation rules or delimitation of the scope of application	•Allocation: in the case of multi-standard BS (multiple technologies provided by one BS) the measured BS power consumption shall be allocated to each technology based on total RF power ratio of the technologies. -Allocation for shared sites between different network operators is not necessary as the standard does not take this case into account.	Shared infrastructure: If several mobile network operators (MNOs) share the same sites, the energy consumption for each MNO is divided separately between the MNOs on the basis of commercial agreements or best practice.	•There is a proportional allocation of measurement points to the strata in the stratified method, based on the number of sites in each stratum. •There is no specific regulation on how to deal with shared infrastructure.
Credibility	**Assessment of uncertainties / data quality**	not mentioned	not mentioned	The Margin of Error of the Mobile Network Estimate shall be calculated
Credibility	**Validation**	not mentioned	not mentioned	not mentioned
Transparency	**Reporting**	•Detailed templates (general information; energy consumption report; KPI report) available for reporting	•Template for report generation available •Detailed requirements for the aspects to be reported, broken down according to the tested sub-network, the analysed locations and their measurement results such as energy consumption, data volume and coverage. •For the CoA (Coverage Area) indicator, the energy consumption must always be extrapolated to one year.	•no template •The confidence level, period of estimation and margin of error, Sample-based estimation of energy consumption

Table 7-22: Overview of the assessment aspects and background information of the standards for the comparative analysis in the category energy management: Mobile access network (RAN) - Part 2

Evaluation criteria	Evaluation aspects	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Background	**Assignment of the network segment**	**RAN: technology-independent**	**RAN: technology-independent**	**RAN: technology-independent**	**RAN: technology-independent**
Background	**Area of application**	Applicable for mobile network operators (MNOs)	• Applicable to energy efficiency measurements of base station sites according to [ITU-T L.1350]. •It can be used as a **conformity assessment standard for ITU-T L.1350.**	•Applicable for a mobile radio access network managed by a network operator. •Primarily for trend analyses, not for a comparison between mobile access networks •This approach makes it possible to apply regulatory objectives to mobile access networks which have the greatest individual energy	-Applicable for a mobile radio access network managed by a network operator. -Primarily for trend analyses, not for a comparison between mobile radio access networks
Background	**Goals**	•Assessment of the energy efficiency of a base station location, taking into account energy consumption	Determination of the measurement of parameters, the requirements for measuring points, measuring conditions and instrumentation	Definition of requirements for the calculation of indicator (energy consumption, energy efficiency, share of renewable energy) for mobile access networks under common governance	**Supporting the requirements of ETSI EN 305 200-2-3** and detailing the implementation
Background	**Scope**	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure
Background	**Technical representativeness**	•Base station locations, independent of technologies •NFV: not mentioned	•Base station locations, independent of technologies •NFV: not mentioned	•for mobile broadband access networks, independent of technologies such as 2G/3G/4G/5G •NFV: NFV devices belong to the RAN of a network operator, but can be operated at other locations. Their energy consumption must be included in the overall energy balance of the access network. In the case of multiple use, only the consumption for the mobile access network is taken into account. If not	Compared to ETSI EN 305 200-2-3, ETSI TS 105 200-2-3 also takes 5G developments such as small cells and multi-access edge computing (MEC) into account.

Evaluation criteria	Evaluation aspects	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
				possible, the report will state: "Consumption without NFV activities"	
Background	**Consideration of various energy sources**	• electricity from the grid • electricity generated on site: by diesel or other types of generators or from renewable sources	• electricity from the grid • electricity generated on site: by diesel or other types of generators or from renewable sources	•Electricity from the grid •Locally generated non-renewable or renewable energy •Any proportion in the mix of utility electricity supplies certified as **"renewable"** by electricity suppliers or in accordance with nationally recognized schemes is **not recognized** in this standard.	In accordance with ETSI EN 305 200-2-3.
Background	**Indicator**	**Site Energy Efficiency (SEE) =** energy consumption of telecommunication equipment (E_{CT}) / total site electrical energy consumption (E_{TS}), E_{TS} is the sum of Electrical energy from a public grid and Electrical energy locally generated	Metrics same as in ITU-T L.1350	• **Energy consumption (KPI_{EC}) (kWh)**: Sum of energy consumption at the operator sites (OS) and energy consumption at the network distribution nodes (NDN). • **Task effectiveness (KPI_{TE}) (bits/Wh)**: total data volume per unit of energy consumed (KPI_{EC}) • **Renewable energy (KPI_{REN}) (%)**: Share of renewable energy in the network's total energy consumption (KPI_{EC})	• **Energy consumption (KPI_{EC}) (kWh)**: additionally, introduction of **energy consumption of small cells (e.g. microcells, picocells, femtocells)** • The rest is the same as in ETSI EN 305 200-2-3.
Background	**Other reference variable** (only relevant for calculating the energy efficiency indicator.)	Not relevant. The focus is only on energy	Not relevant. The focus is only on energy	•Data volume (upstream and downstream)	•Data volume (upstream and downstream)
Background	**Dependencies between standards**	own measurement according to ETSI ES 202 336-12 •Energy meters in the field must fulfil the Class 1 requirements according to [IEC 62053-21].	• ITU-T L.1350 •Measurement reports according to [ISO/IEC 17025] •Energy meters in the field must fulfil the Class 1 requirements according to	•Data volume: ETSI EN 303 472 (normative) •ETSI EN 305 200-1: General requirements for global KPIs for energy management in operational infrastructures.	•ETSI EN 305 200-2-3 as a basis •Compared to ETSI EN 305 200-2-3, ETSI EN 303 472 is no longer normative, but informative.

Evaluation criteria	Evaluation aspects	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
			[IEC 62053-21]. •Requirements for voltage and current measuring devices are specified in [ITU-T L.1315].		
Background	**Description of the measurement methodology:** Specific measurement steps defined in the standard or alternative standards referenced	•Measurement can be direct energy meter, or calculated as a product of voltage and current. •Electricity from the grid: through measurement information from utility companies or own measurement in accordance with **ETSI ES 202 336-12**- •Energy generated on site: via meters or sensors installed on site	•The measurement can be calculated directly as an energy meter or as a product of voltage and current. For DC-supplied equipment, the measuring point is interface A in accordance with [ETSI EN 300 132-2] •energy generated on site: by meters or sensors installed on site	•Energy: Energy is measured either by energy meters from the utility company or by meters installed on site by the telecom network operator. •Data volume: **ETSI EN 303 472**	•Energy: measured, estimated •Data volume: measurement
Robustness	**Method of data collection:**energy consumption	•Continuous real-time monitoring enables trend analyses, but is not always feasible. •Alternatively, a defined, repeatable process should regularly record energy consumption. There are no clear rules; operators must document the process transparently. •The measurement of electrical energy from the electricity grid should be carried out using kWh meters. Energy consumption of telecoms equipment can be calculated as a product of volts, amps and measurement duration.	Energy: On-site measurement with kWh meters or alternatively calculation by measuring voltage and amperage.	•Energy: measurement on site, whereby power measurements are permitted as an alternative, but must be clearly designated as $KPI_{EC\text{-}power}$. •Manufacturer information on appliances may be used to estimate energy consumption in exceptional cases.	•Own metering devices at locations in the access network would be ideal for complete metering, but are often impractical due to high costs and the complexity of large networks. •Energy bills from electricity / gas / fuel suppliers •Estimation by the MNO based on samples of typical access network locations •Internal device measurement: devices with their own consumption recording by e.g. software •Energy consumption of small cells is estimated (number × maximum consumption), as they are often operated by third parties (e.g. end users) and cannot be measured directly by the MNO (mobile network operator).

Evaluation criteria	Evaluation aspects	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Robustness	**Method of data collection:** the other reference variable, if available	Not relevant. The focus is only on energy	Not relevant. The focus is only on energy	Data volume: Measurement according to **ETSI EN 303 472**	•Data volume measurement focuses on aggregated/centralised points (e.g. core network) instead of base stations, granularity flexible. •This represents a broader interpretation than that described in ETSI EN 305 200-2-3, which provides for measurements at base station locations in accordance with ETSI EN 303 472. •One innovation is MEC (Multi-access Edge Computing). Data is no longer necessarily routed through the core network. Each MEC requires data volume recording.
Reproduci-bility	**Measurement methodology:** On-site measurement: measurement period and measurement frequency	•Measurement period: Continuous real-time monitoring is recommended. If not practicable or economical, regular measurements are required as an alternative. When reporting the SEE value, the value averaged over one year should be used. •Measurement frequency: not specified and no documentation required.	•Measurement period: four options for the measurement period (1 day, 1 week, 1 month or 1 year). •Measurement frequency: at least every 15 minutes	•Measurement period: -Continuous, 365 days as standard; -A shorter measurement period (at least 7 days) is permissible if it realistically reflects annual values and is not seasonally distorted. •Measurement frequency: must be between one week and one calendar month •Δt: the maximum permitted deviation at the start time of the measurements.Δt must be less than 2 % of T_{KPI}.	Not explicitly stated. The test is carried out in accordance with EN 305 200-2-3.
Reproduci-bility	**Measurement methodology:** On-site measurement: Ambient conditions	no specification. However, the standard describes environmental conditions as variable influencing factors that affect energy efficiency.	no specification. However, the standard describes environmental conditions as variable influencing factors that affect energy efficiency.	Environmental conditions are described as an influencing factor for energy consumption, but there are no clear requirements for recording or documentation	The consideration of the supporting infrastructure (including cooling) implies that the environmental conditions are recognised as an influencing factor.

Evaluation criteria	Evaluation aspects	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Reproducibility	**Measurement methodology:** On-site measurement: Measuring instruments	•Accuracy requirements for measuring devices are specified. •Energy measuring devices in the field must fulfil the Class 1 requirements in accordance with [IEC 62053-21].	•Accuracy requirements for measuring devices correspond to those in ITU-T L.1350. •Energy meters in the field must fulfil the Class 1 requirements according to [IEC 62053-21]. •Requirements for voltage and current measuring devices are specified in [ITU-T L.1315]. •Calibrated AC and DC energy meters must be used.	not mentioned	not mentioned
Reproducibility	**Measurement methodology:** On-site measurement: Measuring points	•electricity for ICT equipment: located at the power supply interface of the telecoms equipment, taking into account energy losses through the cable. •On-site generated electricity: measured at the output of the local power source (e.g. diesel generator, solar panel) before the power is fed into the site •electricity from the grid: measured at the entrance of the site, where the energy from the public grid enters.	•electricity for ICT equipment: at the input, as close as possible. •The following applies to other power sources: →Basic rule: The energy is normally measured directly at the source (at the grid connection for power from the grid, generator output, output of the renewable source. →Exception: If there is only a single source (no other loads, generators or renewable sources), the measurement can alternatively be taken at the input of the power supply equipment (e.g. distribution unit).	•Measurement at the entrance of the NTE (Network Telecommunications Equipment) at each OS (Operator Site) and at the entrance of each NDN (Network Distribution Node), including the consumption of the infrastructure if it is under joint management.	In accordance with ETSI EN 305 200-2-3.

Evaluation criteria	Evaluation aspects	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Reproducibility	**Methodological definition:** Allocation rules or delimitation of the scope of application	•A shared site is considered as a single unit without splitting the energy consumption of the individual operators/services.→ No clear allocation rule	not mentioned	The standard remains at the overall metering level and applies to the network owned by the same network operator. The shared infrastructure is explicitly excluded. •Flexible with Network Function Virtualisation (NFV): If NFV devices support multiple access networks, the power consumption is allocated for the mobile network under consideration. There is no fixed rule for this. If allocation is not possible, NFV can be excluded, but with a note in the report.	This TS addresses several allocations: •For shared network facilities (e.g. infrastructure or active network component sharing), the allocation is based on energy costs. •In difficult cases (e.g. mixed sites with access network, core network and office equipment), the energy consumption of MEC-ITE does not need to be recorded separately; instead, the total energy consumption of the mobile network can be used as the KPI_{EC}
Credibility	**Assessment of uncertainties / data quality**	not mentioned	not mentioned	not mentioned	not mentioned
Credibility	**Validation**	not mentioned	not mentioned	not mentioned	not mentioned
Transparency	**Reporting**	•No template •No systematic reporting requirements	•No template •ITU-T L.1351 specifies and extends the reporting obligations compared to ITU-T L.1350 with additional information on location, devices, instruments and test setup according to ISO/IEC 17025.	•No template •should report indicator results and 3 basic time specifications: 1) repetition time (measurement frequency); 2) time span between measurements; 3) evaluation period	•a template available •should report indicator results and 3 basic time information: 1) repetition time (measurement frequency); 2) time span between measurements; 3) evaluation period •In addition: 1) separate presentation of energy consumption of OS, NDN and small cells; 2) total number of operational sites (OS), network device nodes (NDN) and small cells.

Source: Own compilation

Table 7-23: Overview of the assessment aspects and background information of the standards for the comparative analysis in the category energy management: fixed access network (FAN) and cable access network (CAN)

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)
Background	**Assignment of the network segment**	**FAN: technology-independent**	**FAN: technology-independent**	**CAN: technology-independent**
Background	**Area of application**	•Applicable for a fixed access network managed by a network operator. •Primarily for trend analyses, not for comparison between fixed access networks •This approach makes it possible to apply regulatory objectives to mobile access networks which have the greatest individual energy	In accordance with ETSI EN 305 200-2-2	•It is applicable for cable access networks (CAN: Cable Access Network) and focuses on the operator-side infrastructure from the headend (corresponds to the operator sites, referred to as headend in the cable network context) to the customer interface, which is defined as the Network Interface Unit (NIU). It is used to quantify and optimise energy efficiency in the CAN area. •Energy consumption and devices in the customer area (e.g. NIU, set-top boxes) are outside the scope of application.
Background	**Goals**	Definition of requirements for the calculation of indicators (energy consumption, energy efficiency, share of renewable energies) for fixed access networks under common governance	**Supporting the requirements of ETSI EN 305 200-2-2** and detailing the implementation	defines indicators for evaluating the energy efficiency of cable access networks (CAN), in particular the hybrid fibre coax (HFC) network segment between the head end (HE) - the central control and management interface between the core network and users - and the network interface unit (NIU) at the end user.
Background	**Scope**	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure	**1) ICT & network components:** -Headend (HE); CMTS (Cable Modem Termination System); EdgeQAM (Edge Quadrature Amplitude Modulator); CCAP (Converged Cable Access Platform); optical transmitters/receivers; -Outside Plant (OSP): Fibre Nodes (FN), Amplifiers, Taps, Couplers, Coaxial Cable, Power Supply (PS). **2) Infrastructure:** The focus is on the network-specific components and their direct energy consumption. Supporting infrastructure such as

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)
				cooling or PDUs **is not** explicitly taken into account.
Background	**Technical representativeness**	Copper lines, fibre to the distribution point (FTTC), fibre to the building (FTTB) and fibre to the home (FTTH)	Copper lines, fibre to the distribution point (FTTC), fibre to the building (FTTB) and fibre to the home (FTTH), - including customer premises equipment (CPE).	Transmission technology such as DOCSIS (Data Over Cable Service Interface Specification), DVB-C (Digital Video Broadcast Cable)
Background	**Consideration of various energy sources**	•Electricity from the grid •renewable energy: generated on site or purchased from the grid (avoid double counting)**-Green'** •Any proportion in the mix of utility electricity supplies certified as "**renewable**" by electricity suppliers or in accordance with nationally recognized schemes is **not recognized** in this standard.	In accordance with ETSI EN 305 200-2-2	•Electricity from the grid •Locally generated non-renewable and renewable energy •Green' energy in the electricity mix that is certified as renewable by electricity suppliers or national regulations is not recognised in this standard.
Background	**Indicators**	•**Energy Consumption (KPI_{EC}) (Wh)**: Sum of the total energy consumption → of all network telecommunications equipment at all Operator Sites (OS), → of all network telecommunications equipment at all Network Distribution Nodes (NDN), and → of all network telecommunications equipment at all Last Operator Connection Points (LOC), including supporting infrastructure where under common governance. •**Task Effectiveness (KPI_{TE}) (bits/Wh)**: Ratio of the total data volume at all Operator Sites to the total energy consumption of the fixed access network (KPI_{EC}) •**Renewable Energy (KPI_{REN})**	• Same as in ETSI EN 305 200-2-2 • Supplement in conjunction with EN 305 200-2-2 →Adds C_{CP} as a new metric to explicitly capture the energy consumption of customer-premises (CP) powered devices	• **Energy Performance KPI (KPI_{EP}) (MB/kWh)** is s calculated as the total effectively data volume (in MB) divided by the energy consumption (in kWh) over the considered period of time such as one hour. • **Energy consumption (KPI_{EC}) (kWh)**: Energy consumption is calculated by multiplying the measured or manufacturer-specified power consumption (in kW) by the operating time (in hours). • **Renewable energy (KPI_{REN}) (%)**: Share of renewable energy in the network's total energy consumption (KPI_{EC}).

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)
		(%): Ratio of the total renewable energy consumption at all Operator Sites, Network Distribution Nodes (NDN), and Last Operator Connection Points (LOC) to the total energy consumption of the fixed access network (KPI_{EC})		
Background	**Other reference variable** (only relevant for calculating the energy efficiency indicator.)	•Data volume	•Data volume	•Data volume: direct measurements or estimation using utilisation of the upstream/downstream channels
Background	**Dependencies between standards**	ETSI EN 305 200-1: General requirements for global KPIs for energy management in operational infrastructures.	ETSI EN 305 200-2-2	ETSI ES 205 200-1: General requirements for global KPIs for energy management in operational infrastructures. Note: ETSI ES 205 200-1 is not ETSI EN 305 200-1, as other standards in the ETSI EN 305 200 series refer to the general requirements of ETSI EN 305 200-1 in context. This difference could be due to the fact that ETSI ES 205 200-2-4 is an ETSI Standard (ES), whereas ETSI EN 305 200-1 is a European Standard (EN).
Background	**Description of the measurement methodology:** Specific measurement steps defined in the standard or alternative standards referenced	•Energy: Energy is measured either by energy meters from the utility company or by meters installed on site by the telecom network operator. •Two options for measuring the data volume: →Preferred if technology allows: measurement of data sent and received at a specific operator site (OS). →Alternatively: A combination of measured and estimated data.	•Energy: Supplement in conjunction with EN ETSI EN 305 200-2-2 for customer premises (CP) devices;C_{CP}: Estimate with 25 % of the maximum consumption of CP devices based on manufacturer specifications •Data volume: Measurement continues to take place at the core interfaces of the OS (operator sites), but MEC (Multi-access Edge Computing) traffic must be tracked separately.	No reference level for the measurement is mentioned

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)
Robustness	**Method of data collection:**energy consumption	•Preferred: The energy consumption should be measured in watt hours (Wh) by electricity meters (e.g. by energy suppliers or the operator's own meters). •Alternative method: Power measurement in watts (W): If direct measurement of energy consumption in Wh is not possible, the energy consumption can be estimated by regular power measurements in watts (W). In this case, the resulting KPI must be labelled as estimated. •If the energy consumption of OS, NDN and LOC is provided by the utility company, its values can be used, provided that the method remains consistent with statistical extrapolation and changes are documented to ensure a valid trend analysis.	•In accordance with ETSI EN 305 200-2-2 •Supplement in conjunction with EN 305 200-2-2 1) Clarification: Most ICT-Sites use electricity meters from the energy supplier for monthly consumption recording, which is used for billing. 2)If direct measurement is not possible, the maximum consumption of the appliances can be used in accordance with the manufacturer's technical specifications. 2)CP appliances (which are supplied with electricity by the end customer): Estimation of the consumption of customer-side devices (e.g. ONTs, FTTdp modems) by manufacturer specifications	•The power consumption is preferably measured directly on site. Alternatively, the manufacturer's specifications for the power consumption of the appliances can be used. •The energy calculation is based on this measured or specified power consumption multiplied by the period under consideration. •The sum of the power consumption is made up of the headend (HE) and the outside plant (OSP). The OSP comprises active components outside the head end, such as fibre nodes and amplifiers, and serves as a shared infrastructure for several customer connections Note: the NIU is a measurement reference point for the data volume, as it marks the end point of the network at the user. However, the energy consumption of the NIU is not included in the CAN calculation. Only the energy of components between the head end and the NIU (without the NIU itself) counts.
Robustness	**Method of data collection:** the other reference variable, if available	Two options for measuring the data volume: •Preferred: Direct recording of the data sent/received at the interfaces of the network termination equipment (NTE) of an operator site (OS), if technically possible. • Alternatively: Combination of measured data traffic at the core network connection of the OS and estimated internal traffic of the FAN	In accordance with ETSI EN 305 200-2-2	•Data volume: Direct measurement (the preferred method) or estimation based on the utilisation of the upstream and downstream channels if no direct measurement data is available

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)
Reproducibility	**Measurement methodology:** On-site measurement: measurement period and measurement frequency	•Measurement period: -Continuous, 365 days as standard; -A shorter measurement period (at least 7 days) is permissible if it realistically reflects annual values and is not seasonally distorted. -Measurement frequency: must be between one week and one calendar month •Δt: the maximum permitted deviation at the start time of the measurements.Δt must beless than 2 % of T_{KPI}.	In accordance with ETSI EN 305 200-2-2	•Measurement period: 1 day •Measurement frequency: not mentioned
Reproducibility	**Measurement methodology:** On-site measurement: Ambient conditions	Environmental conditions are described as an influencing factor for energy consumption, but there are no clear requirements for recording or documentation	In accordance with ETSI EN 305 200-2-2	not mentioned
Reproducibility	**Measurement methodology:** On-site measurement: Measuring instruments	not mentioned	In accordance with ETSI EN 305 200-2-2	not mentioned
Reproducibility	**Measurement methodology:** On-site measurement: Measuring points	•Energy: Operator Sites (OS)/Network Distribution Nodes (NDN)/Last Operator Connection Points (LOC): Measurement at the sites, including the supporting infrastructures if they are under common governance. •Data volume: Ports of the NTEs (network telecommunications devices) connected to the FAN (preferred option). The alternative method measures the data volume at the connection to the core network if the NTEs do not allow direct capture, and	•In accordance with ETSI EN 305 200-2-2 •Supplement in conjunction with EN 305 200-2-2 CPE: No direct measuring points, estimate based on device specifications (Note: CPE devices (Customer Premises Equipment) are not within the scope of this study)	•power consumption: →HE: preferably by direct measurements with a power meter at the appliance input or estimation based on manufacturers specifications if measurements are not available. →OSP: The power is measured at the power supply unit for all network components. •Data volume: →REF_{HE}: The reference point REF_{HE} is the starting point of the HFC network segment in the head end. The entire transmitted data volume (broadcast, downstream, upstream) is recorded here, e.g. by monitoring the CMTS and EdgeQAM outputs.

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)
		supplements this with estimates for internal FAN traffic.		→ REF_{NIU}: The REF_{NIU} reference point is the end point of the HFC network segment at the end user. The received (downstream) and transmitted (upstream) data volume is measured here, e.g. by measurement in the cable modem or by estimation based on channel utilisation (see kDS, kUS).
Reproducibility	**Methodological definition:** Allocation rules or delimitation of the scope of application	The standard remains at the overall metering level and applies to the network owned by the same network operator. The shared infrastructure is explicitly excluded. •Flexible with Network Function Virtualisation (NFV): If NFV devices support multiple access networks, the power consumption is allocated for the mobile network under consideration. There is no fixed rule for this. If allocation is not possible, NFV can be excluded, but with a note in the report.	This TS addresses several allocations: •In the case of shared network facilities (e.g. infrastructure or active network component sharing), the allocation is based on energy costs.	not mentioned
Credibility	**Assessment of uncertainties / data quality**	not mentioned	not mentioned	not mentioned
Credibility	**Validation**	not mentioned	not mentioned	not mentioned
Transparency	**Reporting**	•No template •should report indicator results and 3 basic time specifications: 1) repetition time (measurement frequency); 2) time span between measurements; 3) evaluation period	•Template available •should report indicator results and 3 basic time specifications: 1) repetition time (measurement frequency); 2) time span between measurements; 3) evaluation period •Additional basic information such as: Name of fixed network access, total number of OS (operating sites), NDN (network distribution nodes) and CP devices.	not mentioned

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)
			•Differentiation as to whether the energy consumptionwasmeasured directly (KPI_{EC}) or approximated via power measurements ($KPI_{ECpower}$) •Integrates C_{CP} into KPI_{EC}, but reporting does not specify any additional details.	

Source: Own compilation

Table 7-24: Overview of the assessment aspects and background information of the standards for the comparative analysis in the category energy management: core network and entire network

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ITU-T L.1332 (01/2018)
Background	**Assignment of the network segment**	**ICT location: Core network**	**ICT location: Core network**	**ICT location: entire network**
Background	**Area of application**	•Applicable for network operators; the focus is on ICT sites that contain ICT devices, regardless of which network segments they serve (e.g. core network) •Not regulated: The specific power management of access networks (RAN and FAN) is covered in other parts of the ETSI EN 305 200-2 series. The transport network components are assigned to the scope of the access network in accordance with the ETSI EN 305 200-2-x series. •This approach makes it possible to apply regulatory objectives to mobile access networks which have the greatest individual energy	In accordance with ETSI EN 305 200-3-1	•Applicable for network operators, regardless of technical details •Entire network including ICT devices, infrastructure and maintenance activities
Background	**Goals**	•Evaluation of the energy aspects of **ICT sites** •Focus on energy, not on the specific performance or data traffic of the network components	**Supporting the requirements of ETSI EN 305 200-3-1** and detailing the implementation	-Evaluation of the energy efficiency of an entire network owned by a single operator -based on energy sharing between ICT devices and

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ITU-T L.1332 (01/2018)
				infrastructure, not on technical parameters such as data volume
Background	**Scope**	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure	In accordance with ETSI EN 305 200-3-1	1) ICT equipment (incl. ITE&NTE) 2) Infrastructure 3) Maintenance journey
Background	**Technical representativeness**	ICT sites include: • Operator Sites (OS): Sites that provide direct connections to core and access networks. • Network Data Centres (NDCs): Data centres that are embedded in the core network.	In accordance with ETSI EN 305 200-3-1	Not specifically limited to one network segment
Background	**Consideration of various energy sources**	•Electricity from the grid or local generation •Heat from the grid or local generation •Renewable energy on site •Waste heat • Green' energy in the electricity mix that is certified as renewable by electricity suppliers or national regulations is not recognised in this standard.	In accordance with ETSI EN 305 200-3-1	•Electricity from the grid •Energy from diesel generators •Renewable energy on site •Fuel from maintenance runs
Background	**Indicators**	**•Energy consumption (KPI_{EC}) (MWh)**: Sum of energy consumption at the operator sites (OS) and energy consumption at the Network Data Centres (NDCs) **•Task Effectiveness (KPI_{TE}) (%) (not Must-Have-Indicator)**: the ratio of the total energy consumption of the ICT site to the energy consumption of the ICT equipment in the ICT site. (Note: There is a deviation compared to other standards in the ETSI EN 303 200-2-x series, where “Task Effectiveness” describes the relationship between data volume and energy consumption. In this standard, the “Task Effectiveness” refers to the ratio between the energy consumption of the IT devices and the total energy consumption, including the infrastructure (e.g. cooling). **•Renewable energy (KPI_{REN}) (%)**: Share of renewable energy in the network's total energy	•Metrics same as in ETSI EN 305 200-3-1	•Network infrastructure energy efficiency (NIEE) (%)= (ICT load energy consumption) / (Total energy consumption of the network); The total energy consumption of the network includes electricity from the grid, energy from diesel generators, renewable sources, and optionally, mobile generators and maintenance trips.

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ITU-T L.1332 (01/2018)
		consumption (KPI_{EC}) •Note regarding further indicators, other than Must-Have ones: →**KPI_{REUSE} (%)** the recovered energy divided by KPI_{EC} →**Energy Performanc**e: **KPI_{EP}** = $KPI_{TE} \times(1-W_{REUSE} \times KPI_{REUSE})\times(1-W_{REN} \times KPI_{REN})$ (W: weighting factor)		
Background	**Other reference variable** (only relevant for calculating the energy efficiency indicator.)	Not relevant. The focus is only on energy, not on energy efficiency in relation to data volume.	In accordance with ETSI EN 305 200-3-1	Maintenance drive (optional)
Background	**Dependencies between standards**	ETSI EN 305 200-1: General requirements for global KPIs for energy management in operational infrastructures.	•ETSI EN 305 200-1: General requirements for global KPIs for energy management in operational infrastructures. •ETSI EN 305 200-3-1	•electricity measurement: ETSI ES 202 336-12 •Accuracy of the measuring devices: ITU-T L.1350 (of which "Class 1" for energy meters according to IEC 62053-21)
Background	**Description of the measurement methodology:** Specific measurement steps defined in the standard or alternative standards referenced	•Electricity: Measurement •Heat: Measuring devices according to CEN EN 1434 series: "Heat meters".	In accordance with ETSI EN 305 200-3-1	•Energy: Measurement methods and accuracy of energy consumption must comply with the requirements of ETSI ES 202 336-12.

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ITU-T L.1332 (01/2018)
Robustness	**Method of data collection:** energy consumption	On-site measurement in real operation, taking into account the loss factor depending on the respective measuring point.	•On-site measurement in real operation, taking into account the loss factor depending on the measuring point •Supplement: →For a group of sites, statistically representative sites should be selected in order to estimate the total consumption. →Power consumption measurements are only an internal temporary solution for internal purposes compared to energy consumption measurements and should include the fluctuation of temperatures and utilisation.	•For electricity from the grid: preferably continuous on-site measurement; if not possible, utility bills. •For other energy sources: On-site measurement.
Robustness	**Method of data collection:** the other reference variable, if available	Not relevant. The focus is only on energy, not on energy efficiency in relation to data volume.	Not relevant. The focus is only on energy	not relevant: The focus is only on energy (maintenance activity is optional)
Reproducibility	**Measurement methodology:** On-site measurement: measurement period and measurement frequency	•Measurement period -continuous, 365 days as standard; to take into account the climatic fluctuations of the operational infrastructure •Measurement frequency: must be between one week and one calendar month •Δt: the maximum permitted deviation in the start time of the measurements.Δt must be less than 2 % of TKPI.	In accordance with ETSI EN 305 200-3-1	not specified. prefers continuous on-site measurement
Reproducibility	**Measurement methodology:** On-site measurement: Ambient conditions	Ambient conditions are recognised as an influencing factor for energy consumption (e.g. due to cooling), but no recording or documentation is required	Ambient conditions are recognised as an influencing factor for energy consumption (e.g. due to cooling), but no recording or documentation is required	•No specific requirements for the ambient conditions. However, the standard describes ambient conditions and payload as variable influencing factors that affect energy efficiency.
Reproducibility	**Measurement methodology:** On-site measurement: Measuring instruments	•Calibration requirements for electrical meters are not mentioned. •However, the CEN EN 1434 series: 'Heat meters' is a normative reference. Requirements for the	In accordance with ETSI EN 305 200-3-1	•Measuring devices must support "true RMS (root-mean-square)" (root-mean-square value) •No explicit requirement for

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ITU-T L.1332 (01/2018)
		accuracy and calibration of heat meters should be taken into account."		calibration, but accuracy according to ITU-T L.1350 is assumed.
Reproducibility	**Measurement methodology:** On-site measurement: Measuring points	Measurement points are clearly defined: 1) Energy consumption of the entire ICT site: •Electrical energy from the grid: →Preferred measurement point: input of the transformer. →Alternative measurement points, e.g. output of the transformer or input of the switchgear, require the consideration of loss factors ("measurement penalty", MP) •Electrical energy from local, dedicated generation systems:: →Preferred measurement point: generator output. →Alternative measurement points, e.g. input of the switchgear, require the consideration of loss factors. Conversion factors for diesel, gas, hydrogen and bioethanol are specified in the standard. •Thermal energy: →Measurement at the grid delivery point with heat meter (CEN EN 1434). 2) Energy consumption of ICT appliances (for the calculation of$_{KPITE}$) →Preferred measurement point: Measured at the socket(s) directly supplying the ICT devices (granularity level 3 of ETSI EN 50600-2-2) →Alternative measuring points, e.g. output of the power distribution unit (PDU) or output of the uninterruptible power supply (UPS), require the consideration of loss factors	In accordance with ETSI EN 305 200-3-1	Measuring points are clearly defined: •ICT: at the power feeding interface of the telecommunication equipment considering the energy losses of the cable. **•total input energy of the site: electricity from the grid, measured at low voltage (LV) level before distribution** •Energy from fixed generators (diesel/gas): Measured at the output of the generator before feeding into the LV power distribution system. •Energy from renewable sources: Measured at the output of the energy source before feeding into the electricity distribution system. •2 optional measurements: 1)measured at the output of the mobile diesel generator; 2)measurement of petrol consumption of maintenance vehicles
Reproducibility	**Methodological definition:** Allocation rules or delimitation of the scope of application	No explicit allocation rule for shared infrastructures (e.g. electricity supply). It is left to the operators.	In accordance with ETSI EN 305 200-3-1	No allocation is mentioned. The standard remains at the level of overall measurement and applies to the network belonging to the same network operator

Evaluation criteria	Evaluation aspects	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ITU-T L.1332 (01/2018)
Credibility	**Assessment of uncertainties / data quality**	not mentioned	The TS stipulates that all assessment periods must cover one year, including the permissible inaccuracies according to ETSI EN 305 200-3-1. However, ETSI EN 305 200-3-1 does not contain any concrete specifications on permissible inaccuracies. However, with reference to page 14 ("The estimated statistical accuracy shall be specified"), it is assumed that the calculation of statistical accuracy is mandatory when upscaling measurement data from a small number of sites to a large group.	not mentioned
Credibility	**Validation**	not mentioned	not mentioned	not mentioned
Transparency	**Reporting**	•No template available •Only metric results without further details	•A template available •metric results with little general information	•No template available •Only metric results without further details

Source: Own compilation

Table 7-25: Overview of the assessment aspects and background information of the standards for the comparative analysis in the category energy management: 5G network and NFV

Evaluation criteria	Evaluation aspects	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI EN 303 471 V1.1.1 (2019-01)
Background	**Assignment of the network segment**	**5G mobile network: RAN, core network, end-to-end, NFV, slicing**	**Entire access network: NFV**
Background	**Area of application**	•Defines comprehensive KPIs in areas such as accessibility, integrity, utilisation, retainability and energy efficiency for 5G networks and network slices, including the 5G access network and core network. However, the energy consumption of the transport network segment is not within the scope of this document. •However, the detailed measurement specification (e.g. measurement period, frequency, measurement points) is not the focus of this standard.	•Applicable for NFV applications and their infrastructure (NFVI) that are physically or functionally **outside the boundaries of the access networks, but support these access networks.** In summary, the hardware and software on which the virtualised network functions run is not located directly in the access network, but at a central location, such as a Network Data Centre (NDC) or an Operator Site (OS), which is no longer part of the access network. •**The indicators are primarily used to analyse trends.** They are not intended to allow comparisons between individual implementations of Network Function Virtualisation (NFV) unless the operating conditions can be considered comparable. •The standard is intended to evaluate the energy efficiency of the **entire network function virtualisation infrastructure (NFVI**), including all hardware and software components that support virtualised network functions - **but not individual servers.**
Background	**Goals**	specifies **end-to-end key performance indicators (KPIs)** for the **5G network** and **network slicing, how the indicators are calculated.**	Provide a standardised framework for measuring and trending the energy efficiency of **NFV applications**
Background	**Scope**	1)5G base stations and core network 2) Infrastructure: no. This is because the energy consumption of a network slice is based on the network functions. The energy consumption of the infrastructure is not explicitly mentioned.	1) Network components 2) Infrastructure
Background	**Technical representativeness**	-5G, network slicing, virtualisation -End-to-end covers the entire communication chain from the mobile access network (e.g. NG-RAN) to the core network (e.g. 5GC).	•Supports all types of access networks (fixed, mobile, cable) if they host NFV outside their network boundaries but belong to the access network. •Not specifically limited to one network segment.

Evaluation criteria	Evaluation aspects	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI EN 303 471 V1.1.1 (2019-01)
Background	**Consideration of various energy sources**	not mentioned	•Electricity from the grid •Locally generated non-renewable and renewable energy • Green' energy in the electricity mix that is certified as renewable by electricity suppliers or national regulations is not recognised in this standard.
Background	**Indicators**	**1) Subnetwork: NG-RAN data Energy Efficiency (EE): $EE_{MN,DV}$.** **Data Volume (DV)** divided by Energy Consumption (EC) in operational NG-RAN. The unit of this KPI is **bit/J**. **2) Network Slice: Network slice Energy Efficiency (EE)** **2.1) Energy efficiency of eMBB network slice:** UL and DL **data volumes** of the network slice. The unit of this KPI is **bit/J**. **2.2) Energy efficiency of eMBB network slice – RAN-based:** type eMBB **based on NR measurements**. UL and DL **data volumes** of gNBs. The unit of this KPI is bit/J. **2.3) Energy efficiency of URLLC network slice: two variants:** a)Based on **latency** of the network slice; The unit of this KPI is **$(0.1ms * J)^{-1}$**; b)Based on **both latency and Data Volume (DV)** of the network slice: The unit of this KPI is **bit/(0.1ms*J).** **2.4)Energy efficiency of MIoT network slice: two variants:** a) Based on **the number of registered subscribers** of the network slice; The unit of this KPI is **user/J.** b)Based on **the number of active UEs** (User Equipment) in the network slice: The unit of this KPI is **UE/J**. **3) 5G Energy Consumption (EC)**: The unit of this KPI is **J**. **3.1) NF Energy Consumption (EC)**: describes the Energy Consumption (EC) of a 5G Network Function (NF) by summing up the energy consumption of PNF(s) and/or VNF(s) which compose the NF. **3.2) Subnetwork: 5GC (5G Core) Energy**: by summing up the Energy Consumption of all the Network Functions (EC_{NF}) that compose the 5G core network. **3.3) Network Slice: Network Slice Energy Consumption (EC):** by summing up the Energy Consumption of all the Network Functions (EC_{NF}) that compose the network slice.	•$KPI_{EE\text{-}bit\_transfer}$: Data volume in bits transferred by the NFVI divided by the NFVI energy consumption (bits/kWh) •$KPI_{EE\text{-}packet\_transfer}$: Number of packets transferred by the NFVI divided by the NFVI energy consumption (packets/kWh)

Evaluation criteria	Evaluation aspects	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI EN 303 471 V1.1.1 (2019-01)
		3.4) Subnetwork: NG-RAN Energy Consumption (EC): by summing up the Energy Consumption of all the gNBs that constitute the NG-RAN. Energy Consumption of a gNBs is obtained by summing up the Energy Consumption of all the Network Functions (NF) that constitute the gNB.. **4) Subnetwork: 5GC (Core) Energy Efficiency:** UL and DL data volumes divided by the energy consumption of 5GC. The unit of this KPI is **bit/J.**	
Background	**Other reference variable** (only relevant for calculating the energy efficiency indicator.)	•data volume •latency •registered subscribers •active UEs (User Equipment)	-Data volume in bits -Number of packets
Background	**Dependencies between standards**	•3GPP TS 28.552: Defines performance parameters such as data volume, latency, registered subscribers and active UEs. To understand energy-related indicators in ETSI TS 128 554, reference must be made to 3GPP TS 28.552 and section 3.3 of 3GPP TS 32.404. •ETSI GS NFV-IFA 027: Covers measurements such as virtual CPU, memory and hard disk utilisation and I/O traffic. •ETSI ES 202 336-12: Defines methods for measuring energy consumption in telecommunication networks.	-Energy: Measurement methods/accuracy must comply with ETSI ES 202 336-12. -Measurement of data volume and packets at the physical interfaces, supported by ETSI GS NFV-TST 008
Background	**Description of the measurement methodology:** Specific measurement steps defined in the standard or alternative standards referenced	•The energy consumption of physical network functions (PNF) is measured in accordance with ETSI ES 202 336-12, while the energy consumption of virtualised network functions (VNF) is estimated. The energy consumption of the VNFC is estimated based on vCPU, vMemory, vDisk utilisation or I/O traffic according to ETSI GS NFV-IFA 027. •Data volume: Measurement of the amount of DL (downlink) and UL (uplink) data traffic. •Latency: Measurement of the time for packets in the downlink (DL) and uplink (UL) direction through the network. •Registered subscribers: Measurement at AMF (Access and Mobility Management Function) level •Active UEs: unspecified, possibly recorded via network monitoring systems	•Energy: Measurement methods and accuracy of energy consumption must comply with the requirements of ETSI ES 202 336-12. •Data volume (bits) and number of packets: Measured at the physical interface of the NFVI

Evaluation criteria	Evaluation aspects	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI EN 303 471 V1.1.1 (2019-01)
Robustness	**Method of data collection:**energy consumption	•The energy consumption of physical network functions (PNF) is measured in accordance with ETSI ES 202 336-12, while the energy consumption of virtualised network functions (VNF) is estimated. •Estimation of the energy consumption of virtualised network functions (VNF) is based on "mean vCPU usage; mean vMemory usage; vDisk usage; I/O traffic volume". The physical infrastructure hosting the VNFs is measured and the energy consumption is then allocated to the VNFs based on resource utilisation (Note: The energy consumption of the individual virtual network functions is not the focus of this study).	•Energy: Measurement
Robustness	**Method of data collection:** the other reference variable, if available	Measurement	•Data volume: Measurement •Number of packets: Measurement
Reproducibility	**Measurement methodology:** On-site measurement: measurement period and measurement frequency	Not specified: •The measurement period for energy consumption and other performance parameters (e.g. data volume) should be identical.	•Measuring period -Continuous, 365 days as standard; -A shorter measurement period (at least 7 days) is permissible if it realistically reflects annual values and is not seasonally distorted. •Measurement frequency: must be between one week and one calendar month
Reproducibility	**Measurement methodology:** On-site measurement: Ambient conditions	not mentioned	Environmental conditions are described as an influencing factor for energy consumption, but there are no clear requirements for recording or documentation
Reproducibility	**Measurement methodology:** On-site measurement: Measuring instruments	Measurement methods/accuracy can be found in ETSI ES 202 336-12.	•Energy: Measurement methods/accuracy according to ETSI ES 202 336-12.

Evaluation criteria	Evaluation aspects	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI EN 303 471 V1.1.1 (2019-01)
Reproducibility	**Measurement methodology:** On-site measurement: Measuring points	The energy consumption of physical network functions (PNF) in accordance with ETSI ES 202 336-12	•Energy: ETSI ES 202 336-12The measuring points are written in ETSI ES 202 336-12 •Data volume (bits): Measured at the physical interface of the NFVI as the sum of successfully transmitted and received Layer 2 user data bits in accordance with ETSI GS NFV-TST 008 •Number of packets: Measured at the physical interface of the NFVI as the sum of successfully transmitted and received packets according to ETSI GS NFV-TST 008
Reproducibility	**Methodological definition:** Allocation rules or delimitation of the scope of application	•The case that a VNF or PNF instance is shared by several NFs is not covered in this document. •No explicit allocation rule for shared infrastructures (e.g. power supply). •(not focus of the study:) If a network function (NF) is shared by several network slices, the allocation takes place: →gNB (radio access): The share is calculated based on the data volume of the slice in relation to the total data volume of the gNB. →AMF (registration and mobility management): The share is calculated based on the average number of registered users of the slice in relation to the total number of users of the AMF. →SMF (session management): The share is calculated based on the average number of PDU sessions of the slice in relation to the total number of PDU sessions of the SMF. →UPF (User Plane Function): Based on the data volume via N3/N9 interfaces -For virtual shared resources, the consumption is calculated based on the hardware resources used (vCPU utilisation, vMemory utilisation; vStorage utilisation, I/O data traffic).	•The standard regulates the measurement of the energy consumption of the NFVI as an overall value, independent of the NFV functions. It is specified that the energy consumption should be measurable separately for each access network if the NFVI supports several access networks. However, further specifications are missing. •The standard assumes that the NFVI primarily supports access networks. It remains unclear how to deal with an NFVI that hosts both access network and core network functions and whose energy consumption would have to be split accordingly. •There is no clear regulation on how renewable energy should be divided between ICT and infrastructure consumption.
Credibility	**Assessment of uncertainties / data quality**	not mentioned	not mentioned

Evaluation criteria	Evaluation aspects	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI EN 303 471 V1.1.1 (2019-01)
Credibility	**Validation**	not mentioned	not mentioned
Transparency	**Reporting**	not mentioned	•No template available •Indicator results and basic input parameters

Source: Own compilation

Annex VII.d. Results of the scale representation for the comparative analysis and the overall assessment of suitability in the energy management category

Figure 7-1: Results of the scale representation for the comparative analysis according to the 3-level model in the energy management category

Evaluation Criteria	No.	Evaluation aspects	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ITU-T L.1332 (01/2018)	ETSI EN 303 471 V1.1.1 (2019-01)
		Network segment	RAN: 2G/3G/4G	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	FAN: technology-independent	FAN: technology-independent	CAN: technology-independent	5G mobile network: RAN, core network, end-to-end, NFV, slicing	ICT-Site: Core network	ICT-Site: Core network	ICT-Site: entire network	Entire access network: NFV
	A1.1	Data collection methods: Energy	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	A1.2	Data collection methods: other reference units	●	●	not relevant	not relevant	not relevant	●	●	●	●	●	●	not relevant	not relevant	not relevant	●
	A2.1	Measurement period and measurement frequency	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	A2.2	Environmental conditions during measurement	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	A2.3	Measuring instruments	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	A2.4	Measurement points	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	A2.5	Allocation rules or delineation of the scope of application	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	A3.1	Assessment of Uncertainties	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	A3.2	Validation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	A4	Reporting	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Source: Own compilation

Table 7-26: Summary of the overall assessment of the standards considered in the energy management category

Standard	Overall assessment of suitability
ETSI EN 303 472 V1.1.1 (2018-10)	• **ETSI EN (European Standard) 303 472 V1.1.1 (2018-10)** is suitable as a methodological guide and measurement specification for calculating all three must-have indicators identified in the JRC study (**energy consumption, energy efficiency in relation to data volume and share of renewable energy**) in the mobile access network (**RAN**) under the **2G, 3G and 4G** technologies . The standard takes into account both the **ICT equipment** and the associated **infrastructure** of the network. •The comparability applying the same standard is rated as **high**. The lack of specifications for validation and uncertainty assessment partially reduces the Credibility of the results. However, **detailed reporting requirements** increase transparency and facilitate interpretation, as they enable thorough documentation that supports better traceability and evaluation. •Overall, considering all evaluation aspects, ETSI EN (European Standard) 303 472 V1.1.1 is rated as having a **high** suitability with regard to the required must-have indicators.
ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	• **ETSI ES (ETSI Standard) 203 228 V1.4.1 (2022-04)** is suitable as a methodological guide and measurement specification for calculating two of the three must-have indicators identified in the JRC study (**energy consumption, energy efficiency in relation to data volume**) for the entire mobile access network, including **2G, 3G, 4G, and 5G** technologies. Renewable energy is included in the total energy consumption but is not explicitly mandated as a separate indicators. However, the standard requires the specification of the share of renewable energy sources (e.g., solar, wind, or other renewable energies) as a percentage of the total energy supply in the reports. The standard considers both **ICT equipment** and the associated network **infrastructure.** • The comparability applying the same standard is rated as **medium**. The lack of specifications for validation and uncertainty assessment partially reduces the reliability of the results. However, **detailed reporting requirements** enhance transparency and facilitate interpretation by enabling thorough documentation, which supports better traceability and evaluation. • A **special feature** of ETSI ES 203 228 V1.4.1 is that the standard provides a methodological basis for scaling up the energy consumption of the entire mobile network based on the demographic classes (e.g., rural, urban) of the sites to larger networks (e.g., nationwide). This method is applied when a complete capture of network consumption is not practical or too costly for the operator. • Overall, considering all evaluation aspects, ETSI ES (ETSI Standard) 203 228 V1.4.1 is rated as having a **high** suitability with regard to the required must-have indicators.
ETSI TR 103 540 V1.1.1 (2018-04)	• **ETSI TR (Technical Report) 103 540 V1.1.1 (2018-04**) is suitable as a methodological guide based on two statistical approaches—basic estimation method and stratified estimation method—for calculating one of the three must-have indicators identified in the JRC study (**energy consumption**) in the mobile access network (**RAN**), considering both homogeneous and heterogeneous networks. The standard only considers **ICT equipment**. • The comparability applying the same standard is rated as **low**. However, accounting for uncertainties and reporting on confidence levels, estimation period, error tolerance, and sample-based energy consumption estimation increases transparency and reliability. • A **special feature** of the standard is the ability to estimate the energy consumption of the entire mobile access network (RAN) based on data from representative sites. This method is applied when a complete capture of network consumption is not practical or too costly for the operator. • Overall, considering all evaluation aspects, ETSI TR (Technical Report) 103 540 is rated as having a **medium** suitability with regard to the required must-have metrics .
ITU-T L.1350 (10/2016)	• **ITU-T L.1350 (10/2016)** is suitable as a methodological guide for calculating one of the three must-have indicators identified in the JRC study (**energy consumption**) for base station sites in the mobile access network (**RAN**), applicable independently of technology. The indicator 'Site Energy Efficiency (SEE)' originally defined in the standard describes the ratio between the energy consumption of network components and the total energy consumption at the site. The standard considers both **ICT equipment** and the associated **infrastructure**. • The comparability applying the same standard is rated as **low**. The lack of reporting with detailed framework conditions, which are crucial for interpreting the results, reduces the transparency of the standard. Additionally, the absence of mandatory specifications for validation and uncertainty

Standard	Overall assessment of suitability
	assessment further limits the reliability of the results. • Overall, considering all evaluation aspects, ITU-T L.1350 (10/2016) is rated as having **low** suitability with regard to the required must-have indicators.
ITU-T L.1351 (08/2018)	• **ITU-T L.1351 (08/2018)** serves as a **complementary extension to ITU-T L.1350**, as it specifies concrete requirements for measurement period, measurement frequency, and reporting obligations. The scope and indicator align with those of ITU-T L.1350. • The comparability applying the same standard is rated as **low**, similar to ITU-T L.1350. The lack of mandatory specifications for method validation and uncertainty assessment of results further limits the reliability of the collected data. Compared to ITU-T L.1350, ITU-T L.1351 refines reporting obligations by including additional details on sites, used hardware, measurement instruments, and test setup. However, further specifications are still lacking. • Overall, considering all evaluation aspects, ITU-T L.1351 (08/2018) is rated as having **low** suitability with regard to the required must-have indicators.
ETSI EN 305 200-2-3 V1.1.1 (2018-06)	• **ETSI EN (European Standard) 305 200-2-3 V1.1.1 (2018-06)** is suitable as a methodological guide and measurement specification for calculating all three must-have indicators identified in the JRC study (**energy consumption, energy efficiency in relation to data volume, and share of renewable energy**) in the mobile access network (**RAN**) of a network operator. The standard is applicable independently of technology. Additionally, it addresses **network virtualization**, requiring consideration of NFV devices operated at external sites but belonging to the operator's RAN (see the supplementary standard **ETSI EN 303 471**). If this is not feasible, it must be documented in the report. Both **ICT equipment** and associated **infrastructure** are included. • The comparability applying the same standard is rated as **medium**. The lack of specifications for validation and uncertainty assessment partially reduces the reliability of the results. The standard's reporting requirements mandate the specification of specific parameters, measurement period, and frequency. Detailed descriptions of tested sites, technical representativeness, or supporting infrastructure (e.g., cooling, power distribution) are not explicitly required. • A **special feature** of the ETSI EN 305 200-X series is that it enables the targeted application of regulatory objectives to networks with high energy consumption through the introduction of "Global KPIs," without specifying target values or limits. However, the focus of the present study is on "Objective KPIs." Additionally, it is stipulated that electricity certified as "green" by energy suppliers or national regulations is not recognized as renewable energy. The relevance of this requirement should be verified against current regulatory definitions. • Overall, considering all evaluation aspects, ETSI EN (European Standard) 305 200-2-3 is rated as having **medium** suitability with regard to the required must-have indicators.
ETSI TS 105 200-2-3 V1.2.1 (2019-12)	•**ETSI TS (Technical Specification) 105 200-3-1 V1.2.1 (2019-12)** serves as a complementary technical specification to support the implementation of ETSI EN (European Standard) 305 200-3-1 V1.1.1. This Technical Specification (TS) makes only minor changes to data collection and measurement methodology. However, a significant additional requirement is that, for a large number of sites, a statistically representative selection must be made to estimate total consumption, as measuring all sites is neither practical nor economically feasible. The TS explicitly requires the specification of the estimated statistical accuracy. However, it leaves the methodology for selecting representative sites and calculating statistical accuracy to the network operators. Additionally, power consumption measurements are only permitted as a temporary solution and primarily serve internal comparison purposes. The scope and indicators align with those of ETSI EN 305 200-3-1. • The comparability applying the same standard is rated as **medium**. The lack of specific validation requirements partially reduces the reliability of the results. As an improvement, the TS introduces standardized reporting tables, which enhance transparency by specifying ICT site names and grouping information. • The description of special features in EN 305 200-3-1 continues to apply to this TS. • Overall, considering all evaluation aspects, ETSI TS (Technical Specification) 105 200-3-1 is rated as having **medium** suitability with regard to the required must-have indicators.

Standard	Overall assessment of suitability
ETSI EN 305 200-2-2 V1.2.1 (2018-08)	• **ETSI EN (European Standard) 305 200-2-2 V1.2.1 (2018-08)** is suitable as a methodological guide and measurement specification for calculating all three must-have indicators identified in the JRC study (**energy consumption, energy efficiency in relation to data volume, and share of renewable energy**) in the fixed access network (**FAN**) of a network operator. The standard is applicable independently of technology (except for cable access networks) and covers **operator sites (OS), network distribution nodes (NDN),** and other associated **infrastructure**. Additionally, the standard addresses network virtualization, requiring consideration of NFV devices operated at external sites but belonging to the operator's FAN (see the supplementary standard ETSI EN 303 471). If this is not feasible, it must be documented in the report. Both ICT equipment and associated infrastructure are included. •The comparability applying the same standard is rated as medium. The lack of specifications for validation and uncertainty assessment partially reduces the reliability of the results. The standard's reporting requirements mandate the specification of specific parameters, measurement period, and frequency. Detailed descriptions of tested sites, technical representativeness, or supporting infrastructure (e.g., cooling, power distribution) are not explicitly required. •A **special feature** of the ETSI EN 305 200-X series is that it enables the targeted application of regulatory objectives to networks with high energy consumption through the introduction of "Global KPIs," without specifying target values or limits. However, the focus of the present study is on "Objective KPIs." Additionally, it is stipulated that electricity certified as "green" by energy suppliers or national regulations is not recognized as renewable energy. The relevance of this requirement should be verified against current regulatory definitions. • Overall, considering all evaluation aspects, ETSI EN (European Standard) 305 200-2-2 is rated as having **medium** suitability with regard to the required must-have indicators.
ETSI TS 105 200-2-2 V1.3.1 (2019-12)	• **ETSI TS (Technical Specification) 105 200-2-2 V1.3.1 (2019-12**) serves as a complementary technical specification to support the implementation of ETSI EN 305 200-2-2 V1.1.1, as it addresses implementation requirements such as measurement and estimation methods in greater detail, while these are only fundamentally described in the EN. The indicators align with those of ETSI EN 305 200-2-2. Unlike EN 305 200-2-2, the Technical Specification (TS) extends its scope to include customer premises equipment (CPE) powered by electricity, as their energy consumption is not negligible. • The comparability applying the same standard is rated as **medium**. The lack of specifications for validation and uncertainty assessment partially reduces the reliability of the results. The TS enhances the EN by introducing mandatory reporting templates that require separate disclosure of network segments, thereby increasing transparency. • The description of special features in EN 305 200-2-2 continues to apply to this TS. • Overall, considering all evaluation aspects, ETSI TS (Technical Specification) 105 200-2-2 is rated as having **medium** suitability with regard to the required must-have indicators.
ETSI ES 205 200-2-4 V1.1.1 (2015-06)	• **ETSI ES (ETSI Standard) 205 200-2-4 V1.1.1 (2015-06)** is suitable as a methodological guide and measurement specification for calculating all three must-have indicators identified in the JRC study (**energy consumption, energy efficiency in relation to data volume, and share of renewable energy**) in the **cable access network (CAN)** of a network operator. The standard is applicable within the framework of HFC cable networks independently of technology and covers network components from the headend (equivalent to operator sites, referred to as headend in the cable network context) to the customer interface (NIU: Network Interface Unit) and the OSP (Outside Plant) actively involved in signal transport outside the headend. The standard considers only **ICT equipment.** • The comparability applying the same standard is rated as **low**. The lack of mandatory specifications for method validation and uncertainty assessment partially limits the reliability of the data. • A **special feature** of this standard is that electricity certified as green by energy suppliers or national regulations is not recognized as renewable energy. • It should be noted that the standard is an ES (ETSI Standard), not an EN (European Standard). It is nearly 10 years old, published in June 2015, and it is unclear whether it still reflects the current state of the art. • Overall, considering all evaluation aspects, ETSI ES (ETSI Standard) 205 200-2-4 is rated as having **low** suitability with regard to the required must-have indicators.

Standard	Overall assessment of suitability
ETSI TS 128 554 V18.7.0 (2024-10)	• **ETSI TS (Technical Specification) 128 554 V18.7.0 (2024-10)** is suitable as a methodological guide for calculating two of the three must-have indicators identified in the JRC study (**energy consumption, energy efficiency in relation to data volume**) for the entire 5G network. This TS was developed by the ETSI 3rd Generation Partnership Project (3GPP) and corresponds to **3GPP TS 28.554** Version 18.7.0. It defines comprehensive KPIs (Key Performance Indicators) for evaluating performance, quality, and energy efficiency of a 5G network. However, this study focuses solely on energy and energy efficiency-related indicators. The TS covers the entire 5G network—RAN and core network. It considers both physical 5G network structures and current/future aspects such as 5G virtualization and network slicing. The standard focuses exclusively on **ICT equipment**, while the energy consumption of infrastructure (e.g., buildings, cooling) is not explicitly addressed in the TS. •The comparability applying the same standard is rated as **low**. The lack of specifications for validation, uncertainty assessment, and reporting partially reduces the reliability and transparency of the results. • A **special feature** of ETSI TS 128 554 is its consideration of network virtualization at the functional level. Energy consumption is closely linked to application-specific requirements, such as utilization, latency, computing power, data transmission quality or reliability, and the ability to serve multiple users simultaneously, depending on the use case. Additionally, the TS defines performance parameters beyond data volume for calculating energy efficiency metrics. This provides a foundation for analyzing energy consumption in relation to various performance parameters in the future, thereby improving understanding of the complex 5G network. • Overall, considering all evaluation aspects, ETSI TS (Technical Specification) 128 554 V18.7.0 is rated as having **low** suitability with regard to the required must-have indicators.
ETSI EN 305 200-3-1 V1.1.1 (2018-02)	• **ETSI EN (European Standard) 305 200-3-1 V1.1.1 (2018-02)** is suitable as a methodological guide and measurement specification for calculating two of the three must-have indicators identified in the JRC study (**energy consumption and share of renewable energy**) for ICT sites located in the core network. The standard is applicable independently of technology, except for NFV applications. It considers both **ICT equipment** and the associated network **infrastructure.** • The comparability applying the same standard is rated as medium. The lack of specifications for validation and uncertainty assessment partially reduces the reliability of the results. • A **special** feature of the ETSI EN 305 200-X series is that it enables the targeted application of regulatory objectives to networks with high energy consumption through the introduction of “Global KPIs,” without specifying target values or limits. However, the focus of the present study is on “Objective KPIs.” Additionally, it is stipulated that electricity certified as “green” by energy suppliers or national regulations is not recognized as renewable energy. The relevance of this requirement should be verified against current regulatory definitions. Furthermore, there is a deviation regarding the “Task Effectiveness” indicator. The Task Effectiveness (KPI_{TE}) in ETSI EN 305 200-3-1 (ICT Sites) describes the ratio between the total energy consumption of the site and the energy consumption of the ICT equipment, whereas in other standards of the ETSI EN 305 200 series (e.g., for access networks), KPI_{TE} is defined as the ratio between data volume and total energy consumption. • Overall, considering all evaluation aspects, ETSI EN (European Standard) 305 200-3-1 is rated as having **medium** suitability with regard to the required must-have indicators.
ETSI TS 105 200-3-1 V1.2.1 (2019-12)	• **ETSI TS (Technical Specification) 105 200-3-1 V1.2.1** (2019-12) serves as a complementary technical specification to support the implementation of ETSI EN (European Standard) 305 200-3-1 V1.1.1. This Technical Specification (TS) makes only minor changes to data collection and measurement methodology. A significant additional requirement is that, for a large number of sites, a statistically representative selection must be made to estimate total consumption, as measuring all sites is neither practical nor economically feasible. The TS explicitly requires the specification of the estimated statistical accuracy. However, it leaves the methodology for selecting representative sites and calculating statistical accuracy to the network operators. Additionally, power consumption measurements are only permitted as a temporary solution and primarily serve internal comparison purposes. The scope and indicators align with those of ETSI EN 305 200-3-1. • The comparability applying the same standard is rated as **medium**. The lack of specific validation requirements partially reduces the reliability of the results. As an improvement, the TS introduces standardized reporting tables, which enhance transparency by specifying ICT site names and grouping information. • The description of special features in EN 305 200-3-1 continues to apply to this TS.

Standard	Overall assessment of suitability
	• Overall, considering all evaluation aspects, ETSI TS (Technical Specification) 105 200-3-1 is rated as having medium suitability with regard to the required must-have indicators.
ITU-T L.1332 (01/2018)	• **ITU-T L.1332 (01/2018)** is suitable as a methodological guide and measurement specification for calculating one of the three must-have indicators identified in the JRC study (**energy consumption**). The originally defined indicator NIEE (Network Infrastructure Energy Efficiency) is derived from the ratio of the energy consumption of ICT equipment to the total energy consumption of the network. The latter includes grid electricity, diesel generators, and renewable energies, optionally supplemented by mobile generators and the energy expenditure for maintenance trips. The total energy consumption corresponds to the "energy consumption" indicator defined in the JRC study. The standard is not limited to a specific network segment or technology. It can be applied to the entire network ("**Total Network**"), specifically the entire network owned by an operator. This may include mobile access networks, fixed access networks, core networks, and associated network data centers, as long as they are managed by a single network operator. The standard considers both **ICT equipment** and associated **infrastructure**, supplemented by the **optional inclusion of maintenance activities and mobile diesel generators**. • The comparability applying the same standard is rated as **low**. The lack of specific validation requirements partially reduces the reliability of the results. The absence of reporting with detailed framework conditions, which are crucial for interpreting the results, diminishes the transparency of the standard. • A **special feature** of this standard is that the fuel consumption for maintenance vehicle trips can optionally be included in the energy balance, although the method remains at an estimation level—namely, by converting distances into kWh using a conversion factor. Maintenance activities themselves are considered negligible. • Overall, considering all evaluation aspects, ITU-T L.1332 is rated as having **low** suitability with regard to the required must-have indicators.
ETSI EN 303 471 V1.1.1 (2019-01)	• **ETSI EN (European Standard) 303 471 V1.1.1 (2019-01)** is suitable as a methodological guide and measurement specification for calculating two of the three must-have indicators identified in the JRC study (**energy consumption, energy efficiency in relation to data volume**) in the NFV application of an access network, including the mobile access network (RAN), fixed access network (FAN), and cable access network (CAN). The standard can be applied when NFV applications and the associated **NFV infrastructure (NFVI)** are operated outside the access networks—for example, in central facilities such as a Network Data Centre (NDC) or an Operator Site (OS)—provided they support these access networks. Renewable energy is included in the total energy consumption but is not mandated as a separate indicator. The standard measures the energy consumption of the NFVI as a total value, independent of specific NFV functions. Both **ICT equipment** and associated **infrastructure** are included. • The comparability within the standard is rated as **medium**. The lack of mandatory requirements for method validation, uncertainty assessment, and detailed reporting limits the reliability and transparency of the results. • A **special feature** of this standard is that electricity certified as green by energy suppliers or national regulations is not recognized as renewable energy. • Overall, considering all evaluation aspects, ETSI EN (European Standard) 303 471 V1.1.1 is rated as having **medium** suitability with regard to the required must-have indicators.

Source: Own compilation

Annex VIII. Detailed evaluation of the comparative analysis (WP2): Greenhouse gas emissions

Annex VIII.a. Definition of the three-level model (high, medium, low) for the comparative analysis in the greenhouse gas emissions category

Table 7-27: Definition of the three-level model (high, medium, low) for the comparative analysis in the greenhouse gas emissions category - Scopes 1 & 2

Evaluation criteria	No.	Evaluation aspects	Classification of the evaluation criteria: Definition of the three-level model (high, medium, low)
Robustness	**A1.1**	Primary data: Data collection for Scope 1; e.g. on-site edmeasurement or from consumption data	• Low: no specifications on the procedure for primary data collection • Medium: Key point description of the procedure for primary data collection (e.g. short list of data collection options) • High: Detailed checklist with a prioritization of procedures or information on what needs to be taken into account when collecting data.
Robustness	**A1.2**	Primary data: Data collection for Scope 2; e.g. on-site measurement or from consumption data	• Low: no specifications on the procedure for primary data collection • Medium: Key point description of the procedure for primary data collection (e.g. short list of data collection options) • High: Detailed checklist with a prioritization of procedures or information on what needs to be taken into account when collecting data.
Reproducibility	**A2.1**	Requirements for emission factors for Scope 1 and 2; indication of literature sources/databases for emission factors	• low: no specification regarding the selection of emission factors or estimate or unvalidated supplier information permitted as EF • Medium: Naming of sources with suitable EFs or description of the procedure for finding suitable EFs • High: Specification of requirements for EF (e.g. scientifically determined factor, location-specific & current; with source citation) and/or specification of which databases are to be used.
Reproducibility	**A2.2**	Definition of allocation rules	• Low: No defined allocation rules or unclear delimitation of the scope of application • Medium: Allocation rules or scope of application are generally described but not precisely defined • high: The methodological approach to allocation is clearly defined (e.g. with prioritization of the allocation rule); or the scope of application is clearly defined, i.e. allocation is not necessary
Credibility	**A3.1**	Assessment of data quality / uncertainty assessment: • Is an evaluation mandatory? • If yes, according to which method? Are there any guidance documents?	• Low: No assessment of uncertainties or data quality provided. • Medium: Assessment of uncertainties or data quality optional. • High: Assessment of uncertainties or data quality mandatory.

Evaluation criteria	No.	Evaluation aspects	Classification of the evaluation criteria: Definition of the three-level model (high, medium, low)
Credibility	**A3.2**	Validation: • Is a verification, critical review, etc. required? • If yes, internal or external?	• Low: No or optional validation • Medium: Internal validation required as a minimum • high: external validation required
Transparency	**A4.1**	Calculation of Scope 2 emissions: • market-based • location-based	• Low: No requirement to calculate Scope 2 emissions & no obligation to report on the chosen approach • medium: optional indication of the selected Scope 2 calculation method • High: Specification of the calculation method and/or specification that the selected method must be reported
Transparency	**A4.2**	Requirement for calculating the GWP; e.g. GWP 100a according to IPCC	• Low: No specifications regarding the choice of method for calculating the GWP and no obligation to state the version used or the underlying period in the report. • Medium: Specification for the use of the time frame (e.g. GWP100 or GWP20), but without a clear requirement to document this time frame and version information transparently in the report. • High: Clear specification for documenting the time frame (e.g. GWP100 or GWP20) and the IPCC version used in the report.
Transparency	**A4.3**	Definition of organizational system boundaries: Equity share approach or control approach (financial or operational control)	• low: no description of the organizational system boundaries required in the report • Medium: Specification of the approach chosen to define the organizational system boundaries required in the report • High: Mandatory disclosure of the selected approach, including naming the impact of the approach on the allocation of activities to Scope 1 and 2 or Scope 3.
Transparency	**A4.4**	Mandatory requirements regarding general information in the report; e.g. operational and organizational system boundaries, emission factors used, etc.	• Low: No systematic requirements for reporting on methodological and general framework conditions. • Medium: Reporting on basic input parameters, without explanation of the chosen methods or information on data collection. • High: Detailed general information on the framework conditions (organizational limits, methodological approach; selected emission factors, exclusion of sources/facilities if applicable) as well as basic input parameters in a standardized report template.
Transparency	**A4.5**	Mandatory requirements for the indicators in the report; e.g. differentiation by GHG, extra reporting for biologically stored GHG	• Low: Only sum of Scope 1 and Scope 2 reported. • Medium: Sum of Scope 1 AND sum of Scope 2 differentiated by market- and location-based approach • High: Detailed reporting of GHG emissions → Total scope 1/scope 2 → Scope 2 according to market- and location-based approach → Separate emissions data for all seven GHGs within the scopes → Separate reporting obligation for direct emissions (Scope 1) from biologically sequestered carbon

Source: Own compilation

Table 7-28: Definition of the three-level model (high, medium, low) for the comparative analysis in the greenhouse gas emissions category - Scope 3

Evaluation criteria	No.	Evaluation aspects	Classification of the evaluation criteria: Definition of the three-level model (high, medium, low)
Robustness	A1.1	Requirements regarding the collection and use of activity data for the 15 categories	• Low: no specifications on the procedure for collecting activity data • Medium: Key point description of the procedure for collecting activity data (e.g. short list of data collection options) • High: Detailed checklist with a prioritization of procedures or instructions on what to consider when collecting activity data
Robustness	A1.2	Calculation methods per Scope 3 category, e.g. spend-based method; distance based method	• Low: no calculation methods mentioned • Medium: General list of possible calculation methods • High: Detailed description of the calculation methods per Scope 3 category and/or with prioritization of some calculation methods depending on certain conditions.
Reproducibility	A2.1	Summarized evaluation of specifications for cat. 1-15	• Low: no breakdown of the activities to be taken into account • Medium: generic list of Scope 3 activities • High: ICT-specific focus on Scope 3 activities
Reproducibility	A2.2	Requirements for emission factors; indication of literature sources/databases for emission factors	• Low: no specification regarding the selection of emission factors or estimate or unvalidated supplier information permitted as EF • Medium: Naming of sources with suitable EFs or description of the procedure for finding suitable EFs • High: Specification of requirements for EF (e.g. scientifically determined factor, location-specific & current; with source citation) and/or specification of which databases are to be used
Reproducibility	A2.3	Definition of allocation rules	• Low: No defined allocation rules or unclear delimitation of the scope of application • Medium: Allocation rules or scope of application are generally described but not precisely defined • high: The methodological approach to allocation is clearly defined (e.g. with prioritization of the allocation rule); or the scope of application is clearly defined, i.e. allocation is not necessary
Reproducibility	A2.4	Definition of materiality criteria for Scope 3	• Low: No requirement to determine the materiality of Scope 3 emissions • Medium: voluntary assessment + justification of the materiality of Scope 3 emissions • High: ICT-specific specification of materiality criteria and obligation to justify aspects identified as immaterial
Credibility	A3.1	Assessment of data quality / uncertainty assessment: • Is an evaluation mandatory? • If yes, according to which method? • Are there any guidance documents?	• Low: No assessment of uncertainties or data quality provided. • Medium: Assessment of uncertainties or data quality optional. • High: Assessment of uncertainties or data quality mandatory.

Evaluation criteria	No.	Evaluation aspects	Classification of the evaluation criteria: Definition of the three-level model (high, medium, low)
Credibility	A3.2	Validation: • Is a verification, critical review, etc. required? • If yes, internal or external?	• Low: No validation or optional validation • Medium: Internal validation required as a minimum • high: external validation required
Transparency	A4.1	Mandatory requirements regarding general information in the report; e.g. operational and organizational system boundaries, emission factors used, etc.	• Low: No or optional validation • Medium: Internal validation required as a minimum • high: external validation required
Transparency	A4.2	Mandatory requirements for the indicators in the report; e.g. differentiation by GHG, extra reporting for biologically stored GHG...	• Low: Reporting of GHG emissions, but without further subdivision of Scope 3 emissions into the individual Scope 3 categories • Medium: Detailed reporting of Scope 3 GHG emissions per category • High: Detailed reporting of Scope 3 GHG emissions per category including separate reporting of GHG from biogenic carbon

Source: Own compilation

Annex VIII.b. Results of the assessment aspects and background information on the standards for the comparative analysis in the GHG category

Table 7-29: Overview of the assessment aspects and background information of the standards for the comparative analysis in the category GHG: Scope 1 & 2

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
Background		**Scope / operational limits**	• Scope 1, 2 mandatory • Scope 3 optional	• Scope 1, 2 mandatory • Scope 3 optional
Background		**Area of application**	General standard	ICT specific standard
Background		**Indicators covered (mandatory)**	• Direct greenhouse gas emissions (Scope 1) • Indirect greenhouse gas emissions from purchased electricity (Scope 2)	• Total energy consumption • Direct greenhouse gas emissions (Scope 1) • Indirect greenhouse gas emissions from purchased electricity (Scope 2)

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
Background		**GHG covered**	• CO_2, CH_4, N_2O, SF_6, HFCs, PFCs • Update with the GHG NF_3	CO_2, CH_4, N_2O, SF_6, HFCs, PFCs
Background		**Reporting period**	Annual basis recommended	Annual basis recommended
Background		**Methodological dependencies** on other standards for Scope 1&2	No dependency on other standards, there are relevant additions for Scope 2 (Guidance Scope 2) and Scope 3 (Corporate Value Chain (Scope 3) Accounting and Reporting Standard & Technical Guidance for Calculating Scope 3 Emissions)	• ISO 14064-1 Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals: - Uncertainty assessment and verification process (further reference to ISO 14064-3 and ISO 14065) • IPCC Guidelines for National Greenhouse Gas Inventor: GWP factors • ITU-T L.1410: e.g. Scope 3 requirements / cut-off criteria
Robustness	**A1.1**	**Primary data: Data collection for Scope 1**; e.g. on-site measurement or from consumption data	either: • Collection of GHG emissions through on-site measurement or: • Collection of activity data: - from invoices - through periodic measurement of activity data (e.g. fuel consumption)	• Direct measurement of GHG emissions is generally not applicable for ICT organizations • Collection of activity data: - by measuring energy consumption - by estimates (extrapolations from a representative location or from one good to all applicable goods).
Robustness	**A1.2**	**Primary data: Data collection for Scope 2**; e.g. on-site measurement or from consumption data	• Electricity bill or • Measurement of electricity consumption	• Electricity bill or • Measurement of electricity consumption • Estimates by upscaling actual measurements from one location to all locations • Scaling up the estimated average energy consumption of one good to the total number of goods

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
Reproducibility	**A2.1**	**Requirements for emission factors** for Scope 1 and 2; indication of **literature sources/databases** for emission factors	• Emission factors: - Preference to source- or installation-specific emission factors - Scope 2 emission factors must be selected to match the location-based or market-based approach • Literature sources for Scope 2 emission factors: available in Scope 2 Guidance & reference to GHG tools, some of which contain emission factors,	• emission factors: - from a recognized source - suitable for the greenhouse gas source in question - valid at the time of quantification - which take into account the uncertainty of quantification and are calculated in a manner that provides accurate and reproducible results -consistent with the intended use of the greenhouse gas inventory • No literature sources mentioned
Reproducibility	**A2.2**	Definition of **allocation rules**	• No specific rules • In the case of the equity share approach, the breakdown of issues according to participation must be reported.	• No specific rules • If the generator system/cooling system is used for several ICT goods, it must be allocated.
Credibility	**A3.1**	**Assessment of data quality / uncertainty assessment:** • Is an evaluation mandatory? • If so, by what method? • Are there any guidance documents?	• Uncertainty assessment is optional • No specific method required • Guidance documents are available ("Guidance on uncertainty assessment in GHG inventories and calculating statistical parameter uncertainty", last update 2005) • Uncertainty tool: - Measurement and Estimation Uncertainty of GHG Emissions (2003) - Scope 3 Uncertainty Calculation Tool	• Uncertainty assessment is mandatory for Scope 1 and 2 • According to ISO 14064-1: - Assess uncertainty associated with the quantification approaches - If quantitative estimation of uncertainty is not possible or cost-effective, this must be justified and a qualitative assessment carried out - Principles and methods of ISO/IEC Guide 98-3 can be applied when performing the uncertainty assessment
Credibility	**A3.2**	**Validation**: • Is a verification, critical review, etc. required? • If yes, internal or external?	• Internal or external validation is optional	• Internal or external validation is optional (reference to ISO 14064-1 (2019) Clause 10)
Transparency	**A4.1**	**Calculation of Scope 2 emissions:** • market-based • location-based	• location-based approach in any case • If product- or supplier-specific information on electricity procurement is available, the market-based approach must also be used for the calculation.	not specified
Transparency	**A4.2**	**Requirement for calculating the GWP**; e.g. GWP	Not mentioned	• GWP 100a according to IPCC • No specification of the IPCC method, but the version used must be reported.

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
		100a according to IPCC		
Transparency	**A4.3**	**Definition of organizational system boundaries:** Equity share approach or control approach (financial or operational control)	Mandatory documentation of: • The chosen organizational boundaries, including the chosen consolidation approach • Any specific exclusions of sources, facilities and/or operations.	Mandatory documentation of: • The chosen organizational boundaries, including the chosen consolidation approach • Any specific exclusions of sources, facilities and/or operations.
Transparency	**A4.4**	**Mandatory requirements regarding general information in the report**; e.g. operational and organizational system boundaries, emission factors used, etc.	• organizational boundaries, including the chosen consolidation approach • Operational boundaries and Scope 3 categories, if Scope 3 is included • Reporting period • Base year & explanation, in the event of a recalculation of the base year • Methods used to calculate or measure emissions, with a reference or link to the calculation tools used • Any specific exclusions of sources, facilities and/or operations.	• Description of the reporting organization and the person responsible • organizational boundaries, including the chosen consolidation approach • operational limits • Reporting period • Recalculations of previous reports if necessary • Description of the quantification methods and data collection • Any specific exclusions of sources, facilities and/or operations • Result of the uncertainty assessment • List of calculation errors with an analysis of their impact on previous reports • provide a list of the CO2 and CO2e emission factors used and their origin. For GWP factors, the applicable version of [b-IPCC] shall be provided

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
Transparency	**A4.5**	**Mandatory requirements for the indicators in the report**; e.g. differentiation by GHG, extra reporting for biologically stored GHG	• Total Scope 1 and Scope 2 emissions, regardless of offsetting activities • Emission data for direct CO2 emissions (Scope 1) from biologically bound carbon separate from the Scopes • Scope 2 emissions separated by location-based and market-based method • CH_4 and N_2O emissions resulting from electricity generation from biofuel must be reported in Scope 2 (from Scope 2 Guidance) • Emissions data for all **seven greenhouse gases** separately in metric tons and in tons of CO2 equivalent (Scope 1 & Scope 2)	• Total Scope 1 and 2 greenhouse gas emissions and **broken down by country** (main countries, rest of the world)

Source: Own illustration based on Greenhouse Gas Protocol Initiative (2004) and ITU-T L. 1420 (02/2012). Differences between the standards are highlighted in bold type.

Table 7-30: Overview of the assessment aspects and background information of the standards for the comparative analysis in the category GHG: Scope 3

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
Background		**Name of the standard**	GHG Protocol Corporate Accounting and Reporting Standard (2004); amendment with Scope 2 Guidance (2015)	Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations	Protocol Corporate (Value Chain) Standard (2011)	Scope 3 Guidance for Telecommunication Operators (2023)
Background		**Area of application**	General standard	**ICT specific standard**	General standard	Standard specific for **telecommunications network operators**
Background		**GHG covered**	• CO_2, CH_4, N_2O, SF_6, HFCs, PFCs	• CO_2, CH_4, N_2O, SF_6, HFCs, PFCs	• CO_2, CH_4, N_2O, SF_6, HFCs, PFCs	• CO_2, CH_4, N_2O, SF_6, HFCs, PFCs

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
			• After amendment by Scope 2 Guidance additionally **NF3**		• In Guidance for calculating scope 3 emissions additionally **NF3**	
Background		**Reporting period**	a reporting year (not specified from when to when)	Annual basis recommended	A reporting year matching the financial reporting periods is recommended	At least annual reporting
Background		**Definition of organizational system boundaries:** Equity share approach or control approach (financial or operational control)	Free choice between the options	• Company can choose flexibly between the two options • Regardless of the approach chosen, ICT organizations should consider **all facilities** used for the organization's operations, whether owned **or leased**.	Free choice between the options	• Free choice between the options: Companies can choose flexibly between the control approach (financial or operational control) and the equity share approach. • The definition of the organizational system boundaries largely determines whether emissions from leased assets are assigned to Scope 1/2 or Scope 3 (Category 8 or 13): Upstream leased assets (category 8) and downstream leased assets (category 13)
Background		**Methodological dependencies** and synergies between standards for Scope 3	No dependency on other standards, there are relevant additions for Scope 2 and Scope 3	• ITU-T L. 1410 (11/2024) Methodology for environmental life cycle assessments of information and communication technology goods, networks and services: - LCAs of ICT goods used for the calculation of Scope 3 - Cut-off criteria, applicable to all Scope 3 categories - Operational lifetime of products	GHG Protocol, A Corporate Accounting and Reporting Standard for Scope 1 & 2	• Supplement 57 extends ITU-T L. 1420 with specific instructions for Scope 3 • GHG Protocol, A Corporate Accounting and Reporting Standard • GHG Protocol, Corporate Value Chain (Scope 3) Accounting and Reporting Standard

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
				- Uncertainty assessment for Scope 3 • GHG Protocol Corporate and GHG Protocol Corporate Value Chain (Scope 3): - Scope 3 categories		
Background		**Special features of the methodology** compared to other methods or standards	Scope 3 emissions from capital goods should be fully accounted for in the year of procurement - not spread over the life cycle.	• For **Scope 3 greenhouse gas emissions**: The life cycle impact is applicable to several categories (e.g. purchased goods and services and capital goods). For such categories, it should be noted that **all life cycle phases except the use phase** should be **divided by the operational lifetime** to determine the annual impact. • "Use of hotels" belongs to category 1 of Scope 3 according to this standard; according to Scope 3 guidance for telecommunications operators, it falls under category 6 (business travel). • Category 3 "Waste generated during operation" and category 15 "Investments" are	In contrast to scope 1&2 according to the GHG Protocol, scope 3 emissions do not have to be reported broken down by individual GHG.	• In contrast to scope 1&2 according to the GHG Protocol, scope 3 emissions do not have to be reported broken down by individual GHG. It is recommended that capital goods are not fully accounted for in the year of procurement, but that their emissions are distributed over their expected lifetime. • The **total cradle-to-gate emissions of purchased products and capital goods** must **be taken into account** for the reporting year in which the company purchased or acquired them; compliant with GHGP. This approach differs from ISO 14064-1 and also from ITU L.1420 (i.e. amortized over the life cycle). • Category 10 (processing of sold products) is not considered relevant for telecommunications operators

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
				fully considered "optional"		
Background		Assignment of **databases per Scope 3 category** available	Not mentioned	Not mentioned	Not mentioned	Yes **partially**
Background		**Scope 3 categories identified** as **relevant** for telecommunications network operators	Not mentioned	**Categories 5 and 15** are considered **irrelevant** due to their low significance for ICT and high uncertainty.	Not mentioned	• Category 1: (Purchased goods and services) • Category 2: (capital goods) • Category 3: (fuel and energy-related activities) • Category 8: (Upstream leased assets) • Category 11: (Use of products sold) • Category 13: (downstream leased assets) • Category 15: Depending on the consolidation approach and business model, investments can make a significant contribution to a TC operator's Scope 3 inventory.
Background		**Scope 3 categories identified** as **not relevant** for telecommunications network operators	Not mentioned	**Categories 5 and 15** are considered completely **optional**	Not mentioned	Other categories such as business travel (**category 6**) or employee commuting (**category 7**) may be less significant depending on company specifics, but are still important for complete reporting

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
Robustness	**A1.1**	**Requirements regarding the collection and use of activity data for the 15 categories**	Not specified	The use of secondary data sources is sufficient for Scope 3 activity data. However, it is necessary to validate and verify the data collected. Double counting should be avoided.	Recommendation that high-quality primary data should be collected for the main activities. Otherwise no specific regulations	• The guidance emphasizes the importance of collecting and using primary data directly from sources, such as suppliers and service providers, for the categories considered significant. • For the following categories, the use of secondary data in the average-data method is also possible if no primary data is available: -Category 5: Waste from operational activities - Category 7: Commuting - Category 15: Investments • Double counting is to be avoided; a special note is given in each category where there is a risk of double counting.
Robustness	**A1.2**	**Calculation methods per Scope 3 category**, e.g. spend-based method; distance-based method	Not specified	Not specified	• **Guidance** for calculating Scope 3 emissions for each Scope 3 category is provided in a separate document (Guidance for Calculating Scope 3 Emissions) • No specific specification as to which methods must be used and when • Ranking of methods according to accuracy/precision	• **Guidelines** for calculating Scope 3 emissions for each Scope 3 category are provided • Choice between different methods/approaches possible: - Industry average method, - Supplier-level allocation method, - Product-level method, • Ranking of methods according to accuracy/precision
Reproducibility: Summarized evaluation of specifications for cat. 1-15	**A2.1**	**Summarized evaluation of specifications for cat. 1-15**	Not specified	ITU-T L.1420 contains the same 15 categories for Scope 3 as the GHG Protocol Corporate Value Chain Standard. From these, **3 categories (1,2,11) are** highlighted **as particularly relevant** for ICT companies, while 2	The 15 Scope 3 categories are described in detail, but there is no focus on TC / ICT-specific aspects.	In analogy to the GHG Protocol Corporate Value Chain Standard, the 15 Scope 3 categories are described in detail. The applicability for telecom providers is discussed in depth for each category and a **prioritization** is derived **for 6 particularly ICT-significant categories (1,2,3,8,11,13).**

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
				categories (5 & 15) can be considered optional.		
Reproducibility	**A2.2**	**Requirements for emission factors**; indication of **literature sources/databases** for emission factors	• No Scope 3 specific requirements; source or company specific emission factors are preferred. • No literature sources specifically mentioned for Scope 3, but various life cycle databases are linked on the GHGP website	• Selection of emission factors: - from a recognized source -suitable for the greenhouse gas source in question - valid at the time of quantification - which take into account the uncertainty of the quantification and are calculated in a way that provides accurate and reproducible results -consistent with the intended use of the greenhouse gas inventory • **No literature sources mentioned**	• For scope 3 emissions related to fuels and energy, life cycle emission factors should be used, except for category 3 (combustion is already considered in scope 1 or 2). • **Reference to a list of** databases	• Import and export of electricity must be taken into account at country level for the calculation according to the **location-based approach** • **Reference to a list of databases**. In addition, the potential data sources for emission factors are explained separately for each category: ADEME database, US EPA database, SEAI database, RTE database, International Energy Agency (IEA) "Emission Factors Database"

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
Reproducibility	**A2.3**	Definition of **allocation rules**	No specific rules In the case of the equity share approach, the allocation of emissions must be reported by equity interest.	• No specific rules • If the generator system/cooling system is used for several ICT goods, it must be allocated.	• Step 1: **Avoid allocation** where possible (use of product-based GHG data; sub-metering of energy consumption or other activity data used to produce each output; use of engineering models) • Step 2: **physical allocation** (if it best reflects the causal relationship between the production of outputs and the resulting emissions and data on physical quantities are available) • Step 3: **Allocation using economic factors or other relationships** • Two approaches to allocating greenhouse gas emissions from suppliers: - Supplier allocation - Allocation by the reporting company	• The Guideline refers to the methods described in the GHG Protocol and in ISO 14067 (physical allocation and economic allocation). Transparency requirements are specified in this regard.
Reproducibility	**A2.4**	Definition of **materiality criteria for Scope 3**	In the GHG Protocol, the term "materiality" describes whether an error or omission in the inventory data is significant enough to influence the decisions of users. An error or omission is considered material if it could influence the decisions of users (e.g. investors, regulators or internal	• Cut-off criteria only **for Scope 3** based on ITU-T L.1410, which in turn refers to ISO 14040 and ISO 14044, but not ICT-specific. • ISO 14040 and ISO 14044: The boundary criteria for the initial inclusion of inputs and outputs and the assumptions on which the **boundary criteria**	Materiality is not defined as a formal reporting obligation with fixed thresholds, but as a principle to support decision-making. No numerical limit (e.g. 5%) for materiality of GHG inventories in the respective categories. Users should define for themselves what is material for their stakeholders and business decisions. This definition should be reviewed in the course of the	Scope 3 emissions must be reported if they are considered material, i.e. if their omission or misstatement would distort the overall balance of emissions. Organizations must perform an initial materiality analysis to decide whether certain Scope 3 categories should be included in reporting. When calculating Scope 3 emissions for the first time, it is suggested to focus on the categories that are considered material and not to aim for completeness (materiality before completeness)

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
			management). In relation to Scope 3, the GHG Protocol does not set a numerical threshold (e.g. 5%) for materiality. Companies are encouraged to define their own materiality criteria based on their business context and stakeholder expectations. This definition is subject to external critical review, if it takes place.	are based must be **clearly described**. **The impact** of the selected boundary criteria **on the outcome of** the study must also be **assessed** and **described** in the final report	critical review of the Scope 3 report, i.e. the appropriateness of cut-off criteria should be reviewed in the light of the materiality of possible contributions to the overall result.	
Credibility	**A3.1**	**Assessment of data quality / uncertainty assessment:** • Is an evaluation mandatory? • If yes, according to which method? • Are there any guidance documents?	• Uncertainty assessment is optional • No specific method required • Guidance documents are available ("Guidance on uncertainty assessment in GHG inventories and calculating statistical parameter uncertainty")	• Uncertainty assessment is optional • No specific method required • Reference to ISO 14044	• An assessment of **data quality must** be **reported**, **uncertainty assessment can** be reported • Use of certain data quality indicators is recommended (technology, time, geography, completeness, reliability), but not mandatory. • Guidance for data quality assessment in Appendix C, for uncertainty assessment in Appendix B.	• An assessment of the data quality and uncertainties is expressly recommended. • No specific method required but disclosure in the report is suggested
Credibility	**A3.2**	**Validation:** • Is a verification, critical review, etc. required? • If yes, internal or external?	• Internal or external validation is optional	• Internal or external validation is optional	• Internal or external validation optional • Recommendation: external validation in particular increases the credibility of the results	• Internal or external validation optional • Recommendation: external validation in particular increases the credibility of the results

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
Transparency	**A4.1**	**Mandatory requirements regarding general information in the report**; e.g. operational and organizational system boundaries, emission factors used, etc.	• organizational boundaries, including the chosen consolidation approach • Operational boundaries and Scope 3 categories, if Scope 3 is included • Reporting period • Base year & explanation, in the event of a recalculation of the base year • Methods used to calculate or measure emissions, with a reference or link to the calculation tools used • Any specific exclusions of sources, facilities and/or operations.	• Description of the reporting organization and the person responsible • organizational boundaries, including the chosen consolidation approach • operational limits • Reporting period • Recalculations of previous reports if necessary • Description of the quantification methods and data collection • Any specific exclusions of sources, facilities and/or operations. • Result of the uncertainty assessment for Scope 1&2 • **List of calculation errors** with an analysis of their impact on previous reports	• List of Scope 3 categories and activities included in the inventory • List of Scope 3 categories or activities excluded from the inventory with reasons for their exclusion • Once a base year has been established: the year selected as the Scope 3 base year; the rationale for the choice of base year; the policy for recalculating base year emissions; Scope 3 emissions by category in the base year • For each Scope 3 category, description of data used (including data origin), including activity data, emission factors and global warming potential (GWP) values used to calculate emissions, and **description of data quality** of reported emissions data • Per Scope 3 category Description of methods, allocation methods and assumptions	• Description of the reporting organization. • Documentation of organizational boundaries. • Documentation of the operational limits. • Documentation of category boundaries. • reporting period, covered at least annually. - Considered material Scope 3 categories • Methodology and data sources: Description of quantification methods and data collection • Recalculations, including corrections of the previous financial year • Description of the quantifying methods used for each category within the scope of the study. • Principles for collecting activity data and emission factors (EFs) per category • **Consideration of uncertainty** in relation to the greenhouse gas emissions assessed per category.

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) or ITU-T L Suppl. 57 (06/2023)
Transparency	**A4.2**	**Mandatory requirements for the indicators in the report**; e.g. differentiation by GHG, extra reporting for biologically stored GHG...	Scope 3 emissions data can be reported optionally	Scope 3 emissions can be reported optionally and do not have to be broken down by category.	• All **Scope 3 emissions broken down by category** (15) - In metric tons of CO2 equivalent, excluding **biogenic CO2** (must be reported **separately**) and greenhouse gas trading • For each Scope 3 category: **percentage of emissions** calculated using **data** obtained from **suppliers or other partners** in the value chain	• Results of the Scope 3 GHG assessment should be reported separately for **each of the relevant 15 Scope 3 categories**

Source: Own illustration based on Greenhouse Gas Protocol Initiative (2004), ITU-T L. 1420 (02/2012), Greenhouse Gas Protocol Initiative (2011) and GSMA; GeSi; ITU (2023). Differences between the standards are highlighted in bold type.

Annex VIII.c. Results of the scale representation for the comparative analysis in the greenhouse gas emissions category

Figure 7-2: Results of the scale representation for the comparative analysis according to the 3-level model in the category GHG: Group 1 - Scope 1 & 2

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); extension with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
Robustness	A1.1	Primary data: Data collection for Scope 1		
Robustheit	A1.2	Primary data: Data collection for Scope 2		
Reproducibility	A2.1	Secondary data: Collection for Scope 1 and 2		
Reproducibility	A2.2	Definition of allocation rules		
Credibility	A3.1	Evaluation of data quality / uncertainty assessment		
Credibility	A3.2	Validation		
Transparency	A4.1	Calculation of Scope 2 emissions		
Transparency	A4.2	Requirement for calculating the GWP		
Transparency	A4.3	Definition of organisational system boundaries		
Transparency	A4.4	Mandatory requirements regarding general information		
Transparency	A4.5	Mandatory requirements for the metrics		

Source: Own compilation

Figure 7-3: Results of the scale representation for the comparative analysis according to the 3-level model in the category GHG: Group 2 - Scope 3

Evaluation criteria	No.	Evaluation aspects	GHG Protocol Corporate (2004); amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	GHG Protocol Corporate Value Chain (2011)	GSMA/GeSI/ITU: Scope 3 (2023) and ITU-T L Suppl. 57 (06/2023)
Robustness	A1.1	Requirements regarding the collection and use of activity data for the 15 categories				
Robustness	A1.2	Calculation methods per Scope 3 category, e.g. spend-based method; distance-based method				
Reproducibility	A2.1	Variations with regard to Scope 3 coverage as a sum of Cat 1-15				
Reproducibility	A2.2	Requirements for emission factors; indication of literature sources/databases for emission factors				
Reproducibility	A2.3	Definition of allocation rules				
Reproducibility	A2.4	Definition of materiality criteria for Scope 3				
Credibility	A3.1	Assessment of data quality / uncertainty assessment				
Credibility	A3.2	Validation				
Transparency	A4.1	Mandatory requirements regarding general information in the report; e.g. operational and organisational system boundaries, emission factors used, etc.				
Transparency	A4.2	Mandatory requirements for the metrics in the report; e.g. differentiation by GHG, extra reporting for biologically stored GHG				

Source: Own compilation

Annex IX. Detailed evaluation of the comparative analysis (WP2): Circular economy

Annex IX.a. Definition of the three-level model (high, medium, low) for the comparative analysis in the circular economy category

Table 7-31: Definition of the three-level model (high, medium, low) for the comparative analysis in the circular economy category

Evaluation criteria	No. of the evaluation aspects	Evaluation aspects	Classification of the evaluation criteria: Definition of the three-level model (high, medium, low)
Robustness	**A1**	**Data collection methodology:** **Specificity** of the key input parameters	• low: no commitment to generic or specific data • medium: generic data • high: specific data
Reproducibility	**A2.1**	**Data collection methodology:** **Origin of** the central input parameters	• low: -> if specific data: no definition of data collection methodology -> if generic data: no specification of specific data source • medium: -> if specific data: several data collection methods to choose from / incomplete definition of the data collection method -> if generic data: several data sources to choose from • high: -> if specific data: clear definition of a specific data source and collection methodology -> if generic data: clear definition of a specific data source
Reproducibility	**A2.2**	**Data collection methodology:** **Reference period for database**	• low: no specific requirement for reference period • medium: in a fixed period of time, without requirement for representativeness • high: in a defined period that is representative of production
Credibility	**A3.1**	**Assessment of uncertainties/data quality**	• low: No assessment of uncertainties or data quality provided. • medium: Assessment of uncertainties or data quality optional. • high: Assessment of uncertainties or data quality mandatory.
Credibility	**A3.2**	**Validation**	• low: no validation required, or validation optional • medium: internal validation required as a minimum • high: external validation required

Evaluation criteria	No. of the evaluation aspects	Evaluation aspects	Classification of the evaluation criteria: Definition of the three-level model (high, medium, low)
Transparency	**A4**	**Reporting**	• low: No systematic requirements for reporting on metric results and framework conditions. • medium: Reporting of metric results and/or basic input parameters. • high: Detailed general information on the test framework (system under test, test conditions, location and equipment) as well as indicator results and basic input parameters in a standardized report template.

Source: Own compilation

Annex IX.b. Results of the assessment aspects and background information on the standards for the comparative analysis in the circular economy category

Table 7-32: Overview of the assessment aspects and background information of the standards for the comparative analysis in the circular economy category: Before use

Evaluation criteria	No.	Evaluation aspects	ETSI TR 103 476 V1.1.2 (2018-02)	DIN EN 45556 (2020)	DIN EN 45557 (2020)
Background		**Name**	Environmental Engineering (EE); Circular Economy (CE) in Information and Communication Technology (ICT); Definition of approaches, concepts and metrics	General method for assessing the proportion of reused components in energy-related products; English version EN 45556:2019, English translation of DIN EN 45556:2020-03	General method for assessing the proportion of recycled material content in energy-related products; English version EN 45557:2020, English translation of DIN EN 45557:2020-09
Background		**Area of application**	• Applicable to **ICT infrastructure** of all kinds	• not a network-specific standard Applicable to **energy-related products** of all kinds	• not a network-specific standard Applicable to **energy-related products** of all kinds
Background		**Goals**	• Overview description of existing indicators for circular economy and resource efficiency and examples of their use	• Evaluation of the proportion of reused components in energy-related products at generic level	• Evaluation of the proportion of recycled material in an energy-related product
Background		**Scope**	• basically all network and infrastructure components (due to the general scope of application, but without specifically addressing network and infrastructure components)	• basically all network and infrastructure components (due to the general scope of application, but without specifically addressing network and infrastructure components)	• basically all network and infrastructure components (due to the general scope of application, but without specifically addressing network and infrastructure components)

Background		**Definitions**	• Recycled content: percentage by mass of recycled material in a product or packaging Reuse: any operation in which components of end-of-life products are used for the same purpose for which they were designed Recycling: reprocessing of waste materials in a production process for the original purpose or for other purposes, excluding processing as a means of energy generation Recovery: reprocessing of waste materials in a production process for the original purpose or for other purposes, including processing for energy generation	• Component: Hardware part of a product that cannot be disassembled without destroying or impairing its intended use Reused component: component that is reused with or without modification	• Recycled material: material that is either pre-consumer material or post-consumer material Pre-consumer material: material recovered from waste generated during a manufacturing process, excluding the reuse of materials such as rework, regrind or scrap generated in a process and reincorporated into the same process that generated it Post-consumer material: material recovered from waste generated by households or commercial, industrial and institutional facilities in their role as end users of a finished product
Background		**Dependencies** between **standards**	• No normative references to other standards, only informative references	• normative reference to EN 45559:2019 "Methods for providing information relating to material efficiency aspects of energy-related products" regarding the definition of the sensitivity levels of the data. The standard points out that when reporting indicators for different target groups, the data is evaluated according to sensitivity levels 1, 2 and 3 in accordance with the EN 45559 standard.	• Normative reference to EN 45559:2019 "Methods for providing information relating to material efficiency aspects of energy-related products" only with regard to documentation of the results
Background		**Indicators: Weight** of **recycled** products	• Standard lists several indicators/metrics for recycled content of products; metrics include the **weight of recycled materials in products** The weight of recycled products (must-have-metric) is not mentioned; metrics remain at material level	• not mentioned	• The **weight of recycled materials or parts** (components) is used as an input parameter for metrics for **pre-consumer material content** and **post-consumer material content**. The weight of recycled products (must-have metric) is not mentioned; the metrics remain at component level/material level.
Background		**Indicators: Weight** of **refurbished** products	• not mentioned	• not mentioned	• not mentioned

Background		**Indicators: Number** of **refurbished** products	• not mentioned	• not mentioned	• not mentioned
Background		**Indicators: Weight** of **reused** products	• The standard describes the **proportion of reused parts and sub-parts** in relation to all parts of the ICT infrastructure good; it does **not specify** whether the **proportion is calculated based on mass or number**. The weight of reused products (must-have-metric) is not mentioned; the standard remains at the component level.	• The **weight of reused components** is used as an input parameter for metrics for the proportion of reused components (by mass and number in the product under consideration, by mass balance and by number balance). The weight of reused products (must-have-metric) is not mentioned; the standard remains at the component level.	• not mentioned
Robustness	A1	**Data collection methodology: Specificity** of the key input parameters	• **No commitment to generic or specific data**	• **Specific data** As there are no methods for directly measuring the proportion of recycled components in a product, verification can only be carried out indirectly, e.g. on the basis of documented evidence from the manufacturer, supplier and/or authorized dealer.	• **Specific data** As there are no methods for directly measuring the proportion of recycled components in a product, verification can only be carried out indirectly, e.g. on the basis of documented evidence of traceability submitted by the relevant operator in the certification and monitoring chain (chain of custody).
Reproducibility	A2.1	**Data collection methodology: Origin of** the central input parameters	• **No specification** of data collection methodology / no specification of specific data sources	• **Documented evidence** from manufacturers, suppliers or authorized dealers	• **documented evidence** of the traceability of corresponding operators in the certification and monitoring chain (chain of custody)
Reproducibility	A2.2	**Data collection methodology: Reference period for database**	• **No specific requirement for reference period**	• **defined period** (no longer than one year) that is representative of production volumes	• **defined period** (no longer than one year), which should **reflect the latest available data** and must be representative of the production volume
Credibility	A3.1	Assessment of **uncertainties/data quality**	• not mentioned	• not mentioned	• not mentioned

Credibility	A3.2	**Validation**	• not mentioned	• **Verification** of the proportion of reused components required **on the basis of documented evidence** from the manufacturer, supplier and/or authorized dealer No validation by an authorized internal or external body is mentioned, but the specifically named verification of the input data contributes to the credibility.	• **internal verification by comparing the production quantity** over a certain accounting period with the inputs, corrected for changes in material stock and conversions during the processes No validation by an authorized internal or external body is mentioned, but the specifically named verification of the input data contributes to the credibility.
Transparency	A4	**Reporting**	• **No report formats available**	• **Indicator results and basic input parameters**	• **Indicator results and basic input parameters**

Source: Own compilation

Table 7-33: Overview of the assessment aspects and background information of the standards for the comparative analysis in the circular economy category: End-of-Life

Evaluation criteria	No.	Evaluation aspects	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
Background		**Name**	• Waste 2020	Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 8: Management of end of life of ICT equipment (ICT waste/end of life) EUROPEAN STANDARD	• Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 8: Implementation of WEEE practices for ICT equipment during maintenance and at end-of-life
Background		**Area of application**	• **no network-specific standard** Applicable to sectors (and waste) of all kinds including: all network components (due to the general scope, but without specifically addressing network and infrastructure components)	• Applicable to **ICT equipment** of all kinds	• Applicable to **ICT equipment** and infrastructure of all kinds

Evaluation criteria	No.	Evaluation aspects	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
Background		**Goals**	• Guidance on reporting information on waste-related impacts	• Specification of requirements regarding the management of the EoL phase of ICT equipment	• Provision of a framework for implementation and refinement of the requirements from ETSI EN 305 174-8 Extension of EoL aspects to include the handling of components and sub-assemblies that have been replaced in the course of maintenance measures
Background		**Scope**	• Waste generated by own economic activities (optional: reporting of waste along value chain upstream & downstream)	• ICT locations Network distribution node (NDN) Core networks Fixed access networks Mobile access networks Cable access networks Customer premises Network interface units	• ICT locations Network distribution node (NDN) Core networks Fixed access networks Mobile access networks Cable access networks Customer premises Network interface units
Background		**Definitions**	• Preparation for reuse: testing, cleaning or repair processes in which products or components of products that have become waste are prepared so that they can be used for the same purpose for which they were originally designed • **Recycling: reprocessing of products or components of products that have become waste to produce new materials** • Recovery: Process by which products, components of products or materials that have become waste are reprocessed to fulfill a specific purpose in place of new products, components or materials that would otherwise have been used for that purpose	• **Recycling (of WEEE): any recovery operation by which waste materials are reprocessed into substances, materials or products for the original purpose or for other purposes** • Reuse (of WEEE): any process by which products that are not waste are reused for the same purpose for which they were originally intended • recovery (of WEEE): any process where the main outcome is to put waste to a useful purpose by replacing other substances, materials or products that were used for a specific purpose, or preparing waste for use for that purpose refurbishment seems to be counted as reuse in the standard, a clear definition is not available the term "prepared for reuse" is used several times in the standard, a definition is not available	• **Recycling (of WEEE): any recovery operation by which waste materials are reprocessed into substances, materials or products for the original purpose or for other purposes** • Reuse (of WEEE): any process by which products that are not waste are reused for the same purpose for which they were originally intended • recovery (of WEEE): any operation the main result of which is to put waste to a useful purpose by replacing other substances, materials or products that were used for a specific purpose, or preparing waste for use for that purpose

Evaluation criteria	No.	Evaluation aspects	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
			• Waste: anything that the owner throws away, intends to throw away or is obliged to throw away		
Background		**Dependencies** between **standards**	• not mentioned	• Materials/components/products must have been treated prior to recovery or recycling/preparation for re-use in accordance with Article 8(2) of Directive 2012/19/EU on WEEE; the weights of the respective WEEE must be collected after treatment in accordance with Article 8(2) of Directive 2012/19/EU on WEEE	• is based on ETSI EN 305 174-8. In addition: Formulation of reporting obligations of recyclers, other stakeholders (users of ICT equipment such as network operators; dealers, maintenance companies); operational recommendations for maintenance during the use phase Furthermore, CENELEC EN 50614 and a number of CENELEC EN 50625-x were mentioned as normative references. Each standard is tailored to specific WEEE types or processes, giving different actors clear responsibilities and procedures.
Background		Consideration of different **types of waste**	• **yes (hazardous/non-hazardous waste from different sectors)**	• **WEEE only**	• **WEEE only**
Background		**Weight** of **e-waste**	• Total weight of **hazardous and non-hazardous waste** (in tonnes), **broken down by waste composition** (e.g. **WEEE** for companies in the consumer electronics sector).	**Weight of e-waste** consisting of the sum of e-waste from the following treatments: Preparation for reuse; Reuse of components; Recycling of materials; Energy recovery; Disposal	• **quantity of WEEE processed** (kg per annum)
Background		**Weight** of **recycled** products	• Total weight of hazardous and non-hazardous waste (in tonnes) broken down by recovery operations, including: recycling • GRI 306 defines "recycling" as reprocessing of products or components of products that	• weight of WEEE recycled is part of metric	• quantity of WEEE recycled (kg per annum)

Evaluation criteria	No.	Evaluation aspects	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
			have become waste, to make new materials		
Background		**Weight** of **refurbished** products	• **refurbishment is not mentioned as seperate category** • Total weight of hazardous and non-hazardous waste (in tonnes) broken down by recovery operations, including: other recovery operations **Other recovery operations include refurbishment, among others**	• **refurbishment (and second life) are counted as reuse in the standard**	• not mentioned
Background		**Number** of **refurbished** products	• not mentioned	• not mentioned	• So-called 'other actors', including operators of ICT infrastructure, should report, among other things, the 'ratio of refurbished equipment to the number of devices entering the EoL process'.
Background		**Weight** of **reused** products	• **'Reuse' is not mentioned as a separate category 'Preparation for reuse'** is mentioned as a separate category and, according to the **definition in Directive 2008/98/EC**, includes checking, cleaning, or repairing operations, by which products or components of products that have become waste are prepared to be put to use for the same purpose for which they were conceived	• The standard defines a hierarchy for the recycling of WEEE, with the reuse of complete devices ('reuse of complete WEEE') being given the highest priority. The metric in the standard for 'treated WEEE' includes 'WEEE prepared for reuse', **reused components ('reused by parts')**, recycled materials, energy recovery and disposal. The weight of 'WEEE prepared for reuse' and 'WEEE reused by parts' is part of the formula for calculating the total WEEE treated. However, there is **no definition of 'WEEE prepared for reuse'**. It remains unclear whether this term in the formula actually refers to the product level (whole products). Article 3 (2) of the WEEE Directive (Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) with EEA relevance) refers to Article 3 of the Waste Framework Directive	• When defining metrics for reporting, the standard refers to ETSI EN 305 174-8. This includes, among other things, the metric 'quantity of WEEE prepared for re-use (kg per annum)' with an unclear definition and the metric 'quantity of WEEE re-used by parts (kg per annum)', but not the must-have metric 'weight of reused products'.

Evaluation criteria	No.	Evaluation aspects	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
				(Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives) for the definition of the term 'preparation for reuse'. This defines 'preparing for reuse' as 'checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing'. Accordingly, the term can refer to both entire products and components.	
Robustness	A1	**Data collection methodology: Specificity** of the key input parameters	• Specific data from own survey	• Specific data from own survey	• Specific data from own survey
Reproducibility	A2.1	**Data collection methodology: Origin of** the central input parameters	• different sources to choose from: **Modeling, direct measurement** (e.g. waste transfer bills from contracted waste management companies, external reviews/audits of waste-related data) • It must be reported on: Contextual information required to understand the data and its collection • It **can be reported** on: **reasons for the difference between the weight of waste generated and the weight of waste destined for recovery or disposal** (e.g. precipitation or evaporation, leakages or losses or other changes in the waste)	• **Measurement** of WEEE flows based on actual values OR **estimation** of the weight of WEEE categories before treatment • No specification of measurement or estimation methods	• **No specification of** data collection methodology • It is proposed to use software with asset management functionality
Reproducibility	A2.2	**Data collection methodology:**	• not mentioned	• not mentioned	• 1 year

Evaluation criteria	No.	Evaluation aspects	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
		Reference period for database			
Credibility	A3.1	Assessment of **uncertainties/data quality**	• not mentioned	• not mentioned	• not mentioned
Credibility	A3.2	**Validation**	• The standard specifies processes for collecting and monitoring waste-related data: - Online data entry. - Centralized databases. - Real-time weighbridge measurements. **- Annual external data validation**. Accordingly, the standard specifies external validation of waste-related data as optional.	• not mentioned for the calculation of the indicators. • However, network operators are demanding this: conduct regular audits of contracts with and processes of waste disposal partners and **ensure reliable and auditable reporting**	• not mentioned
Transparency	A4	**Reporting**	• should provide **contextual information about the data and about the data collection** • Metric results	• not mentioned	• only metric results without further details

Source: Own compilation

Annex IX.c. Results of the scale representation for the comparative analysis in the circular economy category

Figure 7-4: Results of the scale representation for the comparative analysis according to the 3-level model in the circular economy category: Before use

Evaluation criteria	No.	Evaluation aspects	ETSI TR 103 476 V1.1.2 (2018-02)	DIN EN 45556 (2020)	DIN EN 45557 (2020)
Robustness	A1	Data collection methodology: Specificity of the central input parameters			
Reproducibility	A2.1	Data collection methodology: Origin of the central input parameters			
Reproducibility	A2.2	Data collection methodology: Reference period for database			
Credibility	A3.1	Assessment of uncertainties/data quality			
Credibility	A3.2	Validation			
Transparency	A4	Reporting			

Source: Own compilation

Figure 7-5: Results of the scale representation for the comparative analysis according to the 3-level model in the category circular economy: end-of-life

Evaluation criteria	No.	Evaluation aspects	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
Robustness	A1	Data collection methodology: Specificity of the central input parameters			
Reproducibility	A2.1	Data collection methodology: Origin of the central input parameters			
Reproducibility	A2.2	Data collection methodology: Reference period for database			
Credibility	A3.1	Assessment of uncertainties/data quality			
Credibility	A3.2	Validation			
Transparency	A4	Reporting			

Source: Own compilation

Annex X. Detailed evaluation of the application effort (WP3): Energy management

Table 7-34: Definition of a 3-level scale system for effort estimation in the energy management category

Preconditions	3-level scale system for assessing the effort involved
Technical preconditions	**Criteria for the categories "low", "medium" and "high"**
Does the standard require technical measures such as direct on-site measurements or installation of measurement equipment?	• low: measurements not necessary / not mandatory • medium: measurements can be carried out with existing equipment or substituted by analysing existing sources • high: measurements usually require the purchase of special measuring equipment
Is data collection required over a longer period of time?	• low: no data collection required for up to 7 days • medium: data collection required for up to 6 months • high: data collection required for 6 months or more
Methodological preconditions	**Criteria for the categories "low", "medium" and "high"**

Preconditions	3-level scale system for assessing the effort involved
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	• low: no specific procedures / methodological guidelines required • medium: standard needs to be adapted to the specific situation of the company / organization (e.g. with regard to energy consumption, emissions, waste) • high: Development of specific methodological guidelines required
Are there methodological dependencies between the standards?	• low: Fewer than two methodological references / dependencies to other already well established standards / methods • medium: two or more other standards / methods must be included (i.e. purchased, read and understood) for compliance with the standard • high: three or more other standards / methods must be included (i.e. purchased, read and understood) for compliance with the standard
Is the template for the reports provided? And is an example included to demonstrate the reporting results?	• low: Reporting template and examples are provided. • medium: Reporting template is provided, but no examples are included, or vice versa. • high: No reporting template or examples are provided.
Is an uncertainty assessment/data quality assessment required? And is an example of uncertainty assessment provided?	• low: Uncertainty assessment/data quality assessment is either not mentioned or considered optional. • medium: Uncertainty assessment/data quality assessment is mandatory, but examples are included. • high: Uncertainty assessment/data quality assessment is mandatory, and no examples are provided.
Organizational preconditions	**Criteria for the categories "low"", "medium" and "high"**
Does compliance with the standard require cooperation between different business areas / organizational units?	• low: no cooperation required • medium: cooperation between two business units / organizational units required • high: cooperation of three or more business units / organizational units required
Does the compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	• low: no cooperation required • medium: cooperation with one stakeholder required • high: cooperation with two or more stakeholders required
Does compliance with the standard require an audit or external review?	• low: auditing or external review not necessary / not mandatory • medium: internal audit required • high: external audit (e.g. critical review) and / or certification by a third party required

Source: Own compilation, **Bold text** indicates criteria with double weighting

Table 7-35: Effort estimation for the application of standards to determine must-have indicators in the energy management category - Part I: RAN

Preconditions	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Network segment	RAN: 2G/3G/4G	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent
Technical preconditions							
Does the standard require technical measures such as direct measurements on site or the installation of measuring devices?	Yes, because the energy consumption must be measured.	This depends on how the energy consumption is recorded: either by direct measurements on site or by the electricity supplier. Metering equipment is required for direct on-site measurements. It is assumed that the data collected by the electricity supplier is based on pre-installed meters.	This depends on how the energy consumption is recorded: either by direct measurements on site or by the electricity supplier. Metering equipment is required for direct on-site measurements. It is assumed that the data collected by the electricity supplier is based on pre-installed meters.	This depends on how the energy consumption is recorded: either by direct measurements on site or by the electricity supplier. Metering equipment is required for direct on-site measurements. It is assumed that the data collected by the electricity supplier is based on pre-installed meters.	Yes, measurements must be taken, either of energy or alternatively of voltage and current.	This depends on how the energy consumption is recorded: either by direct measurements on site or by the electricity supplier. Metering equipment is required for direct on-site measurements. It is assumed that the data collected by the electricity supplier is based on pre-installed meters.	This depends on how the energy consumption is recorded: either by direct measurements on site, by the electricity supplier or by estimates based on samples of typical access network locations by the mobile network operator or by devices. If the data collection is based on an estimate by devices, no measurements are required.
Is it necessary to collect data over a longer period of time?	The standard period for KPI measurement is 365 days. Shorter periods (at least 7 days) are only permitted if the climatic fluctuations are minimal and the data volume development	The minimum duration is one week.	No, it can be decided individually.	No, continuous real-time monitoring is preferred, but not mandatory.	No, optional: 1 day; 1 week; 1 month; 1 year	The standard period for KPI measurement is 365 days, whereby shorter periods (at least 7 days) are only permitted if the climate fluctuations are minimal and the data volume development corresponds to the annual patterns.	Yes: Reference to ETSI EN 305 200-2-3; no separate requirements in this TS.

Preconditions	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Network segment	RAN: 2G/3G/4G	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent
	corresponds to the annual patterns.						
Methodological preconditions							
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	No	No	No	No	No	No	No
Are there methodological references / dependencies to other standards?	• ETSI ES 203 228 (standard is covered in the study): Data volume • ETSI ES 202 336-12: Measurement methods and accuracy for the measurement of power and energy consumption • Standard meter according to ETSI TS 132 425 for LTE; - Standard counter according to ETSI TS 132 412 for UMTS (Note: not relevant as 3G is obsolete). • The "Quality of Service" (QoS)	• Data volume: ETSI TS 132 425 and ETSI TS 132 412 for LTE or for 2G and 3G. • The "Quality of Service" (QoS) counter ETSI TS 123 203 is to be used for reporting the quality of service. • For 5G, the DV (data volume) is to be derived from ETSI TS 128 552 / ETSI TS 128 554 in 3GPP SA5. • For virtualized devices, the measurement method for energy efficiency is described in ETSI EN 303 471.	No	• ETSI ES 202 336-12 is mentioned; if the operators measure the energy themselves, this is not mandatory. • Electrical energy: Class 1 (see class 1 of [IEC 62053-21]) • The accuracy of the voltage and current measurements is defined in [ITU-T L.1320].	• The SEE (Site Energy Efficiency) index: [ITU-T L.1350] • General requirements for voltage and current measuring devices are contained in [ITU-T L.1315]. • Energy meters used in the field must meet the requirements of class 1 in accordance with [IEC 62053-21]. • Measurement reports must comply with the general requirements of [ISO/IEC 17025]. • For devices with a DC power supply, the	• Total data volume for all base stations of the mobile network according to ETSI EN 303 472 (standard covered in this study)	• ETSI EN 305 200 series • This TS supports ETSI EN 305 200-2-3 • Discrepancy: ETSI EN 303 472 is considered informative in this TS, in contrast to EN 305 200-2-3, which is normative.

Preconditions Network segment	**ETSI EN 303 472 V1.1.1 (2018-10)** RAN: 2G/3G/4G	**ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331** RAN: technology-independent	**ETSI TR 103 540 V1.1.1 (2018-04)** RAN: technology-independent	**ITU-T L.1350 (10/2016)** RAN: technology-independent	**ITU-T L.1351 (08/2018)** RAN: technology-independent	**ETSI EN 305 200-2-3 V1.1.1 (2018-06)** RAN: technology-independent	**ETSI TS 105 200-2-3 V1.2.1 (2019-12)** RAN: technology-independent
	counter ETSI TS 123 203 is to be used for reporting on the quality of service.				reference point should be interface A as defined in [b-ETSI EN 300 132-2].		
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	Test reports available, but no examples	Yes, template and example	There is no explicit template, but this standard contains detailed implementation examples and a reporting format for the indicator.	No	No	No	Yes, template available, no examples
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	No	No	The calculation of the margin of error is mandatory; examples of both methods are given.	No	No	No	No
Organizational preconditions							
Does compliance with the standard require cooperation between different business areas / organizational units?	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	No, the standard only refers to BS locations under joint management.	No	Yes, TLAFs are removed from the energy consumption values for the site provided by the electricity supplier. Due to their geographical	No	No	No, shared infrastructures of several operators are excluded	Yes, shared infrastructure between multiple operators is included, with allocation based on energy costs. Note: It is assumed that the infrastructure is

Preconditions	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Network segment	RAN: 2G/3G/4G	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent
			distribution, different base station locations may need to be coordinated with different electricity suppliers.				shared by at least two operators. In addition, appliance manufacturers could also be included if consumption is estimated on the basis of the appliances.
Does compliance with the standard require an audit or external review?	No	Yes, in the case of shared infrastructure between different operators.	No	No	No	No	No

Source: Own compilation.

Table 7-36: Effort estimation for the application of standards to determine must-have indicators in the energy management category - Part II: FAN, CAN and NFV

Preconditions	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	ETSI EN 303 471 V1.1.1 (2019-01)
Network segment	FAN: technology-independent	FAN: technology-independent	CAN: technology-independent	Entire access network: NFV
Technical preconditions				
Does the standard require technical measures such as direct measurements on site or the installation of measuring devices?	This depends on how the energy consumption is recorded: either by direct measurements on site or by the electricity supplier. Metering equipment is required for direct on-site measurements. It is assumed that the data collected by the electricity supplier is based on pre-installed meters.	This depends on how the energy consumption is recorded: either by direct measurements on site, by the electricity supplier or by estimates based on samples of typical access network locations by the mobile network operator or by devices. If the data	No, with a preference for direct measurements, but taking estimates into account.	Yes, because the energy consumption must be measured.

Preconditions	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	ETSI EN 303 471 V1.1.1 (2019-01)
		collection is based on an estimate by devices, no measurements are required.		
Is it necessary to collect data over a longer period of time?	The standard period for KPI measurement is 365 days, whereby shorter periods (at least 7 days) are only permitted if the climate fluctuations are minimal and the data volume development corresponds to the annual patterns.	The standard period for KPI measurement is 365 days, whereby shorter periods (at least 7 days) are only permitted if the climate fluctuations are minimal and the data volume development corresponds to the annual patterns.	No, one hour	The standard period for KPI measurement is 365 days. Shorter periods (at least 7 days) are only permitted if the climatic fluctuations are minimal and the data volume development corresponds to the annual patterns.
Methodological preconditions				
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	No	No	Yes, it is unclear how to deal with shared infrastructure and multiple operators. -> Allocation	Yes, it is mentioned that if the NFVI supports multiple access networks, the energy consumption for each access network (e.g. RAN, FAN) must be separately measurable. However, further specifications are missing. It is assumed that further guidelines on a standardized methodology would be helpful due to the technical complexity.
Are there methodological references / dependencies to other standards?	-ETSI EN 305 200-1: a document with general requirements that deals with global KPIs for operational infrastructures	Normative references -ETSI EN 305 200 series -ETSI EN 305 200-2-2	ETSI ES 205 200-1 V1.2.1 (2014-03) Note: ETSI ES 205 200-1 is not ETSI EN 305 200-1 as other standards in the ETSI EN 305 200 series refer in context to the general requirements of ETSI EN 305 200-1. This distinction may result from the fact that ETSI ES 205 200-2-4 is an ETSI standard (ES),	Yes. -The methods for measuring power consumption and energy and their accuracy shall comply with the requirements of ETSI ES 202 336-12. -Measurement of data volume and data packets at physical interfaces,

Preconditions	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	ETSI EN 303 471 V1.1.1 (2019-01)
			whereas ETSI EN 305 200-1 is a European standard (EN).	supported by ETSI GS NFV-TST 008
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	No	Report template (rudimentary) is provided, no examples	There is no template for reporting, but a sample calculation is provided.	No
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	No	No	No	No
Organizational preconditions				
Does compliance with the standard require cooperation between different business areas / organizational units?	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.	Yes, organizational units such as Facility Management could be involved.
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	No, shared infrastructures of several operators are excluded	Yes, shared infrastructure between multiple operators is included, with allocation based on energy costs. Note: It is assumed that the infrastructure is shared by at least two operators. In addition, appliance manufacturers could also be included if consumption is estimated based on the appliances.	No	Yes, electricity supplier, as the loss caused by the supply company (grid) must be included in the calculation of energy consumption.
Does compliance with the standard require an audit or external review?	No	No	No	No

Source: Own compilation. **Bold text** indicates criteria with double weighting

Table 7-37: Effort estimation for the application of standards to determine must-have indicators in the energy management category - Part III: Core network, sub-network and whole network

Preconditions	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ITU-T L.1332 (01/2018)
Network segment	5G mobile network: RAN, core network, end-to-end, NFV, slicing	ICT location: Core network	ICT location: Core network	ICT location: entire network
Technical preconditions				
Does the standard require technical measures such as direct measurements on site or the installation of measuring devices?	Yes	Yes	Yes	Yes
Is it necessary to collect data over a longer period of time?	Not mentioned	Yes, standard: 365 days	Yes, standard: 365 days	Optional; continuous real-time monitoring is preferable, if this is not possible, monitoring should be carried out as often as possible. When reporting measured values, network site operators should use the average NIEE value measured over a period of one year to obtain an average value.
Methodological preconditions				
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	Yes, this document defines Key Performance Indicators (KPIs) for 5G networks, including network slices, from an end-to-end perspective. It does not specify measurement methods such as measurement period or frequency. The interfaces for measuring data volume (e.g. N3, F1-U) are clearly defined, but physical measurement points for energy consumption are not specified. There are also no clear requirements for the shared use of the infrastructure by different operators.	Yes, there are no clear requirements for the shared use of infrastructure by different operators.	Yes, there are no clear requirements for the shared use of infrastructure by different operators.	No
Are there methodological references / dependencies to other standards?	-3GPP TS 28.552: Performance parameters (e.g. data volume on different interfaces, latency, number of registered subscribers, number of active UEs). Note: To understand	-CEN EN 1434 series -CENELEC EN 50600-2-2: -ETSI EN 305 200-3-1	-CEN EN 1434 series -CENELEC EN 50600-2-2: Definitions for the "availability	- The accuracy of the test equipment shall comply with the requirements of Section 8.1, Table 1 of [ITU-T L.1350].

Preconditions	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ITU-T L.1332 (01/2018)
	3GPP TS 28.552, section 3.3, "Measurement definition template", of 3GPP TS 32.404 must be consulted. -ETSI GS NFV-IFA 027: Average virtual CPU utilization; average vMemory utilization, vDisk utilization, I/O traffic volume (i.e. number of incoming and outgoing bytes on virtual machines) -ETSI ES 202 336-12: Energy consumption		class" of power supply and power distribution systems.	- Class 1 measurement systems are used for the accuracy of energy measurement and should refer to Class 1 of [b-IEC 62053-21]. - The energy consumption of ICT equipment shall be measured directly or reported using the measurement defined in [b-ETSI ES 202 336-12].
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	No	Yes, but no examples	No	No
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	No	Yes, all assessment periods shall be one year, including the tolerable inaccuracies according to ETSI EN 305 200-3-1. Note: ETSI EN 305 200-3-1 does not describe tolerable inaccuracies. Based on page 14: The estimated statistical accuracy shall be stated. It is assumed that the calculation of the statistical accuracy is mandatory.	No	No
Organizational preconditions				
Does compliance with the standard require cooperation between different business areas / organizational units?	Yes, this requires collaboration between IT technicians, virtualized infrastructures, network segment management and facility/energy teams for data collection and analysis.	Yes, facility management	Yes, facility management	Yes, different organizational units can be involved for: -Facility management for diesel generators -Maintenance/logistics for maintenance work

Preconditions	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ITU-T L.1332 (01/2018)
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	-In the case of network slicing calculation (not the subject of this study): Yes, compliance requires collaboration with vendors to provide technical parameters (e.g. energy consumption, vCPU utilization) for network elements (e.g. gNBs) and virtualized platforms. -In the case of the NFV infrastructure as a whole: without differentiating individual functions, the need for external collaboration can be reduced if the operator controls the infrastructure. -Overall cooperation is required in scenarios with shared infrastructure or multiple operators.	Probably yes, as mixed-use premises could mean a shared infrastructure.	Probably yes, as mixed-use premises could mean a shared infrastructure.	No
Does compliance with the standard require an audit or external review?	No	No	No	No

Source: Own compilation. **Bold text** indicates criteria with double weighting

Table 7-38: Results of the semi-quantitative effort estimation in the energy management category - Part I: RAN – indicated in plus signs

Scoring	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Network segment	RAN: 2G/3G/4G	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent	RAN: technology-independent
Technical preconditions							
Does the standard require technical measures such as direct measurements on site or the installation of measuring devices?	+++	++	++	++	+++	++	+

Scoring	ETSI EN 303 472 V1.1.1 (2018-10)	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	ETSI TR 103 540 V1.1.1 (2018-04)	ITU-T L.1350 (10/2016)	ITU-T L.1351 (08/2018)	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	ETSI TS 105 200-2-3 V1.2.1 (2019-12)
Is it necessary to collect data over a longer period of time?	**++++++**	**++**	**++**	**++**	**++**	**++++++**	**++++++**
Methodological preconditions							
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	+	+	+	+	+	+	+
Are there methodological references / dependencies to other standards?	**++++++**	**++++++**	**++**	**++++++**	**++++++**	**++**	**++++++**
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	++	+	++	+++	+++	+++	++
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	+	+	++	+	+	+	+
Organizational preconditions							
Does compliance with the standard require cooperation between different business areas / organizational units?	++	++	+++	++	++	++	++
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	+	++	+++	+	+	+	+++
Does compliance with the standard require an audit or external review?	**++**	**++**	**++**	**++**	**++**	**++**	**++**
Total "+"	**24**	**19**	**19**	**20**	**21**	**20**	**24**
Total "n.d."	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Source: Own compilation. **Bold text** indicates criteria with double weighting; 'n.d.' (indeterminable)

Table 7-39: Results of the semi-quantitative effort estimation in the energy management category - Part II: FAN, CAN and NFV – indicated in plus signs

Scoring	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	ETSI EN 303 471 V1.1.1 (2019-01)
Network segment	**FAN: technology-independent**	**FAN: technology-independent**	**CAN: technology-independent**	**Entire access network: NFV**
Technical preconditions				
Does the standard require technical measures such as direct measurements on site or the installation of measuring devices?	++	+	+	+++
Is it necessary to collect data over a longer period of time?	**++++++**	**++++++**	**++**	**++++++**
Methodological preconditions				
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	+	+	++	+++
Are there methodological references / dependencies to other standards?	**++++**	**++++**	**++**	**++++**
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	++	++++	++	+++
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	+	+	+	+
Organizational preconditions				
Does compliance with the standard require cooperation between different business areas / organizational units?	++	++	++	++
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	+	+++	+	++
Does compliance with the standard require an audit or external review?	**++**	**++**	**++**	**++**
Total "+"	**21**	**24**	**15**	**26**
Total "n.d."	**0**	**0**	**0**	**0**

Source: Own compilation. **Bold text** indicates criteria with double weighting; 'n.d.' (indeterminable)

Table 7-40: Results of the semi-quantitative effort estimation in the energy management category - Part III: Core network, sub network and entire network – indicated in plus signs

Scoring	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ITU-T L.1332 (01/2018)
Network segment	**5G mobile network: RAN, core network, end-to-end, NFV, slicing**	**ICT location: Core network**	**ICT location: Core network**	**ICT location: entire network**
Technical preconditions				
Does the standard require technical measures such as direct measurements on site or the installation of measuring devices?	+++	+++	+++	++
Is it necessary to collect data over a longer period of time?	**n.d.**	**++++++**	**++++++**	**++**
Methodological preconditions				
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	+++	++	++	+
Are there methodological references / dependencies to other standards?	**++++**	**++++++**	**++++**	**++++++**
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	+++	++	+++	+++
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	+	+++	+	+
Organizational preconditions				
Does compliance with the standard require cooperation between different business areas / organizational units?	++	++	++	++
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	++	++	++	+
Does compliance with the standard require an audit or external review?	**++**	**++**	**++**	**++**
Total "+"	**20**	**28**	**25**	**20**

Scoring	ETSI TS 128 554 V18.7.0 (2024-10)	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	ITU-T L.1332 (01/2018)
Total "n.d."	**1**	**0**	**0**	**0**

Source: Own compilation. **Bold text** indicates criteria with double; 'n.d.' (indeterminable)

Annex XI. Detailed evaluation of the application effort (WP3): GHG emissions

Table 7-41: Definition of a 3-level scale system for effort estimation in the GHG emissions category

Preconditions	3-level scale system for assessing the effort involved
Technical preconditions	**Criteria for the "low", "medium" and "high" categories**
Is a special calculation software / database required?	• Low: in practice, no special calculation software / database beyond standard software (e.g. Excel) required • Medium: special calculation software / database required in practice, but available free of charge • High: in practice, special calculation software / database is required and subject to a charge
Methodological preconditions	**Criteria for the "low", "medium" and "high" categories**
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	• Low: no specific calculation procedures / methodological guidelines required • Medium: Need to adapt the standard to the specific situation of the company / organization (e.g. with regard to energy consumption, emissions, waste) • High: Development of specific methodological guidelines for telecommunications networks required
Are there methodological references / dependencies to other standards?	• Low: no methodological references / dependencies on established other standards / methods • Medium: another standard/method must be included (i.e. obtained, read and understood) to fulfill the standard • High: two or more other standards / methods must be included (i.e. sourced, read and understood) to fulfill the standard
How much effort is required to determine Scope 1 / Scope 2 emissions? Only for evaluation of Scopes 1&2	• Low: Standard contains specific guidance for selecting and quantifying the relevant emissions (e.g. estimation methods, calculation approaches, default values, specific recommendations for suitable databases) • Medium: Standard contains specific guidance for the selection of relevant emissions (e.g. decision trees, materiality criteria) • High: no concrete assistance from the standard
How much effort is required to determine Scope 3 emissions? Only for Scope 3 evaluation	• Low: Standard contains specific guidance for selecting and quantifying the relevant emissions (e.g. estimation methods, calculation approaches, default values, specific recommendations for suitable databases for the individual Scope 3 categories) • Medium: Standard contains specific guidance for the selection of relevant emissions (e.g. decision trees, materiality criteria) • High: no concrete assistance from the standard
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	• Low: A report template and examples are provided. • Medium: A report template is provided, but without examples, or vice versa. • High: Neither a report template nor examples are provided.
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	• Low: An uncertainty assessment/data quality assessment is either not mentioned or is considered optional. • Medium: An uncertainty assessment/data quality assessment is mandatory, but examples are included. • High: An uncertainty assessment/data quality assessment is mandatory and no examples are provided.
Organizational preconditions	**Criteria for the "low", "medium" and "high" categories**

Preconditions	3-level scale system for assessing the effort involved
Does compliance with the standard require cooperation between different business areas / organizational units?	• Low: no cooperation required • Medium: Cooperation between two business units / organizational units required Hhigh: cooperation between three or more business units required
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	• Low: no cooperation required • Medium: Cooperation with a stakeholder required • High: collaboration between two or more stakeholders required
Does compliance with the standard require an audit or external review?	• Low: Auditing or external review not necessary / not mandatory • Medium: internal audit required • High: external audit (e.g. critical review) and / or certification by a third party required

Source: Own compilation. **Bold text** indicates criteria with double weighting

Table 7-42: Effort estimation for the application of standards to identify must-have indicators in the GHG category: Scope 1 & 2 (Group 1)

Preconditions	GHG Protocol Corporate Accounting and Reporting Standard (2004), amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
Scope	**Scope 1 & 2**	**Scope 1 & 2**
Technical preconditions		
Is a special calculation software / database required?	•Calculation tools are not necessary. Some calculation tools are freely available; e.g. uncertainty calculation tool or calculation tools with default values for emission factors: cross sector tools for stationary combustion, mobile combustion, HFC use; sector-specific tools (currently no tool specifically for telecommunications network exists). •databases with EF (emission factors) are required, even if no specific databases are specified.	•Calculation tools are not necessary; no specific software or tool is named in the standard •databases with EF (emission factors) are required, even if no specific databases are specified.
Methodological preconditions		
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	Yes, the standard is not specific for telecommunication networks, therefore guidelines need to be developed to allocate only the the emissions associated with the network specific activities.	Yes, the standard is not specific for telecommunication networks, therefore guidelines need to be developed to allocate only the the emissions associated with the network specific activities.
Are there methodological references / dependencies to other standards?	No	•GHG Protocol Corporate (Scope1/2/3) •ISO 14064-1: Uncertainty for scope 1 and 2 (Mandatory) & verification process (Optional)

Preconditions	GHG Protocol Corporate Accounting and Reporting Standard (2004), amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
		•IPCC Guidelines (Scope1/2/3) --> if, for example, CH_4 is converted to its CO_2 equivalent, IPCC characterization factors are required.
How much effort is required to determine Scope 1 / Scope 2 emissions?	There are examples for scope 1 and 2 emission sources, and reference to calculation tools with emission factors, but no specific guidance for selecting and quantifying the relevant emissions or default values	no default values or specific guidelines provided
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	No	No
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	Scope 1 & 2 & 3: No, it's optional	yes, uncertainty assessment is mandatory for Scope 1 and 2. Reference to ISO 14064-1 (2019: Claus 8.3 Assessing uncertainty). No example provided Scope 3: optional
Organizational preconditions		
Does compliance with the standard require cooperation between different business areas / organizational units?	Depends on the organizational structure and the operational boundary. It is assumed that regarding Scope1/Scope 2 at least two internal organizational units are involved: energy management, own vehicel fleet	Depends on the organizational structure and the operational boundary. It is assumed that regarding Scope1/Scope 2 at least two internal organizational units are involved: energy management, own vehicel fleet
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	Depends on calculation approach of organization. It is assumed that regarding Scope 2 at least information from the energy supplier on the composition of the energy is needed	Depends on calculation approach of organization. It is assumed that regarding Scope 2 at least information from the energy supplier on the composition of the energy is needed
Does compliance with the standard require an audit or external review?	Scope 1 & 2 & 3: No, verification is optional	Scope 1 & 2 & 3: No, verification is optional

Source: Own compilation. **Bold text** indicates criteria with double weighting

Table 7-43: Effort estimation for the application of standards to identify must-have indicators in the GHG category: Scope 3 (Group 2)

Preconditions	GHG Protocol Corporate Accounting and Reporting Standard (2004), amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	Protocol Corporate (Value Chain) Standard (2011)	Scope 3 Guidance for Telecommunication Operators
Scope	**Scope 3**	**Scope 3**	**Scope 3**	**Scope 3**
Technical preconditions				
Is a special calculation software / database required?	•Calculation tools are not necessary. Some calculation tools are freely available; e.g. uncertainty calculation tool or calculation tools with default values for emission factors: cross sector tools for stationary combustion, mobile combustion, HFC use; sector-specific tools (currently no tool specifically for telecommunications network exists). •databases with EF (emission factors) are required, even if no specific databases are specified.	•Calculation tools are not necessary; no specific software or tool is named in the standard •databases with EF (emission factors) are required, even if no specific databases are specified.	•Calculation tools are not necessary. Some calculation tools are freely available; e.g. uncertainty calculation tool or calculation tools with default values for emission factors: cross sector tools for stationary combustion, mobile combustion, HFC use; sector-specific tools (currently no tool specifically for telecommunications network exists). •databases with EF (emission factors) are required, even if no specific databases are specified.	•Calculation tools are not necessary, no specific software or tool is named in the standard •databases with EF (emission factors) are required, reference to possible databases is there
Methodological preconditions				
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	Yes, the standard is not specific for telecommunication networks, therefore guidelines need to be developed to allocate only the the emissions associated with the network specific activities.	Yes, the standard is not specific for telecommunication networks, therefore guidelines need to be developed to allocate only the the emissions associated with the network specific activities.	Yes, the standard is not specific for telecommunication networks, therefore guidelines need to be developed to allocate only the the emissions associated with the network specific activities.	The standard is addressed to Telecommunication operators, but not specific and exclusively for telecommunication networks, therefore standard needs to be adapted to the specific network specific activities.
Are there methodological references / dependencies to other standards?	No	•GHG Protocol Corporate (Scope1/2/3) •IPCC Guidelines (Scope1/2/3) --> if, for example, CH_4 is converted to its CO_2 equivalent, IPCC	GHG Protocol Corporate Accounting and Reporting Standard (2004)	• GHG Protocol Corporate • Protocol Corporate (Value Chain) Standard (2011)

Preconditions	GHG Protocol Corporate Accounting and Reporting Standard (2004), amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	Protocol Corporate (Value Chain) Standard (2011)	Scope 3 Guidance for Telecommunication Operators
		characterization factors are required. • GHG Protocol Corporate Value Chain (Scope 3)		
How much effort is required to determine Scope 3 emissions?	There is no specific guidance for selecting and quantifying the relevant Scope 3 emissions as Scope 3 is optional	There are examples for Scope 3 activities and partially recommendations for the procedure for GHG calculation, but no specific methodolocigal guidelines are provided.	Guidance for calculating scope 3 emissions from each scope 3 category is provided in a separate document, "Guidance for Calculating Scope 3 Emissions". It contains decision trees for the choice of calculation method and references to third party databases or other emission factor data sources.	The standard provides calculation methods per Scope 3 category as well as decision trees for the choice of method. A lot of third party databases are recommended in different categories.
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	No	No	No	No
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	Scope 1 &2&3: No, it's optional	Scope 3: No, it's optional	Scope 3: reporting of data quality is mandatory, uncertainty assessment is optional, examples are provided	Scope 3: Yes, but no examples provided
Organizational preconditions				
Does compliance with the standard require cooperation between different	Depends on the organizational structure and the operational boundary. It is assumed that because of extensive 15 categories, several internal units are involved:	Depends on the organizational structure and the operational boundary. It is assumed that because of extensive 15 categories, several internal units are involved: Procurement,	Depending on which categories and methods are considered, different organizational units have to be involved. Due to the extent of the 15 categories, it is assumed that several internal units are involved, such as	Depending on which categories and methods are considered, different organizational units have to be involved. Due to the extent of the 15 categories, it is assumed that several internal units are involved, such as procurement, energy,

Preconditions	GHG Protocol Corporate Accounting and Reporting Standard (2004), amendment with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)	Protocol Corporate (Value Chain) Standard (2011)	Scope 3 Guidance for Telecommunication Operators
business areas / organizational units?	Procurement, manufacturing, marketing, logistics etc.	manufacturing, marketing, logistics etc.	procurement, energy, manufacturing, marketing, research and development, product design, logistics, and accounting.	manufacturing, marketing, research and development, product design, logistics, and accounting.
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	Depends on calculation approach of the organization. It is assumed that regarding Scope 3 several external stakeholders need to be contacted (e.g. treatment of waste, information on transport of goods, LCA information of procured goods etc.)	Depends on calculation approach of the organization. It is assumed that regarding Scope 3 several external stakeholders need to be contacted (e.g. treatment of waste, information on transport of goods, LCA information of procured goods etc.)	Collecting scope 3 emissions data is likely to require wider engagement within the reporting company, as well as with suppliers and partners outside of the company (e.g. treatment of waste, information on transport of goods, LCA information of procured goods etc.)	Collecting scope 3 emissions data is likely to require wider engagement within the reporting company, as well as with suppliers and partners outside of the company (e.g. treatment of waste, information on transport of goods, LCA information of procured goods etc.)
Does compliance with the standard require an audit or external review?	Scope 1&2&3: No, verification is optional	Scope 1&2&3: No, verification is optional	Scope 3: not mandatory, but recommended	Scope 3: not mandatory, but recommended

Source: Own compilation. **Bold text** indicates criteria with double weighting

Table 7-44: Effort estimation for the application of standards to determine must-have metrics in the category GHG: Scope 1 & 2 (Group 1) – indicated in plus signs

Preconditions	GHG Protocol Corporate Accounting and Reporting Standard (2004), extension with Scope 2 Guidance (2015)	ITU-T L.1420 (02/2012)
Technical preconditions		
Is a special calculation software / database required?	**++++**	**++++**
Methodological preconditions		
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	+++	+++

Are there methodological references / dependencies to other standards?	+	+++
How much effort is required to determine Scope 1 / Scope 2 emissions?	**++++**	**++++++**
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	+++	+++
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	+	+++
Organizational preconditions		
Does compliance with the standard require cooperation between different business areas / organizational units?	++	++
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	**++++**	**++++**
Does compliance with the standard require an audit or external review?	+	+
Total "+"	**23**	**29**
Total "n.d."	**0**	**0**

Source: Own compilation. **Bold text** indicates criteria with double weighting; 'n.d.' (indeterminable)

Table 7-45: Effort estimate for the application of standards to determine must-have metrics in the GHG category: Scope 3 (Group 2) – indicated in plus signs

Preconditions	GHG Protocol Corporate Accounting and Reporting Standard (2004)	ITU-T L.1420 (02/2012)	Protocol Corporate (Value Chain) Standard (2011)	Scope 3 Guidance for Telecommunication Operators
Technical preconditions				
Is a special calculation software / database required?	**++++**	**++++**	**++++**	**++++**
Methodological preconditions				
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	+++	+++	+++	++
Are there methodological references / dependencies to other standards?	+	+++	++	+++
How much effort is required to determine the scope 3 emissions?	**++++++**	**++++++**	**++**	**++**

Is the template for the reports provided? And is an example included to demonstrate the reporting results?	+++	+++	+++	+++
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	+	+	++	+++
Organizational preconditions				
Does compliance with the standard require cooperation between different business areas / organizational units?	+++	+++	+++	+++
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	**++++++**	**++++++**	**++++++**	**++++++**
Does compliance with the standard require an audit or external review?	+	+	+	+
Total "+"	**28**	**30**	**26**	**27**
Total "n.d."	**0**	**0**	**0**	**0**

Source: Own compilation. **Bold text** indicates criteria with double weighting; 'n.d.' (indeterminable)

Annex XII. Detailed evaluation of the application effort (WP3): Circular economy

Table 7-46: Definition of a 3-level scale system for effort estimation in the circular economy category

Preconditions	3-level scale system for assessing the effort involved
Technical preconditions	**Criteria for the "low", "medium" and "high" categories**
Does the standard require primary data collection?	• low: Primary data is already existing • medium: Primary data is required, but can be calculated from existing data • high: specific data collection is mandatory in order to obtain primary data
Is data collection required over a longer period of time?	• low: Data collection required for up to 7 days • medium: Data collection required for up to 6 months • high: Data collection required for 6 months or longer
Is special modeling software required?	• low: no special modeling software beyond standard software (e.g. Excel) required • medium: special modeling software required, but available free of charge • high: special modeling software is required and subject to a charge
Methodological preconditions	**Criteria for the "low", "medium" and "high" categories**
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	• low: no specific procedures / methodological guidelines required • medium: standard needs to be adapted to the specific situation of the company / organization (e.g. with regard to energy consumption, emissions, waste) • high: Development of specific methodological guidelines required
Are there methodological references / dependencies to other standards?	• low: no methodological references / dependencies to other already well established standards / methods • medium: another standard / method must be included (i.e. purchased, read and understood) for compliance with the standard • high: two or more other standards / methods must be included (i.e. purchased, read and understood) for compliance with the standard
Is a template provided for the test reports? And is an example included to illustrate the results of the reporting?	• low: Reporting template and examples are provided. • medium: Reporting template is provided, but no examples are included, or vice versa. • high: No reporting template or examples are provided.
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	• low: An uncertainty assessment/data quality assessment is either not mentioned or is considered optional. • medium: An uncertainty assessment/data quality assessment is mandatory, but examples are included. • high: An uncertainty assessment/data quality assessment is mandatory and no examples are provided.
Organizational preconditions	**Criteria for the "low", "medium" and "high" categories**
Does compliance with the standard require cooperation between different business areas / organizational units?	• low: no cooperation required • medium: Cooperation between two business units / organizational units required • high: cooperation between three or more business units required
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	• low: no cooperation required • medium: Cooperation with one stakeholder required • high: collaboration between two or more stakeholders required
Does compliance with the standard require an audit or external review?	• low: Auditing or external review not necessary / not mandatory • medium: internal audit required • high: external audit (e.g. critical review) and / or certification by a third party required

Source: Own compilation. **Bold text** indicates criteria with double weighting

Table 7-47: Effort estimation for the application of standards to identify must-have indicators in the circular economy category: before use (Group 1)

Preconditions	ETSI TR 103 476 V1.1.2 (2018-02)	DIN EN 45556 (2020)	DIN EN 45557 (2020)
Technical preconditions			
Does the standard require primary data collection?	Not specified	Yes	Yes
Is data collection required over a longer period of time?	Not specified	depends; "The period accounted shall be specified, not exceed one year and shall be representative for the production volume."	depends on the type of production (e.g. mass production, to order production, batch production, new material); maximum in case of mass production: 1 year
Is special modeling software required?	Not specified	No	No
Methodological preconditions			
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	Not specified	Yes If proportion of reused components by mass balance is calculated: ""Different products can require different forms to obtain the total mass of reused components, depending on e.g. the complexity of the business, weight of the product, number of products handled in the accounted period. The user of this document shall determine the most suitable approach to evaluate the total mass of reused components in the defined period and document the chosen approach accordingly.""	No
Are there methodological references / dependencies to other standards?	The following standards must be used for "recycled ingredients": - ISO 14021:1999: "Environmental labeling and declaration - Self-declared environmental claims (Type II environmental labeling)" - ETSI ES 203 199: "Environmental Engineering (EE); Methodology for the Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks and services" - BS EN 15343:2007: "Plastics. Recycled plastics. Traceability and assessment of conformity and recycled content of recycled plastics"	Yes, further information on "Methods for providing information on the material efficiency aspects of energy-related products"	No

Preconditions	ETSI TR 103 476 V1.1.2 (2018-02)	DIN EN 45556 (2020)	DIN EN 45557 (2020)
Is a template provided for the test reports? And is an example included to illustrate the results of the reporting?	No	No	No
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	No	No	No
Organizational preconditions			
Does compliance with the standard require cooperation between different business areas / organizational units?	No	No	No
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	No NOTE: challenges of primary data mentioned: "The amount of recycled content (RC) is challenging to estimate for ICT infrastructure. Most parts are bought on a global market, involving long supply chains, and the origin of the material content is not easily trackable." AND alternative suggestes: "For this reason the best assumption seems to be global average recycling data [i.21] and [i.22][32]."	Yes; Remark concerning indirect calculation of proportion of reused components: "Therefore, the verification is by means of documented evidence from the manufacturer, supplier and/or authorized distributor."	Yes
Does compliance with the standard require an audit or external review?	No	No	No

Source: Own compilation. **Bold text** indicates criteria with double weighting

[32] [i.21] ETSI ES 203 199: " Environmental Engineering (EE); Methodology for environmental Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks and services".
[i.22] Recommendation ITU-T L.1410: "Methodology for environmental life cycle assessments of information and communication technology goods, networks and services". NOTE: Available at http://www.itu.int/rec/T-REC-L.1410-201412-I.

Table 7-48: Effort estimation for the application of standards to identify must-have indicators in the circular economy category: EoL (Group 2)

Preconditions	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
Technical preconditions			
Does the standard require primary data collection?	No, not mandatory The source can be primary data, but also secondary data (e.g. from contractors).	Yes	Yes
Is data collection required over a longer period of time?	Not specified	Not specified	Not specified
Is special modeling software required?	No	No	No
Methodological preconditions			
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	No	No	No
Are there methodological references / dependencies to other standards?	No	Directive 2012/19/EU of the European Parliament and of the Council of July 4, 2012 on waste electrical and electronic equipment (WEEE): Definition of proper end-of-life treatment	Directive 2012/19/EU of the European Parliament and of the Council of July 4, 2012 on waste electrical and electronic equipment (WEEE): Definition of proper treatment at the end of life The vendor or the maintenance company should engage contractually with the recycler to guarantee conformance to the relevant CENELEC standards
Is a template provided for the test reports? And is an example included to illustrate the results of the reporting?	A template is provided, but without an example.	No	No
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	No	No	No

Preconditions	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
Organizational preconditions			
Does compliance with the standard require cooperation between different business areas / organizational units?	No	No	Possibly; for ICT equipment, these requirements are usually the responsibility of the "IT department". However, for large telecom operators, the separate responsibilities for ITE and NTE can be split between different departments.
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	Most certainly, as the recycling operations are mostly not internalized.	Most certainly, as the recycling operations are mostly not internalized.	Most certainly, as the recycling operations are mostly not internalized.
Does compliance with the standard require an audit or external review?	No	No	No

Source: Own compilation. **Bold text** indicates criteria with double weighting

Table 7-49: Results of the semi-quantitative effort estimation in the category circular economy: before use (group 1) – indicated in plus signs

Preconditions	ETSI TR 103 476 V1.1.2 (2018-02)	DIN EN 45556 (2020)	DIN EN 45557 (2020)
Technical preconditions			
Does the standard require primary data collection?	n.d.	++++++	++++++
Is data collection required over a longer period of time?	+	+++	+++
Is special modeling software required?	+	+	+
Methodological preconditions			
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	++	++++++	++
Are there methodological references / dependencies to other standards?	+++	++	+
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	+++	+++	+++
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	+	+	+
Organizational preconditions			
Does compliance with the standard require cooperation between different business areas / organizational units?	n.d.	n.d.	n.d.
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	+	+++	+++
Does compliance with the standard require an audit or external review?	++	++	++
Total "+"	**14**	**27**	**22**
Total "n.d."	**2**	**1**	**1**

Source: Own compilation. **Bold text** indicates criteria with double weighting; 'n.d.' (indeterminable)

Table 7-50: Results of the semi-quantitative effort estimation in the category circular economy: EoL (Group 2) – indicated in plus signs

Preconditions	GRI 306	ETSI EN 305 174-8 V1.1.1 (2018-01)	ETSI TS 105 174-8 V1.2.1 (2019-12)
Technical preconditions			
Does the standard require primary data collection?	++	++++++	++++++
Is data collection required over a longer period of time?	+	+	+
Is special modeling software required?	+	+	+
Methodological preconditions			
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	++	++	++
Are there methodological references / dependencies to other standards?	+	++	+++
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	++	+++	+++
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	+	+	+
Organizational preconditions			
Does compliance with the standard require cooperation between different business areas / organizational units?	n.d.	n.d.	++
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	++	++	++
Does compliance with the standard require an audit or external review?	++	++	++
Total "+"	**14**	**20**	**23**
Total "n.d."	**1**	**1**	**0**

Source: Own compilation. **Bold text** indicates criteria with double weighting; 'n.d.' (indeterminable)