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Research project “Comparability of sustainability standards for telecommunications infrastructure”

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List of Abbreviations

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

Executive Summary

Background, Objective, Target Group, and Application

The **background** of the study is the EU Commission's pursuit to establish standardized and comparable reporting of sustainability indicators for telecommunications infrastructure. The JRC study (Baldini et al. 2024) identified eight “must-have indicators” in the three environmental categories of energy management, greenhouse gas emissions, and circular economy. On this basis, the EU Commission is developing a Code of Conduct (CoC) for the sustainability of telecommunications networks, which aims to define standard-based procedures for measuring and evaluating the environmental impact of telecommunications networks. The Federal Network Agency (BNetzA) commissioned this study to provide a scientifically robust background for selecting appropriate standards to develop the CoC. The **objective** of the study is threefold:

- To investigate the comparability and specificity level of selected standards for capturing the must-have indicators identified in the JRC study.
- To estimate the implementation and application effort required for these selected standards.
- To derive recommendations for potential standards to be utilized within the objective of the CoC or for national and further European decision-making processes.

The **target group** includes private decision-makers such as telecommunications network operators, and authorities such as the BNetzA and the European Commission. The primary **application** of the study is to assist the BNetzA in actively contributing to the national and European discussions aimed at defining appropriate sustainability indicators.

System Boundary and Methodological Approach

The study focuses on telecommunications networks as part of ICT infrastructure, encompassing access and core networks as well as supporting infrastructure, including *Network Data Centres (NDCs)* which serve to implement, control, and manage network functions. User end devices and the infrastructure of application providers (content and application providers, or CAPs), such as data centers for data processing or storage, are located outside the system boundary.

The standards considered in this study are analyzed in three consecutive steps:
(1) Completeness Check: 41 energy, 21 greenhouse gas (GHG), and 16 circular economy standards were evaluated based on meta-criteria. Exclusion criteria, such as outdated, unspecific, or overarching standards and those lacking must-have indicators, were applied to identify relevant standards. As a result, 15 energy management, 4 GHG, and 6 circular economy standards were selected.
(2) Comparative Analysis: The selected standards were evaluated based on three key questions: (a) comparability when using the same standard, (b) comparability when using different standards of the same group, and (c) overall suitability. Four evaluation criteria were developed: robustness, reproducibility, credibility, and transparency. Corresponding evaluation aspects were defined for each criterion. The assessment used a three-level model (high, medium, low), visualized with green, yellow, and red dots.
(3) Effort Estimation: Implementation effort was assessed semi-quantitatively (technical, methodological, and organizational requirements) and qualitatively (stakeholder surveys, CAPEX/OPEX, market penetration, and existing knowledge from studies). The results are indicative**.**

Key Results of Comparability and Effort Estimation

- **Energy Management:** The **comparability** of results when applying energy management standards is limited by methodological differences, such as different indicators and metrics, data collection methods (e.g., measurement period or frequency, sampling locations) and delimitations (e.g., shared locations, inclusion of infrastructure). One exception is ETSI EN 303 472, which enables a high degree of comparability of measurement results when applying the standard thanks to clear specifications on measurement processes, data collection, and reporting. However, this only applies to non-shared base station locations and under the assumption of similar operating conditions. Most of the standards examined for energy analysis are used by network operators for internal monitoring of consumption trends over time and are not suitable for comparing measurement results from the same or different standards. Significant similarities between the standards relate to the consideration of renewable energy on site, the preference for real-time measurement, and the consideration of variable environmental conditions (e.g., climate zones) that influence energy consumption. The application of standards is often only suitable for individual locations, while shared infrastructure (infrastructure sharing) requires clear allocation rules. However, these are not regularly included in the standards. Guidelines for assessing data uncertainties and a commitment to external validation are mostly lacking. The **effort** is indicatively estimated to be medium, although high initial implementation costs (especially personnel and material costs) could be reduced in the long term through standardized processes.
- **Greenhouse Gas Emissions:** The **comparability** of the results of GHG assessments is limited just as much as in energy management due to methodological differences:

  Scope 1 & 2: The GHG Protocol Corporate and ITU-T L.1420 are organization-based standards focusing on Scope 1 and 2, with optional Scope 3 reporting. Both use generic methodologies without telecommunications network-specific approaches or allocation rules. ITU-T L.1420 prescribes general criteria for emission factors and uncertainty assessment, while the GHG Protocol does not, but requires location- and market-based accounting in its Scope 2 Guidance. The GHG Protocol mandates breakdown by seven greenhouse gases, whereas ITU-T L.1420 requires country-specific reporting.

  Scope 3: The “GHG Protocol Corporate Value Chain (Scope 3) Standard” complements the base standard with detailed guidance for 15 Scope 3 categories, without requiring external validation. The “GSMA/GeSI/ITU: Scope 3 Guidance for Telecommunication Operators” targets telecommunications companies, offering ICT-specific methods with accuracy recommendations. It allows practical approaches and emphasizes consistent application, which is often challenging. The GSMA/GeSI/ITU Guidance prioritizes relevant categories but is not explicitly network-focused. Emissions from the manufacture of purchased goods (Cat. 1 and 2) are accounted for in the year of purchase in accordance with the GHG Protocol and GSMA Scope 3 standards, while they are distributed over the useful life in accordance with ITU-T L.1420.

  The **effort** for calculating all Scopes is estimated as medium to high. The GHG Protocol is widely used by network operators. Scope 3 emissions reporting is inherently data-intensive, requiring internal and external coordination, and is correspondingly effort-intensive.

- **Circular Economy:** The **comparability** of declarations of recycled content and recycling rates based on the standards is also limited in this category, as they do not contain product-related indicators for “recycled/refurbished/reused” products, but are limited to the component and material level. Although the standards promote the environmental goals of circular economy and resource efficiency—either in general or specifically for ICT—they do not have an explicit network focus. There is a particular need for specific standards in this category. A prerequisite for comparability would be for manufacturers to provide network operators with the necessary data. The **effort** required to meet the standards is estimated to be low to medium. However, this assessment could neither be confirmed nor refuted in the stakeholder survey due to the lack of awareness of the standards.

Conclusions and Recommendations

- Comparable sustainability indicators for network operators are currently lacking due to inconsistent methods and framework conditions. Standards are currently only used for internal trend analysis. Uniform guidelines and the involvement of network operators are necessary to minimize effort, increase acceptance, and enable reliable statements about the environmental footprint of telecommunications networks. The standards do not contain any requirements for validation.
- **Energy Management:** ETSI EN 303 472 (2G/3G/4G) enables results to be compared under similar operating conditions, while ETSI ES 203 228 (2G-5G) allows more flexible measurements, but this makes comparison more difficult. ETSI ES 203 228 describes a method for extrapolating the energy consumption of networks. However, the CoC could include additional specifications on the measurement period and frequency. The ETSI EN 305 200-x series provides a good basis for calculating the must-have indicators. However, the specifications in this series of standards are inconsistent. It would therefore be useful to update the standards. ETSI TS 128 554 is future-oriented (5G RAN/Core), but requires clearer measurement specifications. ETSI EN 303 471 could supplement NFV-based access networks. The allocation of energy consumption at shared locations is complex; the methodology should be transparently documented or specified here. The flexibility of the CoC (draft version dated April 15, 2025) is necessary for practicality, but reduces the comparability of results. A balance between specific requirements (especially regarding measurement periods, extrapolation, and allocation rules) and flexibility in application is recommended. It is therefore suggested that the CoC requirements be evaluated with network operators at an early stage in order to identify practical problems and adapt the CoC if necessary. Given the large number of existing standards and the limited comparability of measurement results based on them, careful consideration must be given to the goal of comparability of results and practical applicability, as well as technological suitability for specific network segments. Consideration could also be given to whether network operators operate multiple network segments or technologies. In this case, it would make sense for the recommended standard to cover as many network areas as possible.
- **Greenhouse Gas Emissions:**
- **<u>Scope 1 & 2</u>**: For the CoC, it is suggested that the GHG Protocol Corporate Standard be specified as a methodological reference, as it is also required by the Delegated Act on CSRD. Furthermore, the CoC could amend the requirements of the GHG Protocol for the documentation of allocation rules so that the allocation of Scope 1 and Scope 2 emissions of the infrastructures jointly operated by different network operators in telecommunications networks is clearly evident (e.g. definition of equity share or operational control model). This would lead to increased transparency with regard to data collection. A definition is needed of which activities are classified as Scope 1 emissions attributable to network operation, for example maintenance trips with the company's own vehicle fleet and direct emissions from refrigerants.
- **<u>Scope 3:</u>** The GSMA/GeSI/ITU: Scope 3 Guidance for Telecommunication Operators standard currently best meets the JRC's must-have indicator for Scope 3. The first step is to define and prioritize the Scope 3 categories relevant to network operations. These are: Category 1 (purchased goods/services), Category 2 (capital goods), Category 3 (energy-related activities, e.g., maintenance trips by external service providers, cable laying) and, if applicable, Category 15 (investments) and Category 8/13 (leased/rented property, plant, and equipment), depending on the business model. All categories must be network-related.

To ensure future comparability of the results of measurements with the standards listed in the CoC, it is recommended that industry-specific average CO_2e emission factors for upstream and downstream processes (e.g., manufacture of network components) be recorded in a publicly accessible database. This simplifies calculations, harmonizes results, and increases the transparency of GHG indicators.

- **Circular Economy:** The GRI 306 standard is suitable for the "E-Waste" indicator in the CoC but offers significant flexibility in implementation. If the CoC requires transparent reporting of E-Waste weight by network components, the ITU-T L.1050 standard serves as a good reference, as it systematically lists key components of network segments. However, for the "recycled/refurbished/reused" indicator at the product level, suitable standards are currently lacking.

1 Introduction

1.1 Background

The digital transformation is affecting almost all areas of the economy and society - from technical infrastructures, industrial production facilities, companies, administrations and retail to households and the education and healthcare sectors. Digitalization is leading to an ever-increasing use of information and communication technologies (ICT), as more and more data is being collected, processed, stored, transmitted and exchanged. At the same time, the demand for ever higher data transmission speeds is increasing. According to the Federal Network Agency's 2024 annual report, around 132 billion gigabytes were transmitted in fixed networks in Germany in 2023 (+9% compared to 2022) and 9 billion gigabytes in mobile networks (+36% compared to 2022). As a result of the increasing volume of data worldwide, a further increase in the global demand for resources for the expansion of the telecommunications infrastructure, rising energy consumption for its operation and an increase in waste from electrical and electronic equipment (WEEE) are expected.

The ecological sustainability goals are already firmly anchored at a political level in both the national and European context. If the environmental impact of telecommunications networks, as the essential prerequisite for the digitalization of society, remains unconsidered, no reliable statements can be made on the environmental impact of digitalization. Against this background, indicators are needed that transparently and comprehensibly record and quantify the environmental impact of the telecommunications sector in order to be able to assess its ecological footprint as reliably as possible.

There are numerous ICT sector-specific standards for assessing the environmental aspects of telecommunications networks, most of which have been developed by the International Telecommunication Union (ITU) and the European Telecommunications Standards Institute (ETSI). In other literature sources, such as the DG-CNECT study (Bilsen et al. 2021) and the JRC study (Baldini et al. 2024), the indicators of the ITU and ETSI standards and other relevant standards were also examined. However, Bilsen et al. (2021) found that only a few of these indicators are actually used in practice.

The entire ICT infrastructure can basically be divided into two main areas: End devicesand telecommunications networks, including data centers. The environmental impact of telecommunication networks has been the least researched.

1.2 Objectives, target group and intended application of the study

The aims of the study are

- the investigation of selected standards with regard to the comparability of the results of measurements and calculations, using the specifications of the respective standards. In particular, the suitability of the standards for recording the must-have indicators identified by the JRC study (Baldini et al. 2024) for the three environmental categories of energy management, greenhouse gases and circular economy in the telecommunications infrastructure is taken into account.
- The similarities and differences between the measurement specifications of the standards, their input parameters and the data collection effort are to be shown,
- Deriving recommendations for potential standards for use in the context of the European Code of Conduct (CoC) for telecommunications networks or for national and European decision-making.

The target group includes telecommunications network operators in order to enable them to select and apply the standards that are suitable for them. In addition, political and other private decision-makers are given the opportunity to make well-founded decisions based on the transparent data. In addition, the study provides scientific findings for authorities such as the German Federal Network Agency (BNetzA) and the European Commission.

Intended application of the study: The EU Commission plans to publish a Code of Conduct on telecommunications networks in 2025. Extensive preparatory work is currently underway to define EU indicators for measuring the environmental footprint of telecommunications networks and services. The results of this study should support the Federal Network Agency in making a constructive contribution to the current national and European debate on the definition of suitable sustainability indicators.

1.3 Objects of investigation

1.3.1 Definition of the system boundary

The system boundary ("scope") to be examined in this project is the telecommunications networks, which can be further subdivided into the areas of ICT equipment and supporting infrastructure (see Figure 1 1). The telecommunications network consists of access networks with different transmission technologies for connecting to the user (end devices and data centers) and the core network, which carries out the central data traffic transport, control, administration and networking of various access network nodes.

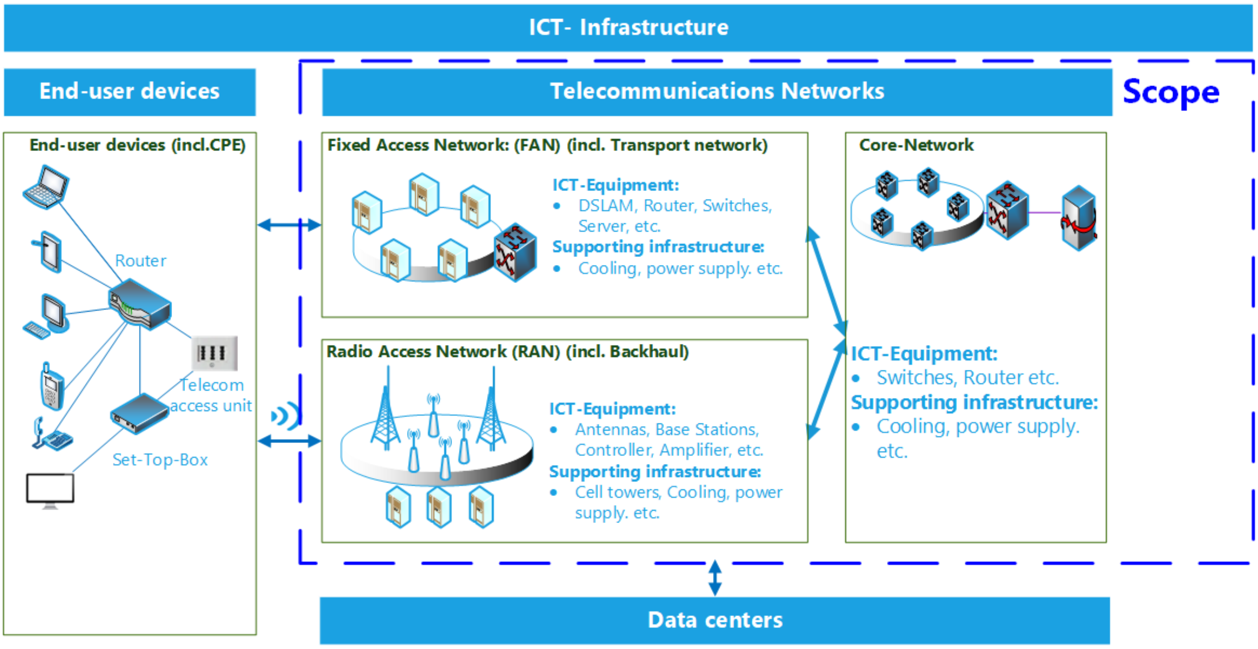
The definition of a network termination point is crucial for defining the system boundary. This describes the boundary between the public telecommunications network and the end user's infrastructure. The orientation is based on the definitions of "network termination point" and "connection of telecommunications terminal equipment" as per the Telecommunications Act.

The Telecommunications Act (TKG 2021) § 3 No. 32 TKG defines: "**network termination point**" means the physical point at which an end user is provided with access to a public telecommunications network; in networks in which switching or routing takes place, the network termination point is designated by a specific network address, which may be linked to the number or name of an end user;"

The Telecommunications Act (TKG 2021) § 73 describes the "**connection of telecommunications terminal equipment**" as follows: "Access to public telecommunications networks at fixed locations shall be installed at a suitable location to be agreed with the end user. This access is a passive network termination point; the public telecommunications network ends at the passive network termination point. For mobile networks, the air interface is generally the network termination point."

The network termination point is the physical point at which the public telecommunications network ends and the end user's infrastructure begins (see Figure 1 1). It forms the transition point between the public telecommunications network and the user's infrastructure. In the fixed network, the network termination point is the end of the access line on the end customer side; in the mobile network, it is the air interface located between the base station of the mobile network and the user's mobile terminal device. Terminals and infrastructures that are connected to the fixed or mobile network are the responsibility of the individual end user and are therefore not part of the telecommunications network. They are therefore not within the system boundary of this study. Consequently, infrastructures such as data centers do not fall within the scope of the study. However, data centers, so-called Network Data Centres (NDCs), which serve to implement, control and manage network functions, are part of the telecommunications network infrastructure and therefore also fall within the scope of the study.

Figure 1-1: System boundary of the present study



Source: Own compilation

1.3.2 Environmental aspects considered and their must-have indicators

In this study, the three categories of energy management, greenhouse gas emissions and circular economy are examined in detail with regard to defined environmental indicators. The environmental indicators are based on the so-called "must-have" indicators classified in the JRC study (Baldini et al. 2024) as a priority for the sustainability of telecommunications networks. Table 1-1 lists the indicators to be considered in connection with the corresponding eight "must-have" indicators.

Table 1-1: Must-have indicators and must-have metrics from the JRC study and focus of analysis in the present study

Category	Must-have indicators	Must-have metrics	Focus of analysis in the present study
Energy management	**Energy consumption**	• Energy consumption in kWh, MWh or GWh	• **Networks or network segments** in the operating phase
	Energy efficiency	• Data volume in relation to energy consumption	
	Use of renewable energy	• Share of renewable energies in total energy consumption • Consumption of renewable energies	
Greenhouse gas emissions	**GHG Scope 1**	• CO_2e in tons	• **Network-related** GHG Scope 1/2/3: refers only to the network, not to the entire organization.
	GHG Scope 2	• CO_2e in tons	
	GHG Scope 3	• CO_2e in tons	
	Before use E-waste generation Use of recycled / refurbished / reused products	• Weight of recycled products • Weight of refurbished products • Number of refurbished products • Weight of reused products	

Category	Must-have indicators	Must-have metrics	Focus of analysis in the present study
Circular economy[1]	**End-of-life (after use)** E-waste generation Use of recycled / refurbished / reused products	• Weight of waste from electrical and electronic equipment • Weight of recycled products • Weight of refurbished products • Number of refurbished products • Weight of reused products	• **Network-related** ICT devices/hardware: refers only to ICT devices that are used in network operations, not to those that are used, for example, in the office areas of an organization

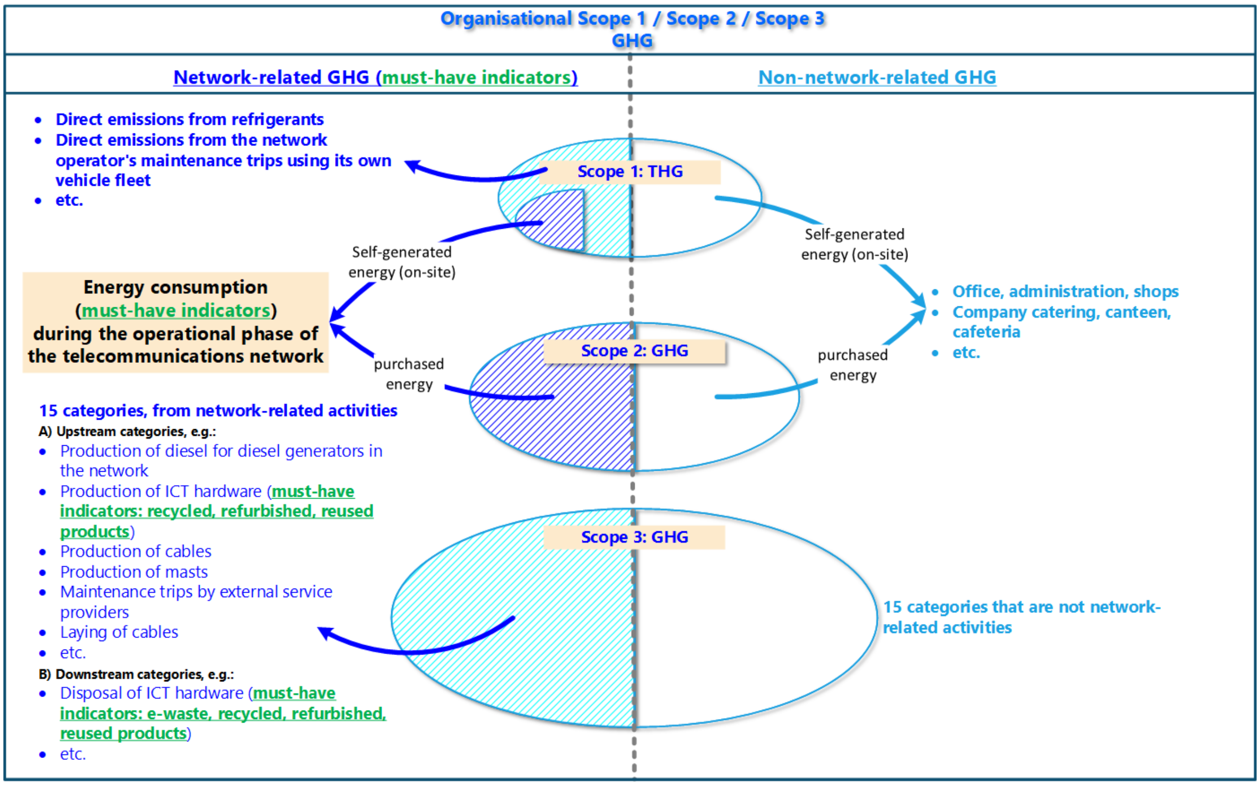
Source: Own compilation based on the JRC study, Table 2 (Baldini et al., 2024)

Figure 1-2 illustrates the correlations between the must-have indicators examined. Telecommunications operators already report (see Annex VI) greenhouse gas emissions in Scope 1, Scope 2 and Scope 3, with Scope 3 being captured at varying levels of detail. The GHG emissions cover all organizational activities, without differentiating between network-related (focus of this study) and non-network-related activities. A separate disclosure of network-related GHG emissions depends on the practical calculations of scope emissions.

The must-have indicators of the JRC study are interlinked in their entirety, interact in their effect and complement each other. Scope 1 and Scope 2 capture the network-related emissions that go beyond energy consumption. The must-have indicators of the circular economy are embedded in the Scope 3 categories and support operators in the calculation of Scope 3. At the same time, the network-related Scope 1 and Scope 3 emissions also capture other direct and indirect emission sources that are relevant for network-related activities.

[1] The indicators relate to products. In the JRC study, there are additional "should-have" indicators, e.g. "Recycled/refurbished/reused components", which, however, are defined at the component level.

Figure 1-2: Illustration of the correlations between the must-have indicators in this study



Source: Own illustration. Note: Not to scale, for illustrative purposes only

It should be noted that there are a number of indicators in the context of the circular economy, such as Upgradability, Reparability, Removability, Durability, Reusability, Recyclability, Recoverability, Refurbishability and Manufacturability (see ETSI TR 103 540 V1.1.1 (2018-04), ETSI TR 103 476 V1.1.2 (2018-02)). However, these indicators describe the potential ability of a product to be durable, reused or recycled. Such indicators are not the focus of the present study and were not classified as must-have indicators in the JRC study.

1.4 Overview of telecommunications networks and network operators in Germany

Mobile networks and network operators

According to data on the statistical evaluation of broadband availability from the Federal Network Agency (BNetzA and BMDV 2025), coverage with 2G is 99.97%, with 4G 98.66%, with 5G DSS[2] 83.7% and with 5G NSA/SA[3] 93.66% of the area in Germany. In Germany, 3G (UMTS) was already completely switched off in 2021 (Verbraucherzentrale NRW e.V. 2023). In 2026, 3G will be switched off across Europe, with the exception of France (where 3G will remain active until 2028/2029) (Weber 2022). According to Deutsche Telekom's media release, the 2G network is expected to be switched off by June 30, 2028 (Hafenrichter 2024).

[2] 5G DSS (Dynamic Spectrum Sharing) means that the capacities of the radio cells are divided between 4G and 5G users.

[3] 5G NSA (Non-Stand-Alone) means that the core network for 5G is still based on the predecessor technology LTE/4G. 5G SA (stand-alone) refers to a pure end-to-end 5G network that is based on 5G from the access network to the core network.

There are three established mobile network operators in Germany: **Vodafone, O2 and Deutsche Telekom**. In 2024, **1&1 AG** was added as the fourth network operator on the German market (1&1 AG 2024). Until 5G network coverage is fully expanded, 1&1 customers will use the Vodafone network.

Fixed networks and network operators

In 2023, the majority of broadband connections in Germany were based on various DSL technologies, which achieved a market share of around 64%. HFC[4] connections, which emerged from "cable television", followed with a share of 22% (8.6 million connections), while fiber optic lines accounted for 11% (4.3 million connections). Stationary wireless broadband services via LTE/5G contributed 2% (0.9 million connections) to the overall distribution (BNetzA 2023).

According to statistics from the Federal Network Agency (BNetzA 2023), Deutsche Telekom AG held a market share of 39% of fixed broadband connections by the end of 2023. This figure largely corresponds to the data from Statista from Q2 2023 (statista 2023). According to this, Deutsche Telekom accounted for 40.3% of connections, followed by Vodafone with 28.5%, 1&1 with 11.1%, Telefónica with 6.5%, the EWE Group with 2.2%, Tele Columbus with 1.9%, Deutsche Glasfaser with 1.6%, M-net and NetCologne each with 1.4% and others with 5.1%.

1.5 Consideration of the regulatory context

Within the scope of this study, it was examined whether and to what extent the EU Taxonomy and the EU-CSRD (Corporate Sustainability Reporting Directive) as political instruments prescribe binding standards or methods for the sustainability reporting of telecommunications network operators.

1.5.1 Examination of the EU taxonomy with regard to the must-have indicators

The EU taxonomy is a classification system for sustainable economic activities, which currently comprises 16 sectors of the economy (see Table 7-1, Annex I.a), to each of which economic activities are assigned. These also include economic activities carried out by telecommunications companies. However, central business areas, such as the "provision and operation of a network infrastructure for telecommunications", are not yet covered by the taxonomy. As a result, large companies such as Deutsche Telekom AG or Telefónica Deutschland Holding AG generated a maximum of 2.5% of their annual turnover (turnover KPI) in 2023 in so-called taxonomy-eligible activities and only 0.2% in so-called taxonomy-compliant activities (see Table 7-3, Annex I.b)

The investigation shows that the EU taxonomy provides a structured and standardized approach to assessing environmental sustainability. However, no specific standards were prescribed as to how environmental aspects should be assessed. Likewise, the must-have indicators examined in this study are not mentioned within the framework of the EU Taxonomy. It should be noted that at the time of writing this report, it is still not quite clear whether the EU taxonomy will integrate the planned EU Code of Conduct for Telecommunications Networks as a binding component.

[4] HFC stands for "Hybrid Fiber/Coax" and combines fiber optic with coaxial cable technology (TV cable network). The data is transmitted via fiber optic cable from central to regional nodes. At the regional nodes, the optical signals are converted into electrical signals, which are then forwarded to the end users via coaxial cable.

1.5.2 Examination of the EU CSRD (Corporate Sustainability Reporting Directive) with regard to the must-have indicators

The Corporate Sustainability Reporting Directive (CSRD), Directive (EU) 2022/2464 (European Union 2022c),, requires certain companies to disclose the data prescribed in the European Sustainability Reporting Standards (ESRS) (Annex II.a). Two of the twelve standards (ESRS E1: Climate Change and ESRS E5: Resource Use and Circular Economy) are related to the content of the must-have indicators examined in this study (ESRS n.d.).

In Annex II.b, correlations between CSRD and telecommunications companies are described. The investigation shows that the must-have metrics *"energy consumption in MWh*" and *"consumption of renewable energy"* examined in this study must be reported as part of ESRS E1 (see Table 7-6, Annex II.b). Furthermore, for activities in energy-intensive sectors, the *"energy intensity"* must be calculated from the total energy consumption in MWh per net sales revenue in currency units (e.g. euros). However, *"energy intensity"* is not a must-have indicator in the JRC study. The GHG-relevant must-have indicators *"GHG Scope 1/2/3"* must also be reported. The *GHG Protocol Corporate Standard* is prescribed as the method. Optionally, the *Organization Environmental Footprint* (Recommendation (EU) 2021/2279 (European Union 2021)) or (DIN EN ISO 14064-1:2018) can be taken into account. In addition, metrics on the circular economy must be reported as part of "ESRS E5-4: Resource inflows" and "ESRS E5-5: Resource outflows". This classification corresponds to the classification into the circular economy "before use" and "end-of-life" (EoL), which was chosen in this study. The reporting requirements under ESRS E5-4 include the "weight of reused or recycled secondary components, products and materials". This includes the must-have metrics *"weight of recycled products"* and *"weight of reused products"*. In addition, ESRS E5-5 reports the "*Total amount of waste generated in tons or kilograms*" broken down by recovery process (including recycling), which is not a must-have indicators in the JRC study. Methods and assumptions for determining the indicators are not prescribed in the reporting under the European Sustainability Reporting Standard (ESRS) but must be disclosed.

1.6 Overview of the structure of the report

The project comprises three substantive work packages (WP). The **completeness check** in WP1 (see section 2) aims to carry out a systematic meta-analysis of the standards in order to identify relevant standards. Based on the selected relevant standards from WP 1, a more in-depth comparability analysis is carried out in WP 2 (see Section 3). Based on the methodological approach (see Section 3.1), the comparability of the results of the measurements and calculations in the categories (energy management, GHG and circular economy) are analyzed when applying the same standard and different standards. This is followed by an **overall assessment of suitability** in the context of the objectives of the study. As part of work phase 3 (WP3) (see section 4), the **application effort** of the selected standards is indicatively estimated. The prerequisites for the application of the standards under consideration are assessed semi-quantitatively. This evaluation is combined with the assessment of market penetration, findings from the stakeholder survey and existing knowledge from the literature in order to determine the overall indicative effort. The **results** of WP2 and WP3 are interpreted together in section 5. Section 6 summarizes **the study** in a **conclusion**, particularly with regard to the possible usage in the Code of Conduct (CoC). Detailed results can be found in the annexes.

2 Systematic analysis of relevant standards and review of the specified standard catalog for completeness

2.1 Methodological approach for the completeness check of the standards at the meta level

First, the basic characteristics of all the standards specified in the service description were recorded on the basis of the following aspects:

- Name of the standard
- Version and status of development
- Publisher
- Availability (free versus paid)

The up-to-dateness or status of the standards was checked (see Annex IV.a), i.e. whether a standard is currently valid, is being revised or is expected to be revised in the near future. The current versions of the standards were used for the study and then analysed at the meta level using the categorization shown in Table 2-1.

Table 2-1: Overview of the categorization for the analysis of the standards at the meta-level in WP1

Categorization	Description
Purpose of the standard	Description of the purpose of the respective standards, including the question of whether they were designed for individual assessments or for comparative assessments - and under what conditions. It is also taken into account whether certain purposes are explicitly excluded in the respective standard.
Area of application	Classification according to their area of application: • General standards • ICT-specific standards • Telecommunications network-specific standards
Type of standard	Description of the type of standard, for example whether it is a methodological guide for calculating environmental aspects or a technical guide for measuring specific parameters.
Focus of the standard	• Description of the investigation focus of the respective standards, differentiated by the addressed emphasis, such as ICT components, networks, digital services, companies, general products, or ICT sites.
Phase of life considered	• Entire life phase • Production (including the entire supply chain) • Operating/utilization phase • End-of-Life
Network segment under consideration	For example, mobile access network (RAN), fixed access network (FAN), cable access network (CAN), core network, entire telecommunications network, etc.
Consideration of ICT components and/or infrastructure	It describes whether a standard only considers ICT equipment and components (e.g. routers, gateways) or also includes the supporting infrastructure (such as cooling systems, power and backup power supply, antenna masts).
Environmental indicators considered	Specific must-have indicators for energy management, GHG, circular economy (see Table 1-1)
Technical representativeness	Description of technical representativeness, e.g: Mobile access network: 2G / 3G / 4G / 5G; Fixed access network; Core network; Subnetwork segment; Entire network

Source: Own compilation

In addition to the categorization identified during the analysis of the standards, the potential relevance of the standards with regard to existing laws and regulations was also examined. For this purpose, each standard was examined using the search functions on the website of the Federal Office of Justice (https://www.gesetze-im-internet.de/) to determine whether and in what context the standard is already taken into account in relevant German laws, ordinances or other legal provisions.

In addition, technically equivalent standards from ITU and ETSI were identified (see Annex III). In cases where their content is identical, the ETSI standards were used for evaluation, as they are available in a more recent version.. After eliminating redundancies, the standards listed in the terms of reference were first systematically analysed at a meta level in an Excel spreadsheet, based on the categorization defined in Table 2-1. This analysis makes it possible to create an overview and check the completeness of the standards examined. If gaps were identified, a supplementary search for other relevant standards was carried out.

2.2 Energy management: Summary of the results

Table 2-2 lists the number of standards considered in WP1, divided into category level 1 (general or specific) and levels 2 and 3 (ICT devices or network-specific) in energy management. A complete overview of the energy management standards examined can be found in Table 7-8 (see Annex IV.a).

Table 2-2: Overview of the number of energy management standards considered in WP1 by category level 1 (general or specific) and levels 2 and 3 (ICT devices or network-specific)

Category Level 1	Quantity	Category Level 2 or Level 3	Quantity		
General standards	**6**	**Organization/Company**	**5**		
		General products and services	**1**		
ICT-specific standards	**3**	**Organization/Company**	**1**		
		ICT equipment, networks and services	**2**		
Telecommunications network-specific standards	**32**	**ICT equipment and devices**	**5**		
		Networks/ ICT Sites	**27**		
				Fixed access network (FAN)	3
				Mobile access network (RAN)	11
				Cable access network (CAN)	1
				Core network	2
				Wireless access network	1
				Mobile radio core network plus Radio Access Controller (RNC) in the RAN	1
				RAN and virtualized core network functions	1
				Entire mobile network	1
				Entire telecommunications network	4
				Virtualization of network functions (NFV)	2
Total: 41 standards					

Source: Own compilation

By applying the exclusion criteria, standards were sorted out and not included in the investigations of WP2 and WP3. In summary, the exclusion criteria are based on the following aspects:

- **Obsolete standards** that are replaced by new ones are no longer considered.
- **Standards at device level** focus on the individual properties and energy consumption of individual devices. The focus of this study is the telecommunications network and the interaction of the various network components.
- **Organization-related standards** are excluded from energy management because must-have indicators relate to energy aspects of the technical infrastructure in the usage phase of the networks.
- **Telecommunications network-unspecific standards and overarching standards,** such as GRI 2-27, ISO 14001, ISO 50001, were excluded.
- **specific LCA-relevant standards**, such as ETSI ES 203 199, were excluded.
- Standards **without prescribed must-have indicators or data collection methodology** were excluded. These include (ITU-T L. 1325 (12/2016)): Green ICT solutions for telecommunication network infrastructures; (ITU-T L. 1382 (06/2020)): Smart energy solutions for telecommunication rooms; (ITU-T L. 1390 (08/2022)): Energy saving technologies and best practices for 5G radio access networks (RAN) and (ETSI TR 103 541 V1.1.1 (2018-05)): Best practices for evaluating the energy efficiency of RAN, their recommended indicators according to (ETSI ES 203 228 V1.4.1 (2022-04)) (already taken into account).
- Standards that address the measurement method for **laboratory measurement or pre-deployment tests,** such as (ETSI ES 202 706-1 V1.8.1) and (ETSI ES 203 539 V1.1.1 (2019-06)), were excluded.

The detailed reasons for the exclusion of certain standards are listed in Table 7-11 in Annex IV.b together with the respective standards. A total of 15 relevant standards in the energy management category are subjected to an in-depth analysis (see section 3.2.1).

2.3 Greenhouse gas emissions: Summary of the results

Table 2-3 lists the number of standards considered in WP1, divided into category level 1 (general or specific) and level 2, depending on the focus of the standards, in the GHG category. A complete overview of the reviewed standards in the GHG category can be found in the annex in Table 7-9.

Table 2-3: Overview of the number of GHG standards considered in WP1 by category level 1 (general or specific) and levels 2 and 3 (ICT devices or network-specific)

Category Level 1	Quantity	Category Level 2	Quantity
General standards	13	Organization/Company	10
		General products and services	2
		Projects	1
ICT-specific standards	7	Organization/Company	2
		ICT equipment, networks and services	4
		ICT equipment & networks	1
Telecommunications network-specific standards	1	Scope 3	1
Total: 21 standards			

Source: Own compilation

In this case as well, exclusion criteria were applied to identify the key standards in the category of greenhouse gas (GHG) emissions. In summary, the exclusion criteria are based on the following aspects:

- **Obsolete standards** that are replaced by new ones are no longer considered.
- **Standards at product or project level,** such as Product Life Cycle Accounting ISO 14040/44 and ETSI ES 203 199. The latter standard deals with the methodology of life cycle assessment of ICT networks and services and can also be used to determine GHG potentials. However, it is not compatible with the must-have indicators identified by (Baldini et al. 2024), which follow the scope (1,2,3) logic of the GHG Protocol. In addition, ETSI ES 203 199 does not support the comparison of LCA results from different organizations, as this would require the assumptions and context of each study to be exactly the same. ISO 14064 - 2 also does not refer to quantified collection and reporting of GHG but to GHG projects to reduce emissions or increase GHG sinks
- **Unspecific and overarching standards** in which neither the must-have indicators nor a concrete data collection methodology are prescribed, such as ISO 14001.
- **Standards that contain indicators** that are **already covered more comprehensively by other standards** were excluded. These include, for example, GRI 305-2, the content of which is already covered by the GHG Protocol Scope 2 Guidance.
- Organizational standards are taken into account in GHG, as there are only such standards here.

It should be noted that ISO 14064-1 is also a specification with guidelines at the organizational level for the quantification and reporting of greenhouse gas emissions, using terms such as direct and indirect emissions instead of Scope 1/2/3. Its logic is similar to that of the GHG Protocol but additionnally addresses aspects related to removals. However, ISO 1406-1 is an optional method described in the CSRD, whereas the GHG Protocol is mandatory and directly provides the must-have indicators (Scope 1/2/3) defined in the JRC study. Furthermore, ISO 14064-1 is a general standard and not specifically tailored to the ICT/telecommunications sector. Therefore, the GHG Protocol is a better fit for the must-have indicators.

In addition to the standards, the tools provided by the GHG Protocol were also reviewed with regard to their relevance and applicability for the accounting of network-related activities (see Annex V.b). It should be noted that the GHG Protocol is currently revising part of its standards and guidelines as well as developing new standards. For this purpose, standard development plans have been created by each Technical Working Group. All documents relating to the standard development and revision process are available in the GHG Protocol repository[5]. According to the schedule published at the beginning of 2025, the revision of the Corporate Standard as well as the standards and guidance for Scope 2 and 3 is expected to be completed in 2027 (Huckins 2025)(see Table 7-17).

The detailed justifications for the exclusion of certain standards are listed in Table 7-12 in Annex IV.b together with the respective standards. A total of 4 relevant organization-related standards in the greenhouse gas emissions category are subjected to an in-depth analysis (see section 3.3.1).

2.4 Circular economy: Summary of the results

Table 2-4 lists the number of standards considered in WP1, broken down by category level 1 (general or specific) and level 2 in the circular economy category. A complete overview of the audited standards in the circular economy category can be found in the annex Table 7-10.

5 https://ghgprotocol.org/standards-development-and-governance-repository, as at: 29.04.2025

Table 2-4: Overview of the number of circular economy standards considered in WP1 by category level 1 (general or specific) and levels 2 and 3 (ICT devices or network-specific)

Category Level 1	Quantity	Category Level 2	Quantity
General standards	5	Organization/Company	2
		General products and services	3
ICT-specific standards	9	Organization/Company	1
		ICT equipment, networks and services	3
		ICT equipment & networks	3
		ICT equipment and devices	2
Telecommunications network-specific standards	2	Base stations	1
		Overall networks	1
Total: 16 standards			

Source: Own compilation

After the meta-level analysis of the circular economy-related standards, standards were excluded and not incorporated into the investigations of WP2 and WP3. In summary, the exclusion criteria are based on the following aspects:

- **Obsolete standards** that are replaced by new ones are no longer considered.
- **Very unspecific and overarching standards** such as ISO 14001, ISO 50001 were excluded.
- **Specific standards** such as the LCA-relevant standard (ETSI ES 203 199 V1.4.1 ((2024-11)),, or the assessment of the circularity of an individual product according to (ITU-T L. 1023 (08/2023)) were excluded.
- Standards that **do not** specify **must-have indicators or a data collection methodology** were excluded.

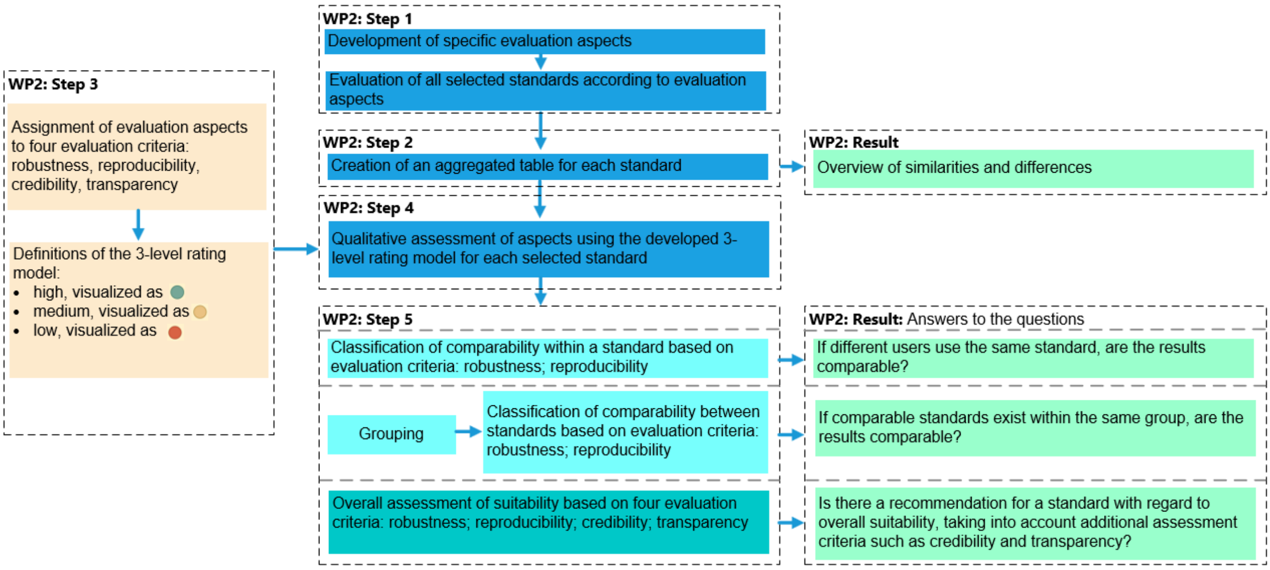
The detailed justifications for the exclusion of certain standards are listed in Table 7-13 in Annex IV.b together with the respective standards. A total of 6 relevant standards in the circular economy category are subjected to an in-depth analysis (see section 3.4.1).

3 Similarities and differences among selected standards

3.1 Methodological approach for the comparative analysis

The methodological approach for WP2, presented in Figure 3-1, comprises a multi-step procedure for the assessment of standards. This includes the development of specific assessment aspects and the analysis of the selected standards (step 1), the creation of an aggregated overview table (step 2), the development of an assessment method and a three-stage assessment model (step 3), the assessment of the standards (step 4) and the analysis of the comparability of the results when applying one standard and applying different standards and their overall suitability (step 5).

Figure 3-1: Overview of the methodological approach for the comparability analysis



Source: Own compilation

The methodology is explained below:

- **Step 1: Development and analysis of the assessment aspects:** First, specific assessment aspects were developed for the categories of energy management, greenhouse gas emissions and circular economy. The standards selected from WP1 were systematically analyzed.
- **Step 2: Creation of an overview table**: In view of the extensive information from the analyses of the standards in the first step, an aggregated overview table was created for each category. This overview serves to summarize the essential characteristics of the standards and enables a quick comparison of differences and similarities. The summaries of the overview tables form the basis for the further evaluation steps.
- **Step 3: Development of the evaluation method:** In this step, an evaluation method was developed. As part of the analysis, four evaluation criteria were defined that are relevant for comparability and quality characteristics (see Table 3-1): Robustness, reproducibility, trustworthiness and transparency. The evaluation aspects were then assigned to these criteria. In addition, a three-stage evaluation model with the levels “high”, ‘medium’ and “low” was defined for the respective evaluation aspects. The levels “high”, “medium” and “low” are represented on a scale by colored dots: green for “high”, yellow for ‘medium’ and red for “low”. A detailed description of the assessment model is provided for the respective categories (energy management, greenhouse gas emissions and circular economy). The focus of the assessment criteria varies depending on the category. In the area of greenhouse gas emissions, for example, the focus is more on the aspects of trustworthiness and transparency, as the data collection method and the underlying databases vary considerably depending on the organization. In the energy management category, on the other hand, the focus is on reproducibility in order to ensure consistent and comprehensible results. In the circular economy category, the focus is also on evaluation aspects that affect reproducibility.

Table 3-1: Definitions of the evaluation criteria

Evaluation criteria (EN)	Definition in the present study
Robustness	In the context of a standard, **robustness** means that the application of the procedures and indicators described in the standard leads to comparable and reliable results for varying system states of the network under consideration. This also applies taking into account the degrees of freedom in the approach permitted in the standard (e.g. data acquisition through energy measurement at a central feed-in point versus estimation of energy consumption based on manufacturer information).
Reproducibility	**Reproducibility** refers to the characteristic of a standard to deliver comparable results when the conditions and procedures defined in it are reapplied at a later time or by different individuals. This presupposes that only comparable calculation methods and methodological framework conditions are used for repeated application to the same object of investigation. Furthermore, a standard is considered reproducible if the results of its application cannot be significantly influenced by the user's individual assumptions.
Credibility	A standard is considered **credible,** if validation of the results is required by either an internal or external audit. A robust calculation method for KPIs includes mechanisms for error detection and correction. This can be achieved, for example, through redundancy, statistical uncertainty assessment and plausibility checks.
Transparency	The **transparency** of a standard is assessed according to the requirements it places on docu-menttation and traceability in its application. The documentation of the results obtained should at best include the following information: Designation of the object of investigation (system under test) and the boundaries of consideration (scope), simplifications and estimates made, general framework conditions and assumptions (e.g. allocation rules) as well as other relevant details (e.g. external data sources). The information must be clearly understandable for third parties.

Source: Own compilation

- **Step 4: Evaluation of the standards**: Based on the defined evaluation method, the selected standards were evaluated according to robustness, reproducibility, credibility and transparency with corresponding levels of "high", "medium", or "low".
- **Step 5: Analysis of comparability and overall suitability:** The analysis in this step serves to evaluate the answers to three central questions of this study:
  - **Comparability when using the same standard**: Are the results of the measurements or calculations comparable when standards are used within the same groups (evaluation criteria robustness and reproducibility)?
  - **Comparability between standards**: are the results comparable when standards are used within the same groups?

  Overall suitability: Is there a recommendation for a standard with regard to overall suitability, taking into account additional evaluation criteria such as trustworthiness and transparency?

The assessment of the comparability and reliability of the results of the measurements or calculations when using the same standard as well as different standards is based on the assessment aspects of robustness and reproducibility (see Table 3-1). For example, specifications based on continuous or representative measurements are more robust than data obtained by upscaling individual points.

The analysis of the comparability of the results of the measurements or calculations when different standards are applied is only relevant and expedient if several standards are available within the same group. For this reason, groups are initially formed based on similar characteristics, for example according to grid segments in the energy category, according to predefined scopes in accordance with the GHG Protocol Corporate in the GHG category or according to life cycle phases (before use and end-of-life) in the circular economy category. The exact groups are described in the respective categories (see sections 3.2.1; 3.3.1; 3.4.1).

Finally, the overall assessment of the suitability of the standards is carried out using all four evaluation criteria (robustness, reproducibility, credibility, transparency). This method makes it possible to systematically and comprehensibly assess the suitability of the standards for the study. It should be noted that the evaluation aspects in this work package were not weighted in order to enable a direct and transparent comparison of the aspects defined in different standards. This approach allows similarities and differences between the standards to be identified directly without subjective prioritization through weighting.

3.2 Comparative analysis of the standards in the energy management category

3.2.1 Overview of the selected standards

Table 7-19 in Annex VII shows the 15 selected standards, which were divided into six groups. The grouping is based either on the same network segment (group 1 to group 4) or on common characteristics (group 5 and group 6) (see Table 3-2).

Groups 1 to 4 cover the following network segments: Radio access network (RAN), fixed access network (FAN), cable access network (CAN) as well as core network, subnetwork or the entire network. Depending on the area of application, some standards can be assigned to several groups. For example, the ITU-T L.1332 standard is applicable to an ICT site managed by an operator that comprises a RAN, FAN or core network. The standard (ETSI TS 128 554 V18.7.0 (2024-10))) (equivalent to 3GPP TS 28.554) covers both the 5G RAN and the 5G core network and therefore belongs to group 1 and group 4. Group 5 comprises two standards that describe the scaling method from the subnetwork to the overall network. This is particularly relevant if it is not practicable or too costly for the operator to fully record the energy consumption in the entire network of a network operator. Group 6 comprises two standards that deal with "Network Functions Virtualization (NFV)" in the operational phase of the network. This technology has become increasingly important, particularly in the core network.

Table 3-2: Classification of energy-relevant standards depending on their application focus

Group	Standards	Network segment
Group 1: RAN (10)	ETSI EN 303 472 V1.1.1 (2018-10))	RAN: 2G/3G/4G
	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
	ETSI ES 203 228 V1.4.1 (2022-04) / ITU-T L. 1331 (01/2022)	RAN: technology-independent
	ETSI TS 128 554 V18.7.0 (2024-10))	5G mobile network: RAN, core network, end-to-end, NFV, slicing
	ITU-T L. 1332 (01/18)	ICT location: entire network
	ETSI EN 303 471 V1.1.1 (2019-01))	Entire access network: NFV
Group 2: FAN (4)	ETSI EN 305 200-2-2 V1.2.1 (2018-08))	FAN: technology-independent

Group	Standards	Network segment
	ETSI TS 105 200-2-2 V1.3.1 (2019-12))	FAN: technology-independent
	ITU-T L. 1332 (01/18)	ICT location: entire network
	ETSI EN 303 471 V1.1.1 (2019-01))	Entire access network: NFV
Group 3: CAN (3)	ETSI ES 205 200-2-4 V1.1.1 (2015-06))	CAN: technology-independent
	ETSI EN 303 471 V1.1.1 (2019-01))	Entire access network: NFV
	ITU-T L. 1332 (01/18)	ICT location: entire network
Group 4: Core network, sub-network, entire network (4)	ETSI EN 305 200-3-1 V1.1.1 (2018-02))	ICT location: Core network
	ETSI TS 105 200-3-1 V1.2.1 (2019-12))	ICT location: Core network
	ETSI TS 128 554 V18.7.0 (2024-10))	5G mobile network: RAN, core network, end-to-end, NFV, slicing
	ITU-T L. 1332 (01/18)	ICT location: entire network
Group 5: Scaling (2)	ETSI TR 103 540 V1.1.1 (2018-04))	RAN: technology-independent
	ETSI ES 203 228 V1.4.1 (2022-04) / ITU-T L. 1331 (01/2022)	RAN: technology-independent
Group 6: NGV (2)	ETSI TS 128 554 V18.7.0 (2024-10))	5G mobile network: RAN, core network, end-to-end, NFV, slicing
	ETSI EN 303 471 V1.1.1 (2019-01))	Entire access network: NFV

Source: Own compilation

3.2.2 Comparability of the results when applying the same standard

Table 3-3 summarizes the evaluation results of the comparability when applying the same standard. The basis of the evaluation is documented in Annex VII.b: Table 7-20 defines a three-level model (high, medium, low) based on the respective evaluation aspects; Table 7-21 to Table 7-25 in Annex VII.c document the evaluation aspects and background information on the individual 15 selected standards; Annex VII.d provides an overview of the evaluation results according to the three-level model, represented by green, yellow and red dots.

Table 3-3: Comparability of results when applying the same standard - Energy management

Network segment	Standard	Stufe	Comparability within a standard
RAN: 2G/3G/4G	**ETSI EN 303 472 V1.1.1 (2018-10)**	High	The comparability is rated as **high**. This results from the combination of a clear definition of the measurement period and frequency, as well as detailed specifications for test framework conditions, indicator results, and basic input parameters in a standardized reporting template. Some flexibility remains in the description of the measurement points. For multiple technologies at a base station, the total values are proportionally allocated based on the radiated RF power of each technology. An allocation for shared sites between different network operators is not considered in this standard.
RAN: technology-independent	**ETSI ES 203 228 V1.4.1 (2022-04)**/ITU-T L.1331	Medium	The comparability is rated as **medium**. The standard provides a solid and uniform basis for determining the energy consumption of a mobile access network, the classification of sites into demographic classes (e.g., urban, rural), and the extrapolation of subnetworks to larger networks. At the same time, for reasons of practicality, it allows considerable flexibility in application, particularly in the choice of measurement period. A weekly (7 days), monthly (30 days), or annual (365 days) measurement is permissible. The comparability of results heavily depends on practical implementation, including optional elements such as the inclusion of additional classifications (topography, climate zones) in extrapolation. There is no fixed specification for allocation. The division of energy consumption at shared sites between different network operators is left to the operators.
RAN: technology-independent	**ETSI TR 103 540 V1.1.1 (2018-04)**	Low	The comparability is rated as **low**. This results from the high degree of flexibility in both the measurement methodology and the statistical estimation method, as the standard does not provide mandatory specifications but merely defines statistical procedures (e.g., the sampling method for homogeneous networks or the stratified ("strata") collection for heterogeneous networks). It should be noted that the primary objective of the standard is to provide a basis for the scaling-up method using statistical procedures, not an exact measurement specification. There is no specific regulation on how to handle shared infrastructure.
RAN: technology-independent	**ITU-T L.1350 (10/2016)**	Low	The comparability is rated as **low**. This is due to the high degree of methodological flexibility. In particular, there is no specification regarding measurement period and frequency, which can significantly impair the robustness and reproducibility of the results. Additionally, a shared site is treated as a single unit without allocating energy consumption to individual operators, which reduces the robustness of the results.
RAN: technology-independent	**ITU-T L.1351 (08/2018)**	Low	The comparability is rated as **low**, similar to ITU-T L.1350. The energy collection method is specified in more detail compared to ITU-T L.1350; however, it allows considerable flexibility in the measurement period by offering options of one day, one week, one month, or one year. Furthermore, reproducibility is enhanced by requirements for clear documentation of the ambient temperature. The allocation rule for shared sites between different network operators remains unresolved.
RAN: technology-independent	**ETSI EN 305 200-2-3 V1.1.1 (2018-06)**	Medium	The comparability is rated as **medium**, as on-site measurements are combined with calculations. Power measurements are permissible for practical reasons, with energy consumption calculated by multiplying power and operating time. The lack of specific requirements for environmental conditions is unlikely to significantly impair the reproducibility of results, provided the user adheres to standardized measurement procedures, such as the calibration of measurement instruments. The standard specifies clear requirements for the measurement period: a default of 365 days, with shorter periods (at least 7 days) permitted if they realistically reflect annual values and avoid seasonal biases. This ensures high reproducibility and robustness of results. The standard applies at the level of overall measurement and pertains to the network belonging to the same network operator. Shared infrastructure is explicitly excluded.

Network segment	Standard	Stufe	Comparability within a standard
RAN: technology-independent	**ETSI TS 105 200-2-3 V1.2.1 (2019-12)**	Medium	The comparability is rated as **medium.** The requirements for measurement periods and frequency align with those in ETSI EN 305 200-2-3. The TS specifies allocation parameters for energy costs more precisely, which enhances reproducibility. Unlike ETSI EN 305 200-2-3, allocation is not explicitly excluded, as ETSI TS 105 200-2-3 is limited to the same network operator.
FAN: technology-independent	**ETSI EN 305 200-2-2 V1.2.1 (2018-08)**	Medium	The comparability is rated as **medium**, as on-site measurements are combined with calculations. Power measurements are permissible for practical reasons, with energy consumption calculated by multiplying power and operating time. The lack of specific requirements for environmental conditions is unlikely to significantly impair the reproducibility of results, provided the user adheres to standardized measurement procedures, such as the calibration of measurement instruments. The standard specifies clear requirements for the measurement period: a default of 365 days, with shorter periods (at least 7 days) permitted if they realistically reflect annual values and avoid seasonal biases. This ensures high reproducibility and robustness of results. The standard applies at the level of overall measurement and pertains to the network belonging to the same network operator. Shared infrastructure is explicitly excluded.
FAN: technology-independent	**ETSI TS 105 200-2-2 V1.3.1 (2019-12)**	Medium	The comparability is rated as **medium**. The requirements for measurement periods and frequency remain identical to those in ETSI EN 305 200-2-2. However, the TS specifies energy costs as allocation parameters for shared network facilities, which improves reproducibility. Unlike EN 305 200-2-2, allocation is not required, as this standard applies only to networks belonging to the same network operator. Shared infrastructure is explicitly excluded. The flexibility of data collection remains consistent with EN 305 200-2-2: on-site measurements are preferred, while alternative methods (e.g., electricity bills) are permissible for practical reasons.
CAN: technology-independent	**ETSI ES 205 200-2-4 V1.1.1 (2015-06)**	Low	The comparability is rated as **low**. This results from the flexibility in measurement and estimation methods as well as the measurement period (one day), which can influence the results. Additionally, ETSI ES 205 200-2-4 captures power consumption instead of direct energy measurement, which can lead to lower accuracy, particularly with fluctuating power.
5G mobile network: RAN, core network, end-to-end, NFV, slicing	**ETSI TS 128 554 V18.7.0 (2024-10)**	Low	The comparability is rated as **low**. This is due to the high degree of flexibility in measurement. In particular, there is no specification regarding measurement period and frequency, which can significantly impair the robustness and reproducibility of results. However, the standard clearly defines measurement points with physical interfaces for capturing data volume according to 3GPP TS 28.552. The full interpretation of this specification, 3GPP TS 28.552, requires 3GPP TS 32.404. The TS describes a clear procedure for data collection for the combination of physical 5G and NFV: through actual measurements of energy consumption in physical 5G networks and through estimation of energy consumption in virtualized 5G networks based on the utilization of virtualized resources at the component level (e.g., average virtual CPU utilization, memory utilization, disk usage, I/O traffic). However, the focus of the present study is not on the application of NFV at the component level. NFV is, however, highly relevant for determining energy consumption based on application scenarios. The primary focus of the study is on capturing energy aspects for network segments.
ICT location: Core network	**ETSI EN 305 200-3-1 V1.1.1 (2018-02)**	Medium	The comparability is rated as **medium**. This is due to clear specifications for the measurement period—defaulting to 365 days, with shorter periods (at least 7 days) permitted if they realistically reflect annual values and avoid seasonal biases. Detailed requirements for measurement points with corresponding loss factors increase the reproducibility of results. The lack of specific requirements for environmental conditions and measurement instruments—beyond the regulated calibration of heat meters according to CEN EN 1434—may not significantly affect result reproducibility, provided the user implements basic measurement steps such as instrument calibration and documentation of ambient temperatures that can influence the energy consumption of network equipment. Some flexibility remains in the allocation of energy consumption in shared infrastructure, as this is left to the operators.

Network segment	Standard	Stufe	Comparability within a standard
ICT location: Core network	**ETSI TS 105 200-3-1 V1.2.1 (2019-12)**	Medium	The comparability is rated as **medium**. The requirements for measurement periods and frequency remain identical to those in ETSI EN 305 200-3-1. The lack of specific requirements for allocation in shared infrastructure impairs the reproducibility of the results.
ICT location: entire network	**ITU-T L.1332 (01/2018)**	Low	The comparability is rated as **low**. The high variability of measurement results is due to the significant flexibility in measurement. In particular, the lack of specifications for measurement period and frequency can significantly impair the robustness and reproducibility of results. However, there are clear specifications for measurement points, instruments, and methods, such as the preferred continuous on-site measurement or, if not feasible, the use of utility bills. Nevertheless, measurement period and frequency remain variable. Allocation is not required, as the standard exclusively covers networks of the same operator.
Entire access network: NFV	**ETSI EN 303 471 V1.1.1 (2019-01)**	Medium	The comparability is rated as **medium**. This is due to clear specifications for the measurement period—defaulting to 365 days, with shorter periods (at least 7 days) permitted if they realistically reflect annual values and avoid seasonal biases. The standard focuses on capturing the energy consumption of the NFVI (Network Functions Virtualisation Infrastructure) as a total value. If the NFVI supports multiple access networks, the energy consumption should be measurable separately for each network, but detailed specifications for this are lacking, allowing users to choose their own approaches. Such flexibility can significantly influence the results. The standard appears to assume that the NFVI primarily supports access networks, leaving it unclear how to handle an NFVI that hosts both access and core network functions and whose energy consumption would need to be allocated accordingly.

Source: Own compilation

3.2.3 Comparability of results when applying different standards

The comparability between the standards examines whether the results are comparable if different standards within the same group (see Table 3-2) are used. The standards have different scopes and coverages. Table 3-4 provides an overview, independent of the groups, of whether the energy consumption of the supporting infrastructure (e.g. air conditioning systems, power supply) is taken into account in the respective standards and which required must-have metrics are defined. It should be emphasized that the ETSI EN 303 472 standards, the ETSI EN 305 200-x series and the associated TS (Technical Specifications) include all three energy-related must-have indicators, with the exception of the ETSI EN 305 200-3-1 standard. A difference can be seen in comparison to other standards in the ETSI EN 303 200-2-x series, where the "Task Effectiveness" metric describes the relationship between data volume and energy consumption. In the ETSI EN 305 200-3-1 standard, on the other hand, the "task effectiveness" metric refers to the relationship between the energy consumption of the IT devices and the total energy consumption, including the supporting infrastructure (e.g. cooling). It should be noted that the standard ETSI ES 202 336-12[6] serves as a frequently cited reference for the basic description of the measurement principle and the accuracy of the measurement data. This standard is used solely as a complement to the energy management standards and was therefore not analyzed further.

With regard to the indicators for renewable energy, not all the standards considered explicitly list these as a separate metric. However, the ETSI ES 203 228 standard requires that the share of renewable energy generated on-site be reported. It is noteworthy that almost all selected standards require that renewable energy generated on-site be included in the overall energy balance. It should be emphasized that 'green' energy in the electricity mix, certified as renewable by electricity suppliers or national regulations, is not recognized as renewable energy in the standards ETSI EN 305 200-2-3, ETSI EN 305 200-2-2, ETSI ES 205 200-2-4, ETSI EN 305 200-3-1, and ETSI EN 303 471, regardless of different network segments. This requirement should be reviewed in light of the current regulatory framework. According to the corrigendum of Commission Delegated Regulation (EU) 2023/2772 of July 31, 2023, energy is only considered to originate from renewable sources if its origin is clearly stipulated in the contractual agreements with suppliers. This includes agreements for the procurement of renewable electricity, standardized green electricity tariffs, or market instruments such as guarantees of origin for renewable energy in Europe, certificates for renewable energy in the USA and Canada, or comparable instruments ((European Commission 2023d), AR 32 j, page 90).

6 Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model

Table 3-4: Comparison of the selected standards in terms of scope and must-have indicators

Network segment	Standard	Consideration of the supporting infrastructure	Must-have indicator 1: Energy consumption	Must-have indicator 2: Energy efficiency = data volume/energy consumption	Must-have indicator 3: Renewable energy as a separate indicator	Must-have indicator 3: no separate metric, however renewable energy in total consumption
RAN: 2G/3G/4G	ETSI EN 303 472 V1.1.1 (2018-10)	yes	yes	yes	yes	yes
RAN: technology-independent	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	yes	yes	yes	no*	yes
RAN: technology-independent	ETSI TR 103 540 V1.1.1 (2018-04)	no	yes	no	no	yes
RAN: technology-independent	ITU-T L.1350 (10/2016)	yes	yes	no	no	yes
RAN: technology-independent	ITU-T L.1351 (08/2018)	yes	yes	no	no	yes
RAN: technology-independent	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	yes	yes	yes	yes	yes
RAN: technology-independent	ETSI TS 105 200-2-3 V1.2.1 (2019-12)	yes	yes	yes	yes	yes
FAN: technology-independent	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	yes	yes	yes	yes	yes
FAN: technology-independent	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	yes	yes	yes	yes	yes
CAN: technology-independent	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	no	yes	yes	yes	yes
5G mobile network: RAN, core network	ETSI TS 128 554 V18.7.0 (2024-10)	no	yes	yes	no	not mentioned
ICT location: Core network	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	yes	yes	no	yes	yes
ICT location: Core network	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	yes	yes	no	yes	yes
ICT location: entire network	ITU-T L.1332 (01/2018)	yes	yes	no	no	yes

Network segment	Standard	Consideration of the supporting infrastructure	Must-have indicator 1: Energy consumption	Must-have indicator 2: Energy efficiency = data volume/energy consumption	Must-have indicator 3: Renewable energy as a separate indicator	Must-have indicator 3: no separate metric, however renewable energy in total consumption
Entire access network: NFV	ETSI EN 303 471 V1.1.1 (2019-01)	yes	yes	yes	no	yes

Source: Own compilation. However, * requires the proportion of renewable energies on site to be stated in the report

A comprehensive description of all assessment aspects considered can be found in Annex VII.c Table 7-21 to Table 7-25.

3.2.3.1 Group 1: Mobile access network (RAN)

The basis for the grouping is explained in section 3.2.1. Table 3-5 compares two relevant assessment aspects (measurement period and allocation) of the respective RAN standards by way of example, in order to illustrate the flexibility of the requirements and the resulting limited comparability. It should be noted that the ETSI EN 303 471 standard supports the determination of energy consumption for NFV applications in access networks as a supplementary method.

Overall, the comparability of the results when using different standards is **limited** due to different provisions.

Table 3-5: Comparison of two assessment aspects of the standards in Group 1: RAN

Network segment	Standards	Measuring period and measuring frequency	Allocation rules or delimitation of the scope of application
RAN: 2G/3G/4G	**ETSI EN 303 472 V1.1.1 (2018-10)**	• Measurement period: **Standard 365 days**, at least 7 days (representative, not seasonally biased). • Measurement frequency: Flexible, document clearly in the measurement report.	Allocation: Split according to **RF power of the technologies**; shared sites of several operators **not taken into account**.
RAN: technology-independent	**ETSI TR 103 540 V1.1.1 (2018-04)**	Measuring period **freely selectable**, must be specified with energy consumption.	not mentioned
RAN: technology-independent	**ITU-T L.1350 (10/2016)**	**Not specified**, continuous on-site measurement preferred.	Shared sites are considered as one unit; no allocation of consumption and no allocation rule.
RAN: technology-independent	**ITU-T L.1351 (08/2018)**	• Measurement period: four options for the measurement period (**1 day, 1 week, 1 month or 1 year**). • Measuring frequency: at least every 15 minutes	not mentioned
RAN: technology-independent	**ETSI EN 305 200-2-3 V1.1.1 (2018-06)**	• Measurement period: **Standard 365 days**, at least 7 days (representative, not seasonally biased). • Measurement frequency: Between 1 week and 1 month	• Refers to total measurement of a network operator's network, **shared infrastructure excluded** • NFV applications of the RAN, also at other sites: Include in RAN energy balance. Shared multiple access networks: Mobile consumption only or exclusion with reporting note.

Network segment	Standards	Measuring period and measuring frequency	Allocation rules or delimitation of the scope of application
RAN: technology-independent	**ETSI TS 105 200-2-3 V1.2.1 (2019-12)**	According to ETSI EN 305 200-2-3	Shared networks: Allocation according to **energy costs**.
RAN: technology-independent	**ETSI ES 203 228 V1.4.1 (2022-04)**/ITU-T L.1331	• Measurement period: **Flexible (7, 30 or 365 days).** • Measurement frequency: Not specified, document in the report.	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.**
5G mobile network: RAN, core network	**ETSI TS 128 554 V18.7.0 (2024-10)**	Not specified	No explicit allocation rule for shared sites

Network segment	Standards	Measuring period and measuring frequency	Allocation rules or delimitation of the scope of application
ICT location: entire network	**ITU-T L.1332 (01/2018)**	Not specified, continuous on-site measurement preferred.	The standard remains at the level of overall measurement and applies to the network **belonging to the same network operator**
Entire access network: NFV	**ETSI EN 303 471 V1.1.1 (2019-01)**	• Measurement period: **Standard 365 days**, at least 7 days (representative, not seasonally biased). • Measurement frequency: Between 1 week and 1 month	The energy consumption for different access network types (e.g., fixed network or mobile network) should be measurable separately if the NFVI supports multiple access networks. However, further specifications on this are lacking

Source: Own compilation

3.2.3.2 Group 2: Fixed access network (FAN)

The number of standards applicable to FAN is lower compared to RAN. Table 3-6 compares two selected assessment aspects between the standards by way of example. As already explained, ETSI EN 303 471 only addresses NFV applications.

Overall, the comparability of the results when using different standards **limited** due to different requirements.

Table 3-6: Comparison of two assessment aspects of the standards in Group 2: FAN

Network segment	Standards	Measuring period and measuring frequency	Allocation rules or delimitation of the scope of application
FAN: technology-independent	**ETSI EN 305 200-2-2 V1.2.1 (2018-08)**	• Measurement period: **Standard 365 days**, at least 7 days (representative, not seasonally biased). • Measurement frequency: Between 1 week and 1 month	• Refers to total measurement of a network operator's network, shared infrastructure excluded • NFV applications of the FAN, also at other sites: Include in FAN energy balance. Shared multiple access networks: Fixed access network consumption only or exclusion with reporting note.
FAN: technology-independent	**ETSI TS 105 200-2-2 V1.3.1 (2019-12)**	• According to ETSI EN 305 200-2-2	Shared networks: Allocation according to **energy costs.**
ICT location: entire network	**ITU-T L.1332 (01/2018)**	Not specified, continuous on-site measurement preferred.	The standard remains at the level of overall measurement and applies to the network belonging to the same network operator
Entire access network: NFV	**ETSI EN 303 471 V1.1.1 (2019-01)**	• Measurement period: Standard 365 days, at least 7 days (representative, not seasonally biased). • Measurement frequency: Between 1 week and 1 month	The energy consumption for different access network types (e.g., fixed network or mobile network) should be measurable separately if the NFVI supports multiple access networks. However, further specifications on this are lacking

Source: Own compilation

3.2.3.3 Group 3: Cable access network (CAN)

The ETSI ES 205 200-2-4 standard is the only one that specifically addresses cable access networks. In addition, the ITU-T L.1332 standard, which applies to ICT sites regardless of the network segment, and the NFV-specific standard ETSI EN 303 471, which is applicable to all types of access networks (mobile, fixed and cable access), are also relevant. The two general standards have already been explained in the sections on RAN and FAN and will not be discussed again here. It should be noted that the CAN-specific standard ETSI ES 205 200-2-4 already shows a low level of comparability when examining comparability of the results when using the same standard (see Table 3-3). It should be emphasized that it is an ETSI standard (ES), while other standards in the same series are European Standards (EN) with Technical Specifications (TS). As the standard has not been revised since 2015, it is recommended to assess its current technological validity..

3.2.3.4 Group 4: Core network, sub-network, entire network

ETSI EN 305 200-3-1 and the associated ETSI TS 105 200-3-1 serve as a methodological guide and measurement specification for calculating the energy aspects of ICT sites in the core network. They define a standardized measurement methodology, e.g. a measurement period of 365 days. In contrast, ETSI TS 128 554 for 5G core networks and ITU-T L.1332 for ICT sites in the entire network offer greater flexibility in terms of measurement period and frequency. Differences in other assessment aspects, such as the defined measurement points, make it even more difficult to compare the standards.

3.2.3.5 Group 5: Standards describing scaling approaches

ETSI TR 103 540 and ETSI ES 203 228 offer different methodologies for extrapolating sub-networks to larger networks for the mobile access network.

- ETSI TR 103 540 V1.1.1 (2018-04) differentiates according to network homogeneity:
  - Homogeneous networks: Representative statements can be made using randomly selected samples.
  - Heterogeneous networks: Stratified estimation method (strata) with layers such as number of base stations, radio modules, outdoor temperature, RF utilization or BS types, supported by guidelines.
- ETSI ES 203 228 V1.4.1 (2022-04) based on demographic classes of locations (e.g. urban, rural). In addition, optional classifications such as topography or climate zones can be included in the upscaling to increase the accuracy of the analysis.

3.2.3.6 Group 6: Standards related to Network Function Virtualisation (NFV)

The two standards that deal with the topic of Network Function Virtualization (NFV) in the operating phase have different levels of granularity:

- ETSI EN 303 471 V1.1.1 (2019-01) follows a simplified approach with aggregated measurements for the entire NFVI, without differentiating between VNFs or components such as CPU and RAM. The focus is on a holistic view as a supplement for RAN and FAN infrastructures.
- ETSI TS 128 554 V18.7.0 (2024-10) provides a more detailed analysis, measuring the energy consumption of physical network functions (PNF) and estimating the consumption of virtualized functions (VNF) based on parameters such as vCPU, vMemory and I/O traffic. The NFV is crucial for determining energy consumption by application scenario. However, the focus of this study is on recording energy aspects for network segments, not on the application level.

3.2.4 Overall assessment of suitability

The suitability of the standards examined is summarized in Table 3-7. In principle, the classification of the overall assessment of suitability remains within the same range as the classification of comparability of the results when using the same standard (see section 3.2.2). An exception is ETSI ES 203 228, whose rating has been raised to "high" by detailed reporting requirements. These requirements enable thorough documentation that supports better traceability and evaluation.

Table 3-7: Energy management: overview of the overall suitability assessment

Network segment	Standard	Overall assessment of suitability
RAN: 2G/3G/4G	ETSI EN 303 472 V1.1.1 (2018-10)	**high**
RAN: technology-independent	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	**high**
RAN: technology-independent	ETSI TR 103 540 V1.1.1 (2018-04)	medium
RAN: technology-independent	ITU-T L.1350 (10/2016)	low
RAN: technology-independent	ITU-T L.1351 (08/2018)	low
RAN: technology-independent	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	medium
RAN: technology-independent	ETSI TS 105 200-2-3 V1.2.1 (2019-12)	medium
FAN: technology-independent	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	medium
FAN: technology-independent	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	medium
CAN: technology-independent	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	low
5G mobile network: RAN, core network, end-to-end, NFV, slicing	ETSI TS 128 554 V18.7.0 (2024-10)	low
ICT location: Core network	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	medium
ICT location: Core network	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	medium
ICT location: entire network	ITU-T L.1332 (01/2018)	low
Entire access network: NFV	ETSI EN 303 471 V1.1.1 (2019-01)	medium

Source: Own compilation

Two additional assessment criteria, credibility and transparency, were included in the overall suitability assessment. It should be noted that none of the standards examined in this study contain any requirements for validation. However, the absence of such requirements in the standards does not preclude users from carrying out corresponding validations. Only the explicit requirements of the standards themselves are evaluated in this study.

With regard to the valuation aspect of uncertainty assessment, some standards deal with statistically relevant aspects. Two standards should be emphasized in this context:

- ETSI TR 103 540 V1.1.1 (2018-04): This standard takes into account the confidence level and the error tolerance for sample-based estimates of energy consumption. The suitability was therefore classified as medium.
- ETSI TS 105 200-3-1 V1.2.1 (2019-12): This standard stipulates that all assessment periods must cover one year. When upscaling measurement data from a small number of sites to a large group, the calculation of statistical accuracy is mandatory.

A detailed summary of the entire assessment of the 15 standards can be found in Table 7- in Annex VII.d

3.3 Comparative analysis of the standards in the greenhouse gas emissions category

3.3.1 Overview of the selected standards

The four selected standards were divided into 2 groups. Group 1 includes those standards that primarily address GHG scopes 1 & 2. Group 2 includes all standards that relate partially or exclusively to Scope 3[7]. The 15 Scope 3 categories according to the GHG Protocol are listed in Annex V.a. The analysis of the two groups differs in terms of the assessment criteria and assessment aspects applied.

Table 3-8: Classification of organization-related standards on greenhouse gas emissions depending on their focus of application

Group	Standard	Application focus
Group 1 and 2	GHG Protocol Corporate Accounting and Reporting Standard (Greenhouse Gas Protocol 2004), Extension with Scope 2 Guidance (2015) (Greenhouse Gas Protocol 2015)	Scope 1 & 2; Scope 3 optional
Group 1 and 2	(ITU-T L. 1420 (02/12))	Scope 1 & 2; Scope 3 optional
Group 2	Protocol Corporate (Value Chain) Standard (2011) (Greenhouse Gas Protocol 2011)	Scope 3 only
Group 2	Scope 3 Guidance for Telecommunication Operators (GSMA; GeSi; ITU 2023)	Scope 3 only

Source: Own compilation

3.3.2 Comparability of the results of GHG-assessments when using the same standard

Table 3-9 provides an overview of the comparability results of the results when using the same standard. This comparability examines whether different users of the same standard achieve comparable results.

Table 3-9: GHG: Overview of the comparinility of GHG-assessment results when using the same standard

GHG groups	Standards	Comparability when using the same standard
Scope 1 & Scope 2	GHG Protocol Corporate Accounting and Reporting Standard (2004) & Scope 2 Guidance	low
	ITU-T L.1420 (02/2012)	medium
Scope 3	GHG Protocol Corporate Accounting and Reporting Standard (2004) & Scope 2 Guidance	low
	ITU-T L.1420 (02/2012)	low
	Protocol Corporate (Value Chain) Standard (2011)	medium
	Scope 3 Guidance for Telecommunication Operators (2023)	**high**

[7] Group 2 in turn also includes the standards from Group 1, as these optionally address Scope 3, albeit not in detail. The evaluation in Group 2 is carried out with a special focus on the methodological requirements for Scope 3.

Source: Own compilation

The evaluation is based on Table 7-27 and Table 7-28 in Annex VIII.a. Annex VIII.b shows detailed tables with the results for standards in the GHG category, which form the basis for the analyses presented below. Annex VIII.c provides an overview of the assessment results according to the three-level model, represented by green, yellow and red dots.

Explanations on comparability when using standards in GHG Group 1: Scope 1&2

GHG Protocol Corporate Accounting and Reporting Standard (2004) & Scope 2 Guidance

The GHG Protocol Corporate is used worldwide and is recognized by experts as an established reporting standard. The standard is written in general terms and serves as a basic method for determining and reporting an organization's greenhouse gas emissions across all sectors. The generic approach opens up a large number of degrees of freedom in the methodological implementation of data collection and calculations, which results in a limited comparability of GHG-assessment results. The procedure for collecting primary data for Scope 1 and 2 is only explained by way of example and there are no specifically formulated criteria for selecting emission factors. It should also be noted that there is no clear handling of allocation cases in the sense of allocation rules or a prioritized approach.

ITU-T L.1420 (02/2012)

This is an independent standard and defines the methodological approach and reporting of GHGs of an ICT company. In many respects, it is based on the GHG Protocol Corporate. The comparability of GHG-assessment results that are based on this standard is classified as medium. The standard does not provide a concrete procedure for recording the primary data of Scope 1 and 2 and no allocation rules are prescribed. In comparison to the GHG Protocol Corporate, criteria for the selection of emission factors are specified, although these are also to be regarded as general.

Explanations on comparability of results when using standards in GHG Group 2: Scope 3

GHG Protocol Corporate Accounting and Reporting Standard (2004)

The GHG Protocol Corporate Standard (2004) provides only weak guidance for the calculation of Scope 3 greenhouse gas emissions. There are many degrees of freedom in the methodological execution of the GHG-calculations, which is why the comparability of Scope 3 results that rely on the base standard is classified as low. Specifically, this means that there are no requirements for data collection and calculation methods for Scope 3. The activities to be taken into account for the individual Scope 3 categories are also not broken down in more detail. Furthermore, comparability is impaired by imprecise specifications on the choice of emission factors and a lack of specifications on the application of allocation and cut-off rules.

ITU-T L.1420 (02/2012)

This standard explicitly addresses Scope 3 and mentions some ICT-specific aspects for consideration in Scope 3. Nevertheless, the comparability within the standard is rated as low overall, as it leaves many degrees of freedom in the methodical calculation of Scope 3 greenhouse gas emissions. It does not provide detailed specifications for data collection for Scope 3 and the calculation of Scope 3 emissions. The classification of the relevance of the individual Scope 3 categories for ICT companies is neutral to positive for comparability, but there is no focus on network-related activities. The guidelines for the selection of emission factors are particularly noteworthy, even though they are rather general. There are no methodological guidelines on the procedure for allocation cases; only a single example is given here in which an allocation must be made, without specific instructions being given. With regard to the delimitation criteria, there are no clear rules on how these are to be implemented. However, comparability is ensured by the requirement to document the underlying criteria.

Protocol Corporate (Value Chain) Standard (2011)

The comparability of the GHG-assessment results that rely on the GHG Protocol Corporate (Value Chain) Standard (2011) is rated as medium. This assessment is based on the following aspects: Although the standard provides generic recommendations for data collection, there is no specification of a uniform approach for the ICT or telecommunications sector. A similar situation can be seen in the calculation methods for the individual Scope 3 categories. Although the standard provides concrete guidelines in a separate document "Technical Guidance for Calculating Scope 3 Emissions" (Greenhouse Gas Protocol Initiative 2013),, there are no specific guidelines as to which method must be used and when. In some cases, the methods were prioritized based on their precision. Specific activities are assigned to the individual Scope 3 categories, although no network-specific assignment is made. There are no comprehensive specifications regarding the selection of emission factors. However, a list of databases with emission factors is referenced . The specification of allocation rules is to be regarded as positive with respect to comparability. There are no specific requirements regarding particular cut-off criteria. For the respective Scope 3 categories, it is already specified which activities must be recorded at a minimum. The disclosure and justification of exceptions are mandatory.

Scope 3 Guidance for Telecommunication Operators (2023)

The Scope 3 Guidance for Telecommunication Operators provides instructions for calculating GHG emissions for each Scope 3 category. In principle, however, it is possible to choose between different methods, which have been prioritized according to their accuracy. It also provides specific guidelines regarding the collection of activity data for the Scope 3 categories. In contrast to the GHG Protocol Corporate (Value Chain) Standard, this guideline has been designed specifically for telecommunications network operators, which is also the focus of the assignment of the activities to be recorded for the individual Scope 3 categories. Due to the more specific requirements for the Scope 3 categories, comparability is relatively high. Further positive aspects include the requirements for the selection of emission factors and the specification of cut-off criteria. Potential data sources for emission factors are explained separately for each category. No specific cut-off criteria are specified; instead, the selection of Scope 3 categories is based on their relevance ("materiality"), for which reference is made to other standards. With regard to the allocation rules, allocation options are mentioned, but there is no prioritization, which reduces comparability somewhat. Overall, the comparability within the guidance can be classified as high.

3.3.3 Comparability of GHG-results when using different standards

The differences and similarities between the standards in the GHG category are shown below. The characteristic “comparability of GHG-results when using different standards” considered in this section refers to the question of whether the application of different standards within the same group for assessing GHG emissions leads to comparable results. In other words: To what extent does the result of a GHG calculation depend on which of the alternative standards is used as the calculation method.

The standards were only compared with each other within the same group based on their scope of application. The similarities and differences between the standards per assessment aspect can be viewed in Annex VIII.b.

3.3.3.1 Comparability GHG-results when using different standards in GHG Group 1: Scopes 1 and 2

Both the GHG Protocol Corporate Accounting and Reporting Standard (2004), including the Scope 2 Guidance extension, and also ITU-T L.1420 (02/2012) are organization-related standards that focus primarily on Scopes 1 & 2. Scope 3 GHG emissions can optionally be calculated and reported in both standards and provide methodological guidance. Compared to the GHG Protocol Corporate, ITU-T L.1420 (02/2012) is more specific to ICT organizations, although there is no specific reference to network related activities.

The main differences in the methodological approach are that:

- **ITU-T L.1420 (02/2012)** contains specific regulations on the selection of the time frame for the **characterization factors**[8] and conditions for the selection of **emission factors** (albeit in general terms). There are no specifications on this in the GHG Protocol.
- In contrast, the extension of the **GHG Protocol Corporate** with the Scope 2 Guidance clearly specifies **the approaches** according to **which Scope 2** emissions must be accounted for and reported (location-based and market-based approach). There is no statement on this in ITU-T L.1420 (02/2012).

Another difference lies in the **reporting obligations**:

- According to the GHG Protocol, GHG emissions must be reported separately for each of the 7 **individual greenhouse gases**; emissions from **biogenic carbon** must be reported separately as well. ITU-T L.1420 (02/2012) does not require this breakdown, instead, GHG emissions must be reported by **country** (main countries & rest of the world).

3.3.3.2 Comparability of GHG-results when using different standards in GHG Group 2: Scope 3

The GHG Protocol Corporate Accounting and Reporting Standard (2004) (general standard) and ITU-T L.1420 (02/2012) (ICT-specific standard) both cover all three scopes, with Scope 3 listed as an optional addition. The Protocol Corporate (Value Chain) Standard (general standard) and the Scope 3 Guidance for Telecommunication Operators (ICT-specific standard) focus on the accounting and reporting of Scope 3 GHG emissions and, unlike the first two standards, define mandatory requirements for Scope 3. However, the use of these standards to calculate Scope 3 emissions is essentially a voluntary decision for companies.

The main differences in the methodological approach lie in the fact that:

- In ITU-T L.1420 (02/2012), for GHG emissions for which LCA data can be used (e.g. purchased goods), all life cycle phases except the use phase are divided by the operational lifetime to determine the annual impact. In all other standards, the total GHG emissions of a product (from all life cycle phases) are accounted for in the year in which it is purchased or sold.
- The Scope 3 Guidance for Telecommunications Operators prioritises which Scope 3 categories are most relevant for telecommunications operators, namely "Purchased goods and services"

[8] characterization factor: factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator (ISO 14044, section 3.27). For example, emissions of different greenhouse gases are converted into CO_2 equivalents using characterization factors. The characterization factors for global warming potential (GWP) are based on the IPCC Assessment Reports (AR). Depending on the version of the report, the characterization factors may vary. The most recent IPCC Assessment Report is from 2021 (AR6). The GHG Protocol has provided an overview of the IPCC characterization factors in its tools (see Table 7-16)

(category 1), "Capital goods" (category 2), "Fuel and energy related activities" (category 3), "Upstream /Downstream leased assets" (category 8 / category 13), "Use of sold products" (category 11), and, depending on the consolidation approach and business model, category 15 ("Investments"). Category 10 ("Processing of sold products") is considered irrelevant and may be excluded. ITU-T L.1420 (02/2012), on the other hand, identifies categories 5 ("Waste from operations") and 15 ("Investments") as optional. The other two standards are general and do not prioritise Scope 3 categories.

- The specific Scope 3 standards provide detailed information on the calculation of Scope 3 categories, including the process for defining allocation rules. This is missing from the GHG Protocol Corporate Accounting and Reporting Standard (2004) and ITU-T L.1420 (02/2012).
- The Scope 3 Guidance for Telecommunication Operators provides the most precise information on the procedure for primary data collection, the selection of emission factors and calculation specifications. However, it does not specify which characterisation factors should be used. These are specified in ITU-T L.1420 (02/2012) and in the Protocol Corporate (Value Chain) standard.
- For the specific Scope 3 standards, an assessment of the data quality/uncertainty assessment is mandatory; for the more general standards, this is optional.

The main differences in the reporting obligations are that:

- For the Scope 3 specific standards, the Scope 3 GHG emissions must be reported broken down according to the individual Scope 3 categories; for the GHG Protocol Corporate Accounting and Reporting Standard (2004) and ITU-T L.1420 (02/2012), reporting of Scope 3 emissions is optional. The reporting requirements are highest for the Protocol Corporate (Value Chain) Standard, where biogenic CO_2 (i.e. Carbon dioxide that comes from the combustion of biological materials, such as biomass, and is therefore part of the current carbon cycle) must also be reported separately, Furthermore, the percentage of emissions calculated using data from the supply chain must be reported.

3.3.4 Overall assessment of suitability

The suitability of the investigated GHG standards is summarized in Table 3-10.

Table 3-10: GHG: Overview of the overall suitability assessment

GHG groups	Standards	Overall assessment of suitability
Scope 1 & Scope 2	GHG Protocol Corporate Accounting and Reporting Standard (2004) & Scope 2 Guidance	medium
	ITU-T L.1420 (02/2012)	medium
Scope 3	GHG Protocol Corporate Accounting and Reporting Standard (2004)	low
	ITU-T L.1420 (02/2012)	low
	Protocol Corporate (Value Chain) Standard (2011)	low
	Scope 3 Guidance for Telecommunication Operators (2023)	**high**

Source. Own compilation

<u>**Explanations on the suitability of the standards in GHG Group 1: Scope 1 & 2**</u>

GHG Protocol Corporate Accounting and Reporting Standard (2004) & Scope 2 Guidance

The GHG Protocol Corporate, including the Scope 2 Guidance extension, is a useful guide to the methodology and reporting of an organization's greenhouse gas emissions. The standard is formulated in general terms and is used by companies around the world, regardless of sector.

Transparency is promoted by setting clear reporting requirements on the approach to defining organizational system boundaries, the calculation of Scope 2 emissions, the methodological approach and the indicators. However, transparency is limited by the lack of reporting requirements on the selection of characterisation factors. The credibility of the results is also restricted, as there are no mandatory requirements for conducting an uncertainty assessment or an external validation. The GHG Protocol Corporate is highly relevant due to its widespread distribution and use by many companies, but the existing gaps, particularly in the comparability and credibility of the results, mean that the standard is only rated as moderately suitable in terms of the required "must-have" indicators, because there are still shortcomings, particularly with regard to the comparability and reliability of the accounting results.

ITU-T L.1420 (02/2012)

This is an independent standard for the methodological approach and reporting of an ICT company's GHG emissions. The standard is based on the GHG Protocol Corporate in many respects (e.g. definition of organizational boundaries), but differs in others (e.g. requirements for Scope 2 calculation). The standard explicitly states that it can be used as a supplement to the GHG Protocol with a focus on ICT organizations. Similar to the GHG Protocol, the comparability when using the same standard is rated as medium.

In terms of transparency, it is considered positive that the IPCC version used to select the characterisation factors and the approach used to define the organizational system boundaries are to be reported. However, the standard has gaps compared to the GHG Protocol Corporate, in particular with regard to the reporting requirements for the metrics and the specification of the calculation of Scope 2 emissions. The reliability of the results is assessed as medium, as an uncertainty assessment is mandatory compared to the GHG Protocol Corporate, but there is no external validation of the results. An analysis of the available evaluation aspects shows a medium suitability with regard to the required must-have indicators indicators. In contrast to the GHG Protocol Corporate, the requirements are ICT specific and therefore more focused on the needs of the telecommunications sector. However, it does not specifically address network related activities. Furthermore, there is so far only limited publicly accessible evidence demonstrating that companies are making practical use of ITU-T L.1420 (see Annex VI).

Explanations on the suitability of the standards in GHG Group 2: Scope 3

GHG Protocol Corporate Accounting and Reporting Standard (2004)

The GHG Protocol Corporate can also be used as a guideline for the methodology and reporting of an organization's GHG emissions for Scope 3. However, the basic standard is formulated in general terms and provides little guidance on data collection and calculation of Scope 3 emissions. Due to the general approach, there are many degrees of freedom in the methodological execution of the calculations, which is why the comparability of GHG-calculations in the Scope 3 is considered to be low. However, transparency is promoted by the specification of clear reporting requirements regarding the definition of organizational system boundaries and the methodological approach. As there is no mandatory requirement to report Scope 3 emissions, transparency is severely limited in this case. The credibility of the results for Scope 3 results is low, as there are also no mandatory requirements to perform an uncertainty assessment or external validation for Scope 3. Taking all aspects into account, the suitability of the GHG Protocol Corporate as a sole standard for Scope 3 is low.

ITU-T L.1420 (02/2012)

In principle, ITU-T L.1420 can be used to calculate and report the Scope 3 emissions of an ICT company. Unlike the base standard of the GHG Protocol Corporate, ITU-T L.1420 explicitly addresses Scope 3 and mentions some ICT-specific aspects to be considered in Scope 3. However, overall comparability when the same standard is applied by different users is assessed as low (see Assessment of comparability within a standard). On the one hand, transparency is promoted by clear requirements for the documentation of organizational system boundaries and the methodological approach, but on the other hand, no concrete reporting requirements are given for the Scope 3 indicators. The credibility of the results for Scope 3 is low, because although an uncertainty assessment is mandatory compared to the GHG Protocol, no external validation of the results is required. The overall suitability of the standard is rated as low. Although there is an ICT specific focus in the Scope 3 categories, overall the comparability of the results cannot be guaranteed, nor are there sufficient requirements for the credibility and transparent presentation of the results.

Protocol Corporate (Value Chain) Standard (2011)

The GHG Protocol Corporate (Value Chain) Standard (2011) is an extension of the GHG Protocol Basic Standard for Scope 3. This non-ICT-specific guideline provides detailed instructions for calculating and reporting GHG emissions for the 15 Scope 3 activity categories. As with the GHG Protocol Basic Standard, the frame of reference is the organization – no technology-specific delineation of ICT systems is provided. Although the comparability of GHG-results when using this standard is better than the standards focusing on Scopes 1 and 2, it is still only rated as medium. On the one hand, the credibility of the results is limited as there is no requirement for external validation. On the other hand, the required assessment of data quality enhances the credibility of the results. This standard has clear advantages in terms of transparency, as both the indicators and the methodological approach must be presented in the results report. Due to the lack of a specification for telecommunication networks and the limited comparability and credibility of the results, the suitability of the GHG Protocol Corporate (Value Chain) Standard (2011) is rated as medium.

Scope 3 Guidance for Telecommunication Operators (2023)

This Scope 3 guidance, adapted by ITU as a supplement to ITU L.1420, is **specifically designed for telecommunications network operators**. It provides guidance on how to calculate ICT-specific greenhouse gas emissions for each Scope 3 category. Due to the detailed description of the relevant Scope 3 categories, the results generated by this methodology are highly comparable. However, the comparability assumptions assume that all users consistently apply the same methodologies per category according to the specified prioritisation. In practice, this complete consistency of methodology is almost impossible to achieve due to the complexity and scope of the categories. For each Scope 3 category, the guideline provides several calculation methods along with corresponding indications of accuracy. In particular, the following **Scope 3 categories** are highlighted as material for telecom companies and should be prioritised:

- Category 1: Purchased goods and services
- Category 2: Capital goods
- Category 3: Fuel and energy-related emissions (not included in Scope 1 / 2)
- Category 8 / Category 13: Upstream / Downstream leased assets
- Category 11: Use of sold products
- Category 15: Investments (depending on consolidation approach and business model).

As these categories are often difficult to quantify, it is up to the user to decide which method to use for each category, depending on its practicality. According to one network operator interviewed in the stakeholder survey, category 11 is perceived irrelevant for network infrastructure as it mainly concerns the Business-to-Consumer (B2C) area, such as routers sold to end users.

The credibility of the Scope 3 results is limited, since an uncertainty assessment must be carried out, but external validation of the results is not required. Transparency is rated as high, as detailed documentation of the methodology, indicators and emission factors (EFs) used must be provided for each category. In summary, the suitability of this standard is rated as high, despite the deficiencies in credibility. The suitability of the standard could be further improved by adjusting the requirements for the validation of results.

3.4 Comparative analysis of the standards in the circular economy category

3.4.1 Overview of the selected standards

The six standards selected were divided into two groups (see Table 3-11). Group 1 includes the standards that deal with aspects of the circular economy before use. Group 2 includes all standards that relate to aspects of the circular economy at the *end of life* (EoL).

Table 3-11: Grouping of circular economy standards

Group	Group	Abbreviation	Name
Group 1	Circular economy: Aspects before use	(ETSI TR 103 476 V1.1.2 (2018-02))	Environmental Engineering (EE); Circular Economy (CE) in Information and Communication Technology (ICT); Definition of approaches, concepts and metrics
		(DIN EN 45556:2020-03)	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
		(DIN EN 45557:2020-09)	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
Group 2	Circular economy: Aspects EoL	(GRI 306)	Waste 2020
		(ETSI EN 305 174-8 V1.1.1 (2018-01))	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)
		(ETSI TS 105 174-8 V1.2.1 (2019-12))	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

Source: Own compilation

3.4.2 Comparability of results when applying the same standard

Table 3-12 provides an overview of the comparability of results when applying the same standard. This comparability examines whether different users of the same standard achieve comparable results.

Table 3-12: Circular economy: overview of comparability of results when applying the same standard

Group	Standards	Comparability when applying the same standards
Before use	ETSI TR 103 476 V1.1.2 (2018-02)	low
	DIN EN 45556 (2020)	medium
	DIN EN 45557 (2020)	medium
End-of-Life (EoL)	GRI 306	medium
	ETSI EN 305 174-8 V1.1.1 (2018-01)	medium
	ETSI TS 105 174-8 V1.2.1 (2019-12)	medium

Source: Own compilation

The basis for the evaluation is in Annex IX.a. Annex IX.b contains detailed tables with the results for standards in the circular economy category, which form the basis for the evaluations presented below. Annex IX.c provides an overview of the evaluation results according to the three-level model, represented by green, yellow, and red dots.

Explanations on comparability of results when applying the same standard in the "Before use" group

ETSI TR 103 476 V1.1.2 (2018-02)

The comparability when applying the same standard is rated as low. This is due to the lack of information regarding data collection and processing, which significantly reduces the robustness and reproducibility of the results for the proposed indicators. Furthermore, no reference period is defined.

DIN EN 45556 (2020)

The comparability when applying the same standard is classified as medium. This results from existing specifications regarding the specificity of the central input parameters and the reference period for data collection, which must be representative of the production volume. This results in comparatively good robustness and reproducibility of the results.

DIN EN 45557 (2020)

The comparability when applying the same standard is classified as medium. This results on the one hand from relatively clearly described specifications regarding the specificity of the central input parameters and the reference period for data collection, which must be representative of the production volume and reflect the recent data. This results in comparatively good robustness and reproducibility of the results. On the other hand, the lack of specifications for the recording methodology (e.g. origin of the central recording parameters) has a negative impact on comparability.

Explanations on comparability when applying the same standard in the "End-of-Life" group

GRI 306

The comparability when applying the standard is classified as medium, as although specific data is to be used to calculate the indicator (weight of e-waste generation), no reference period is defined and different sources (modeling, direct measurement) are possible. These can lead to different results for the e-waste indicator. There is also leeway in the breakdown of data by waste type, as no fixed key is prescribed. The reporting organization should provide information on the type of data collection and can thus increase reproducibility.

ETSI EN 305 174-8 V1.1.1 (2018-01)

The comparability when applying the standard is classified as medium, as specific data is to be used, but WEEE flows can be both measured and estimated and no reference period is defined. In addition, input parameters ("WEEE prepared for reuse") for the calculation formula of the "weight of e-waste" indicator are not sufficiently clearly defined, meaning that the application of the standard may lead to different allocations of waste streams and consequently different results. The lack of reporting requirements limits reproducibility.

ETSI TS 105 174-8 V1.2.1 (2019-12)

The comparability when applying the standard is classified as medium. This Technical Specification (TS) serves as supplementary documentation to support and refine the requirements of ETSI EN 305 174-8. In contrast to the EN, the EoL aspects (end-of-life aspects) are extended in the TS to include the treatment of components and sub-assemblies that have been replaced in the course of maintenance measures. However, the focus of this study is on the must-have indicators at product level, not at component level. The calculation of the indicators is based on ETSI EN 305 174-8 and requires specific data. The definition of the input parameter "WEEE prepared for reuse" remains unclear, as already stated in ETSI EN 305 174-8. In contrast to ETSI EN 305 174-8, which does not specify a fixed reference period for data collection, the TS specifies a one-year reporting period. The lack of requirements for the representativeness of this period makes it difficult to compare the indicators between different users, as different operating contexts and product life cycles are not taken into account. The reporting is structured differently according to recycler and other actors. However, the lack of specifications for documenting the data collection methods and the origin of the data limits the reproducibility of the indicators.

3.4.3 Comparability of results when applying different standards

The differences and similarities between the standards are outlined below. The standards were only compared within the same group based on their scope. In Table 7-32 and Table 7-33 in Annex IX.b, the similarities and differences between the standards per assessment aspect can be viewed in detail.

3.4.3.1 Comparability of results when using different standards in group 1: Before use

It is not possible to compare the results with regard to the must-have indicators at the product level required by the JRC, as this is not consistently addressed in the three standards under consideration. At component level, it is possible to compare the "proportion of re-used parts" specified in ETSI TR 103 476 with the "reused components" defined in DIN EN 45556. However, as these are defined at component level, no further analysis is carried out here. In addition, there is a similarity between the "recycled content of the product" mentioned in ETSI TR 103 476 and the "recycled material content" defined in DIN EN 45557 for pro-consumer and post-consumer level. However, due to the different levels of consideration (product versus component level), it is not possible to compare the results here.

3.4.3.2 Comparability of the results when applying different standards in Group 2: End-of-Life

The comparability of the results with regard to the must-have indicator "Weight of e-waste" is low between all standards. According to GRI 306, the weight of e-waste is not explicitly highlighted as a separate category, but falls under the general waste categories. In ETSI EN 305 174-8 V1.1.1 (2018-01) and ETSI TS 105 174-8 V1.2.1 (2019-12), the weight of e-waste is calculated as the sum of WEEE prepared for reuse, reused components, recycled WEEE, WEEE recovered for energy recovery and disposed WEEE. The figure is given in kilograms per year, although the definition of "prepared for reuse" remains unclear.

Similarly, the must-have indicator "weight of recycled products" is also difficult to compare between all standards. However, a positive aspect here is that all the standards considered are based on comparable definitions of recycling.

The results of the must-have indicator "Weight of refurbished products" are not comparable, as GRI 306 and ETSI EN 305 174-8 V1.1.1 (2018-01) include refurbishment in other recycling categories ("Preparation for reuse") and do not report it separately as an independent indicator. The must-have indicator "Number of refurbished products" is only mentioned in ETSI TS 105 174-8 V1.2.1 (2019-12).

The comparability of the results with regard to the must-have indicator "Weight of reused products" cannot be assessed, as GRI 306 does not contain this indicator and both ETSI EN 305 174-8 V1.1.1 (2018-01) and ETSI TS 105 174-8 V1.2.1 (2019-12) are unclear about the definition of the reuses that are named in the context of reuse ("prepared for reuse").

3.4.4 Overall assessment of suitability

Two further assessment criteria were included in the overall suitability assessment: credibility and transparency. The overall assessment of suitability for the standards examined can be seen in the following Table 3-13.

Table 3-13: Circular economy: overview of the overall suitability assessment

Group	Standards	Overall assessment of suitability
Before use	ETSI TR 103 476 V1.1.2 (2018-02)	low
	DIN EN 45556 (2020)	medium
	DIN EN 45557 (2020)	medium
End-of-Life (EoL)	GRI 306	low
	ETSI EN 305 174-8 V1.1.1 (2018-01)	low
	ETSI TS 105 174-8 V1.2.1 (2019-12)	medium

Source: Own compilation

Explanations on the suitability of the standards in the "Before use" group

ETSI TR 103 476 V1.1.2 (2018-02)

As a technical report, ETSI TR 103 476 V1.1.2 is only suitable as an introduction to the topic of circular economy and resource efficiency and is applicable to ICT infrastructure of all kinds. Indicators for the recycled content of products, i.e. the proportion of recycled material used in the product, are listed, with particular emphasis on the amount of recycled material in a product or packaging with reference to ISO 14021:1999. However, the must-have indicator "weight of recycled products" is not mentioned. The proportion of reused parts (components) in the total parts of the ICT infrastructure product under consideration is shown. However, it is not defined whether the proportion must be calculated in terms of mass or number. The indicator focuses on the component level, while the must-have indicator "weight of reused products" is not mentioned.

Comparability when applying the standard is rated as low. In addition, there are no requirements for validating and documenting the indicator results, which significantly limits their trustworthiness and transparency.

DIN EN 45556 (2020)

DIN EN 45556 is suitable as methodological guidance for calculating indicators for the proportion of reused components (by mass/number at product level, by mass balance and number balance). The indicator and the parameters used remain at the component level. The must-have indicator "weight of reused products" identified in the JRC study is not mentioned. The standard is therefore more suitable for the corresponding "should-have" indicator identified in the JRC study.

The comparability when applying the standard is classified as medium. Only medium requirements for the validation of the results and a lack of requirements for the assessment of uncertainties/data quality limit the trustworthiness. There is also leeway in reporting, which also reduces transparency.

DIN EN 45557 (2020)

DIN EN 45557 is suitable as a methodological guide for calculating indicators for pre-consumer material content and post-consumer material content. These indicators are calculated using the weight of recycled materials and components. The must-have indicator "weight of recycled products" identified in the JRC study is not addressed. The standard is therefore more suitable for the corresponding "should-have" indicator identified in the JRC study.

The comparability when applying the standard is classified as medium. However, only medium requirements for the validation of the results of the measurements and a lack of requirements for the assessment of uncertainties/data quality limit the trustworthiness. There is also leeway in reporting, which also reduces transparency.

Explanations on the suitability of the standards in the "End-of-Life" group

GRI 306

GRI 306 is suitable as methodological guidance for reporting waste volumes. The standard takes all sectors and waste into account and therefore covers both network components and infrastructure. The must-have indicators "weight of e-waste" and "weight of recycled products" identified in the JRC study are mentioned; the must-have indicator "weight of refurbished products" is listed as part of the category "other recovery operations". Calculation formulas are not given.

Comparability within the standard is classified as medium. Furthermore, flexibility remains in the breakdown of data by waste types, as no fixed classification is prescribed. The lack of specifications for validation and uncertainty assessment limits the credibility of the results. A special feature of the standard is the differentiation between waste generated on the one hand and waste handed over (for recovery) on the other, along with an indication of possible reasons for discrepancies between these two stages in the waste lifecycle. Users of the standard can report on the reasons for deviations in their results.

ETSI EN 305 174-8 V1.1.1 (2018-01)

ETSI EN 305 174-8 V1.1.1 (2018-01) is suitable as methodological guidance for the calculation of various indicators for WEEE from the ICT sector. The standard covers all types of WEEE from the ICT sector, without restriction to specific networks or technologies. The must-have indicators "weight of e-waste" and "weight of recycled e-waste" identified in the JRC study are mentioned. A calculation formula is provided for the "weight of e-waste," which comprises the sum of "WEEE prepared for reuse", "reused by parts", "WEEE recycled", "WEEE for energy recovery", and "WEEE for destroyed". The category "WEEE prepared for reuse" is not clearly defined. For example, it is unclear to what extent the metrik "weight of reused products" is included.

Comparability applying the standard is rated as medium. The lack of requirements for reporting on selected calculation methods limits the reproducibility, and the lack of requirements for uncertainty assessment and validation limits the credibility of the results. A special feature of the standard is the schematic representation of FAN and RAN, an overview table of WEEE in communication networks and the prioritisation of different WEEE recycling methods.

ETSI TS 105 174-8 V1.2.1 (2019-12)

ETSI TS 105 174-8 V1.2.1 (2019-12) is suitable as methodological guidance for the calculation of various indicators for WEEE from the ICT sector. The standard considers all types of WEEE from the ICT sector without restriction to specific networks or technologies. The standard builds on ETSI EN 305 174-8 V1.1.1 (2018-01), partially specifies it, and extends the target groups of the standard to all actors along the ICT lifecycle, including manufacturers, vendors, ICT users, maintenance companies, and recyclers. The metrics of must-have indicators "weight of e-waste" and "weight of recycled e-waste" identified in the JRC study are named with reference to ETSI EN 305 174-8 V1.1.1 (2018-01). For the category "WEEE prepared for reuse", the same ambiguities exist as for ETSI EN 305 174-8 V1.1.1 (2018-01).

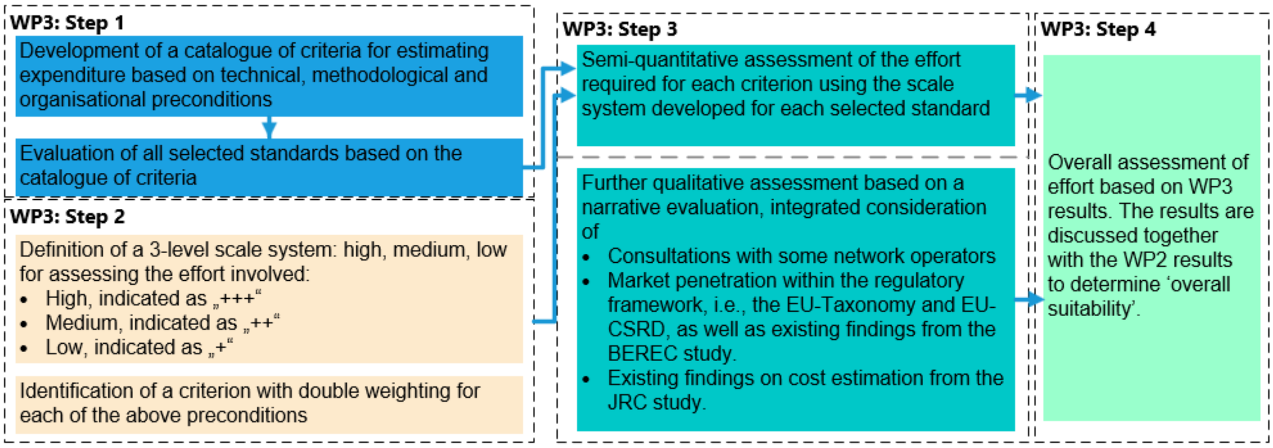
Comparability within the standard is rated as medium. The lack of requirements for reporting on selected calculation methods limits the reproducibility, and the lack of requirements for uncertainty assessment and validation limits the credibility of the results.

4 Effort in applying selected standards for all categories

4.1 Methodological approach for the effort estimation

A four-step procedure was developed and applied to determine the effort required to implement the standards examined (see Figure 4-1).

Figure 4-1: Overview of the methodological approach for the effort estimation



Source: Own compilation

In a first step, a list of criteria for the technical, methodological and organizational preconditions was developed for all categories (i.e. energy management, GHG emissions and circular economy).

In a second step, a 3-level scale system was developed for each defined criterion, which allows the respective effort to be classified into the levels "low", "medium" and "high". For each of the three above-mentioned preconditions, a criterion particularly relevant to the effort was selected, which is given double weighting during the evaluation..

For some standards, not all criteria could be evaluated, so certain criteria were marked as "n.d." (not determinable). In the overall assessment of the effort, a high effort ("+++" for single weighting; "++++++" for double weighting) was conservatively assumed for these criteria in order to avoid underestimating the effort. To determine the total effort from all criteria, the number of "+ " was converted into a percentage (low:≤ 33 %; medium: 33 %< x < 68 %; high:≥ 68 %). The double weighting and undeterminable criteria for individual standards were taken into account accordingly when calculating the total effort.

On this basis, the third step comprises a semi-quantitative assessment of the effort required for each selected standard. This is followed by a further qualitative assessment, which primarily integrates cost information obtained in the course of a stakeholder consultation with a few network operators[9]. However, there can be significant differences in costs between the one-time implementation and the ongoing fulfillment of a standard. Existing measuring equipment, trained personnel, but also experience in reporting and established data collection often significantly reduce the required time and effort. For this reason, particular attention was paid during the stakeholder consultation to differentiating between initial and recurring effort. In addition, aspects such asmarket penetration and existing findings on cost estimation from the JRC study were also included in the assessment.

Finally, in the fourth step, an overall assessment of the effort is made and the results are discussed with the results on overall suitability.

[9] Altogether, four responses were collected..

4.2 Assessment of market penetration

Market penetration is another important aspect when estimating the cost of implementing a standard.

A key indicator of market penetration is, for example, the incorporation of a standard into national laws as well as EU regulations, which are directly applicable at the national level, and/or EU directives, which require transposition into national law. In this context, reference is made to the analysis of the regulatory context in Chapter 1.5 .

In addition to the regulatory context, the results of the stakeholder survey (see above) were included in the assessment of market penetration. In particular, the question of the extent to which the four network operators surveyed are familiar with the standards examined and the extent to which they are already being used as part of existing compliance obligations was investigated. Due to the small sample size, the results of the stakeholder survey only represent approximate values and can be used to check the plausibility of further findings. They do not represent reliable results.

Finally, relevant information from the literature was also taken into account. This includes, in particular, (BEREC 2023), Annex I of which contains estimates of the frequency of application of the standards listed there in the environmental reporting of companies.

Against this background, the following aspects are examined in this study with a view to estimating market penetration and – where applicable or relevant – taken into account in the cost estimate:

- Are there normative references for the standard in the regulatory context?
- Is the standard known to potential users?
- How frequently is the standard applied in practice according to (BEREC 2023)?

4.3 Effort estimation for the implementation of standards in the energy management category

4.3.1 Results from the semi-quantitative effort estimation

The following Table 4-1 below describes the technical, methodological and organizational requirements and their explanation, which serve as the basis for the effort estimate. An estimate was made for the 15 energy management standards assessed by the study on the basis of the defined test criteria.

Table 4-1: Energy management: Basis for effort estimation taking into account technical, methodological, and organizational preconditions

Preconditions	Explanation
Technical preconditions	
Does the standard require technical measures such as direct measure-ments on site or the installation of measuring devices?	If own metering is required, it is assumed that a metering device, such as a meter, should be installed. If energy consumption is measured either directly on site or by the electricity supplier, it is assumed that the electricity supplier's meters are already installed so that no additional meters are required.
Is it necessary to collect data over a longer period of time?	Continuous data collection over a longer period of time increases the accuracy of the data, but requires more effort. This arises in particular when data has to be recorded and reported on a regular basis. Accordingly, the effort is assessed with **double** weighting
Methodological preconditions	
Do specific procedures / methodological guidelines need to be	For example, if a standard does not explicitly exclude shared infrastructure between different network operators and does not define clear allocation rules,

Preconditions	Explanation
developed for the application of the standard?	a further specification is required. Or if the standard does not define any measurement methods, such as the measurement period.
Are there methodological references / dependencies to other standards?	The assessment of the effort required to comply with standards is based on the number of necessary references that need to be taken into account. Understanding the often interlinked standards requires a considerable amount of time and resources, as standards often refer to other standards. In this context, the number of references serves only as an indicative guideline. Multi-level nested references increase the effort even further, but are not considered in this study. It should be noted that not all normative references of a standard are automatically included in the total number of references. Instead, it is examined whether the criteria analyzed in this study refer to further references. These references are then consolidated. Furthermore, the number of references does not necessarily reflect the scope of content of the respective reference. This requirement is therefore given **double** weighting, as the effort involved could possibly be underestimated.
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	A clearly structured report template and examples reduce the workload and at the same time ensure greater transparency.
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	The uncertainty assessment increases the reliability of the results, but involves additional effort.
Organizational preconditions	
Does compliance with the standard require cooperation between different business areas / organizational units?	The assessment of this precondition is based on the scope of a standard under consideration. If a standard takes into account the energy consumption of the infrastructure (e.g. air conditioning, UPS), cooperation with building management is assumed.
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	If shared sites operated by different network operators considered in a standard, cooperation with another network operator is assumed.
Does compliance with the standard require an audit or external review?	An external review increases the quality requirements but also entails additional effort, and was therefore given **double** weighting in this assessment. It represents an ongoing effort if annual reporting must be externally audited.

Source: Own compilation, bold text indicates criteria with double weighting

The summarized results of the effort estimation for the 15 energy-relevant standards examined are presented in Table 4-2. The results show that most of the standards were classified as "medium" in terms of the effort involved in their application. Standards with low effort have flexible measurement periods and low methodological dependencies, while nested references increase the time required. It should be noted that the effort for scaling from the sub-network to the overall network is not assessed in the ETSI ES 203 228 standard, as it depends heavily on the practical implementation and is therefore difficult to assess. No standard prescribes external verification as a requirement. Details on the assessment of the effort involved in applying the respective standards in accordance with the 3-level assessment criteria can be found in Annex X.

Table 4-2: Summary of the results from the semi-quantitative assessment of the effort estimation for standards in the energy management category

Network segment	Standards	Effort estimation
RAN: 2G/3G/4G	ETSI EN 303 472 V1.1.1 (2018-10)	medium
RAN: technology-independent	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	low
RAN: technology-independent	ETSI TR 103 540 V1.1.1 (2018-04)	low
RAN: technology-independent	ITU-T L.1350 (10/2016)	medium
RAN: technology-independent	ITU-T L.1351 (08/2018)	medium
RAN: technology-independent	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	medium
RAN: technology-independent	ETSI TS 105 200-2-3 V1.2.1 (2019-12)	medium
FAN: technology-independent	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	medium
FAN: technology-independent	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	medium
CAN: technology-independent	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	low
5G mobile network: RAN, core network, end-to-end, NFV, slicing	ETSI TS 128 554 V18.7.0 (2024-10)	medium
ICT location: Core network	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	medium
ICT location: Core network	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	medium
ICT location: entire network	ITU-T L.1332 (01/2018)	medium
Entire access network: NFV	ETSI EN 303 471 V1.1.1 (2019-01)	medium

Source: Own compilation

4.3.2 Findings from interviewing individual stakeholder

For energy management, the stakeholder survey led to the conclusion that the fulfillment of the standards under consideration causes considerable costs in some cases. This applies in particular to the initial expenditure, which is characterized by high personnel and material costs. Personnel costs arise primarily due to the fact that it is not yet possible to read the metering equipment automatically. One reason cited for this is the combination of old and new technology used and the lack of reception in some cases. The purchase of meters and their digital integration into the existing IT infrastructure also causes high material costs. Estimates of the stakeholders surveyed for the initial outlay amount to more than 1% of the total investment costs (capital expenditure - CAPEX). Even for SMEs, this could result in costs in the order of around EUR 1 million; in addition, 1-2 full-time employees would have to be hired. However, as soon as the infrastructure for measurement is established or automated, the costs should be reduced by a factor of 10 and amount to less than 0.1% of CAPEX.

4.3.3 Conclusion of the effort estimation of the category energy management

The following Table 4-3 summarizes the results of the effort estimation. In addition to the semi-quantitative assessment of the effort required to apply the standards, an indicative estimate of current market penetration as well as the results of interviewing individual stakeholder are also provided.

Table 4-3: Overview of the results of the effort estimation in the energy management category

Network segment	Standards	Semi-quantitative evaluation	Market penetration penetration	Interviwes with individual stakeholders
RAN: 2G/3G/4G	ETSI EN 303 472 V1.1.1 (2018-10)	medium	• None of these standards are mentioned in the taxonomy or the CSRD. • Survey: Network operators are partially aware of the ETSI standards, but there is no evidence of their practical application • BEREC study (BEREC 2023): ETSI EN 303 472 and ETSI ES 203 228 were used by some network operators	• Initial expenditure: more than 1% of CAPEX, • Subsequently expected <0.1% CAPEX
RAN: technology-independent	ETSI ES 203 228 V1.4.1 (2022-04)/ITU-T L.1331	low		
RAN: technology-independent	ETSI TR 103 540 V1.1.1 (2018-04)	low		
RAN: technology-independent	ITU-T L.1350 (10/2016)	medium		
RAN: technology-independent	ITU-T L.1351 (08/2018)	medium		
RAN: technology-independent	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	medium		
RAN: technology-independent	ETSI TS 105 200-2-3 V1.2.1 (2019-12)	medium		
FAN: technology-independent	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	medium		
FAN: technology-independent	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	medium		
CAN: technology-independent	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	low		
5G mobile network: RAN, core network, end-to-end, NFV, slicing	ETSI TS 128 554 V18.7.0 (2024-10)	medium		
ICT location: Core network	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	medium		
ICT location: Core network	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	medium		
ICT location: entire network	ITU-T L.1332 (01/2018)	medium		
Entire access network: NFV	ETSI EN 303 471 V1.1.1 (2019-01)	medium		

Source: Own compilation

4.4 Effort estimation for the implementation of standards in the GHG emissions category

4.4.1 Results from the semi-quantitative effort estimation

The determination of the effort required to apply the standards in the GHG emissions category was based on an analysis of criteria that were formulated as key questions. These criteria included the technical, methodological and organizational preconditions that are linked to GHG accounting and reporting by the respective standards. The preconditions are presented and explained in Table 4-4.

Table 4-4: GHG: Basis for effort estimation taking into account technical, methodological, and organizational preconditions

Preconditions	Explanation
Technical preconditions	
Is special modeling software required?	The effort required to prepare a GHG report depends largely on the availability of software that can be used to structure and correlate the collected data in order to subsequently determine the GHG impact of the activities in the respective scopes. The question relates to the requirement of a standard to create or procure special software and is therefore assessed using **double** weighting.
Methodological preconditions	
Do specific procedures / methodological guidelines need to be developed for the application of the standard?	The effort required to prepare a GHG report for the first time can be higher, as there are no established procedures for data collection ("learning curve"). If a standard only specifies a few requirements in this regard, the effort required to prepare such requirements independently is higher.
Are there methodological references / dependencies to other standards?	Cross-references to other standards that must be complied with increase the workload for users (standards must be procured, read and implemented in addition to the GHG standard).
How much effort is required to determine Scope 1 / Scope 2 emissions? Only for evaluation of Scopes 1&2	The level of detail and scope of data collection for Scope 1&2 required by the analyzed standard is considered here. Detailed instructions for data collection are seen as a contribution to reducing the workload. It should be noted that the assessment criteria of the comparability analysis are generally associated with greater effort in terms of robustness, reproducibility and transparency. This aspect is therefore assessed using **double** weighting.
How much effort is required to determine Scope 3 emissions? Only for Scope 3 evaluation	See above. It should also be noted that the effort required to determine Scope 3 is generally significantly higher than for Scope 1&2, which is not taken into account when assessing the effort required to apply a standard. It is only a question of whether a standard helps to reduce the effort (e.g. through detailed and ICT-specific instructions). This aspect is therefore assessed using **double** weighting.
Is a template provided for the reports? And is an example included to illustrate the results of the reporting?	A report template can relieve users of a standard of much of the work involved in creating their own report structure and is therefore seen as reducing the workload.
Is an uncertainty assessment/data quality assessment required? And is an example provided to assess the uncertainty?	The requirement for an uncertainty assessment increases the evaluation of robustness, reproducibility and transparency. However, this is an additional work step that is associated with increased effort. Templates and examples can help to minimize this additional effort.
Organizational preconditions	
Does compliance with the standard require cooperation between different business areas / organizational units?	The interaction of different areas of a company (e.g. technology, procurement, controlling) to determine the GHG-relevant activities requires an increased communication effort. A standard can influence this aspect if detailed specifications or instructions are provided.
Does compliance with the standard require cooperation with external stakeholders (e.g. suppliers, customers)?	This aspect is assessed using **double** weighting,because external communication requires increased communication effort and more data processing.

	A standard can influence this aspect if detailed specifications or instructions are given.
Does compliance with the standard require an audit or external review?	The external review of GHG reporting is an additional work step and cost factor, but it has a positive effect on the assessment criteria of comparability (reproducibility and transparency).

Source: Own compilation, bold text indicates criteria with double weighting

The following Table 4-5 shows the summarized estimate of the effort for the GHG-related standards for the two groups "Scopes 1 & 2" and "Scope 3".

Table 4-5: Summary of the results from the semi-quantitative assessment of the effort estimation for standards in the GHG category

Group	Standards	Effort estimation
Group 1 (Scopes 1&2)	GHG Protocol Corporate Accounting and Reporting Standard (2004), Amendment with Scope 2 Guidance (2015)	medium
	ITU-T L.1420 (02/2012)	high
Group 2 (Scope 3)	GHG Protocol Corporate Accounting and Reporting Standard (2004),	medium
	ITU-T L.1420 (02/2012)	high
	Protocol Corporate (Value Chain) Standard (2011)	medium
	Scope 3 Guidance for Telecommunication Operators	medium

Source: Own compilation

Details on the assessment of the effort involved in applying the respective standards according to the 3-level assessment criteria can be found in Annex XI. The assessment that the effort involved in applying the ITU-T L.1420 standard in Scope 1 & 2 is high is primarily due to the mandatory requirement for an uncertainty assessment or quantified data quality assessment. In addition, the methodology to be applied is dependent on other standards, which must therefore also be procured and implemented. For Scope 3, the effort required for ITU-T L.1420 is considered high due to the lack of specific methodological guidelines for the Scope 3 categories. .

4.4.2 Findings from interviewing individual stakeholders

In the "GHG emissions" category, interviewing individual stakeholder revealed that compliance with the standards under consideration could be associated with considerable costs in some cases.

As with energy management, this applies above all to the initial outlay, which is characterized by high personnel and material costs. Personnel costs arise primarily due to the fact that a large amount of raw data on individual locations and activities has to be collected for the GHG data analysis in the core and connection network and then manually aggregated, consolidated and analyzed. This is the case, at least in the introductory phase, if there is no systematic or automated structure for data collection. In addition, there are usually no technical measuring points for emissions or energy consumption points at the beginning. The purchase and installation of electricity meters and their digital integration into the existing IT infrastructure also entails high investment costs. Estimates from the stakeholders surveyed for the initial outlay amount to 1 - 5 % of the total investment costs (CAPEX). As soon as the infrastructure for metering is established or automated, however, the costs should be reduced by a factor of 10.

When asked about the main cost drivers for the effort, the stakeholders primarily named data collection for Scope 3 (in accordance with the GHG Protocol), which accounts for around two thirds of the costs, while the remaining third is attributable to Scope 1 and Scope 2. A large part of the costs would be caused by upgrading the ESG software in order to be able to convert the recorded consumption into GHG emissions using conversion factors from various databases. However, the primary benefit of the upgraded ESG software would be to ensure compliance with the CSRD. In addition, communication with suppliers and customers to determine the GHG potential of the relevant Scope 3 can take a considerable amount of time and therefore involve personnel costs. It is described as difficult to obtain manufacturer data on the CO_2e of purchased goods. There is an increased need for communication, particularly in the introductory phase, which can only be partially automated so far. A materiality analysis carried out in advance helps to identify the relevant categories. Although this in turn requires additional effort, the results of the analysis can be used to focus data collection afterwards and thus plan efficiently. One interviewee reported that no extra effort is required to collect data on activities in categories 3.1, 3.2, 3.3 and possibly 3.15, as this data is already available in the accounting system. The further conversion steps in Scope 3 emissions can in principle be automated with suitable software and databases for emission factors. However, other stakeholders surveyed reported that specific product-related emission factors are hardly available to date.

4.4.3 Conclusion of the effort estimation in the GHG category

The results of the effort estimation are aggregated in the following Table 4-6.

Table 4-6: Overview of the results of the effort estimation in the GHG category

Group	Standards	Semi-quantitativ evaluation	Market penetration	Surveying individual stakeholders
Group 1 (Scopes 1&2)	GHG Protocol Corporate Accounting and Reporting Standard (2004), Amendment with Scope 2 Guidance (2015)	medium	high	• Initial expenditure: approx. 1-5% of CAPEX, • Subsequently expected <0.1% CAPEX
	ITU-T L.1420 (02/2012)	high	low	
Group 2 (Scope 3)	GHG Protocol Corporate Accounting and Reporting Standard (2004)	medium	medium	
	ITU-T L.1420 (02/2012)	high	low	
	Protocol Corporate (Value Chain) Standard (2011)	medium	medium	
	Scope 3 Guidance for Telecommunication Operators (2023)	medium	low*	

Source: Own presentation, *Note: This guidance, also published as Supplement 57 to ITU-T L.1420, was only mentioned in individual cases as a methodological basis in the GHG reports of relevant TC companies. However, this does not mean that it is not applied at all. An empirically verified statement is therefore not possible within the scope of this study.

The results show that the introduction of GHG reporting at company level could represent a not inconsiderable effort for companies. This is mainly due to the nature of the task of collecting and aggregating the relevant activity data and calculating GHG figures from it. In this context, there is above all an increased communication effort, both within the company and with external stakeholders such as suppliers and customers. The effort involved also depends on the choice of standard or guideline. However, the particularly time-consuming work steps involved in GHG accounting result primarily from the complexity of the data collection itself and less from the choice of method defined in the respective standard. This applies in particular to Scope 3, which requires extensive data collection in 15 activity categories. For this reason, the effort involved in Scope 3 is estimated to be higher than for Scopes 1+2 anyway, regardless of the standard used. However, the Scope 3 Guidelines in particular help to reduce the effort involved by providing detailed methodological guidance as well as guidance on prioritizing the materiality of activities.

The market penetration of the GHG Protocol Corporate Accounting and Reporting Standard is very high, as it is used by many companies in various industrial sectors worldwide. In the standard, reporting covers Scopes 1&2 and increasingly also Scope 3, which has a high GHG relevance in the telecommunications sector. The specific Scope 3 Guidance for Telecommunication Operators has not yet been comprehensively adapted, especially as it is a relatively new guideline (2023). However, no robust empirical survey on the frequency of application of standards was carried out as part of this study.

4.5 Effort estimation for the implementation of standards in the circular economy category

4.5.1 Results from the semi-quantitative effort estimation

In principle, a largely comparable list of criteria was used to estimate the costs in the "circular economy" category as for the "energy management" category (see Table 4-1). However, adjustments had to be made to the technical preconditions and the following criteria defined, with a double weighting for the first criterion:

- Does the standard provide for primary data collection?
- Is it necessary to collect data over a longer period of time?
- Is special modeling software required?

The criteria for the methodological preconditions, on the other hand, were adopted unchanged from the "Energy management" category. Instead of the second criterion, however, the first criterion was given double weighting. The reason for this is that the standards in the "Circular economy" category are not specific to the network infrastructure and therefore the development of specific procedures or methodological guidelines requires a particularly high level of effort. For the organizational preconditions, both the criteria and the weightings applied remained unchanged.

The following table contains the summarized assessment of the effort for the standards of the two groups "Before use" and "End-of-life" of the category "Circular economy". An overview of the definitions for the assessment criteria used and their assignment to a 3-level scale system can be found in Table 7-46 in Annex XII.

Table 4-7: Summary of the results from the semi-quantitative assessment of the effort estimation for standards in the circular economy category

Group	Standards	Effort estimation
Before use	ETSI TR 103 476 V1.1.2 (2018-02)	medium
	DIN EN 45556 (2020)	medium
	DIN EN 45557 (2020)	medium
End-of-Life (EoL)	GRI 306	low
	ETSI EN 305 174-8 V1.1.1 (2018-01)	low
	ETSI TS 105 174-8 V1.2.1 (2019-12)	low

Source: Own compilation

Details on the assessment of the effort involved in applying the respective standards in accordance with the 3-level assessment criteria can be found in Annex XII.

4.5.2 Findings from the stakeholder interviews

When interviewing stakeholders, it was unfortunately not possible to back up the results of the semi-quantitative cost estimate in the "Circular economy" category with concrete cost information regarding personnel and material costs.

Most of the stakeholders surveyed stated that it is not currently possible to estimate the costs quantitatively and that it is therefore not possible to classify the total costs in relation to the investment costs (CAPEX) and operating costs (OPEX).

In principle, recording and reporting would only be practicable in the future if suppliers were to provide corresponding information on the individual indicators. The product inventories of existing ERP (Enterprise Resource Planning) databases would also have to be supplemented with additional fields, e.g. to be able to collect information on whether the product is "refurbished". Additional personnel costs (mainly in the form of training requirements) would also be incurred in the purchasing departments of companies.

4.5.3 Conclusion of the effort estimation in the category circular economy

The following table summarizes the results of the effort estimation. With regard to the market penetration of the standards examined, it can be stated that there are no normative references in the regulatory environment and that these are not known to the stakeholders surveyed. For these reasons, it can be assumed that most of the standards examined are not currently applied in practice. One exception is GRI 306, which was mentioned by at least eight of the 81 companies surveyed in the BEREC questionnaire (2023) in connection with environmental reporting. Overall, the market penetration of the standards in the "circular economy" category is therefore classified as low. With regard to the possibilities for quantifying the effort with information from the stakeholder survey, please refer to chapter 0 .

Table 4-8: Overview of the results of the effort estimation in the circular economy category

Group	Standards	Semi-quantitative evaluation	Market penetration	Stakeholder interviews
Before use	ETSI TR 103 476 V1.1.2 (2018-02)	medium	• No normative references • Standards are largely unknown • Hardly used in practice (exception GRI 306)	Expenditure Currently not quantifiable
	DIN EN 45556 (2020)	medium		
	DIN EN 45557 (2020)	medium		
End-of-Life (EoL)	GRI 306	low		
	ETSI EN 305 174-8 V1.1.1 (2018-01)	low		
	ETSI TS 105 174-8 V1.2.1 (2019-12)	low		

Source: Own compilation

5 Overview of results

5.1 Energy management

The energy-relevant standards examined in the study are suitable for internal company trend analyses, but less suitable for comparisons or for aggregating the measurement results into a meaningful data basis between grid operators. Table 5-1 is an overview of the results and shows the low comparability and limited suitability.

One exception is the ETSI EN 303 472 standard, whose comparability of results is classified as high due to clear specifications on measurement processes and data collection. In addition, the detailed reporting requirements provide a solid basis for assessing comparability. The suitability of ETSI ES 203 228 is also rated as high due to such specifications.

As a general rule, if the comparability of the results of the measurements is limited when a standard is applied, the comparability of the measurement results of the standard is also not guaranteed. Overall, the limited comparability is due to different indicators, variations in the data collection methods (measurement period, measurement frequency, measurement points) and different delimitations (split locations, inclusion of infrastructure), which can lead to different measurement results.

The main similarities between the standards are the inclusion of locally generated renewable energy in the energy balance, regardless of whether this is shown as a separate indicator. In addition, continuous real-time measurement of energy consumption is preferred and environmental conditions such as temperature or load profiles are regarded as variable influencing factors that affect energy consumption and energy efficiency. The flexibility of the standards' requirements is often due to practicality, as it is often impractical or too costly for operators to fully record network consumption. Many standards apply exclusively to sites operated by a single network operator and exclude shared infrastructure in the application. However, infrastructure sharing has considerable potential for cost savings and is increasingly being used by network operators. Shared infrastructure between different network operators requires clear allocation rules. Where standards specify allocation rules, the parameters vary, e.g. RF power for RAN, energy costs or agreements that network operators define through commercial regulations or best practice. Only a few standards that are relevant for statistical calculations contain specifications for uncertainty assessment. Requirements for internal or external validation are missing in all standards.

The initial and ongoing effort of most standards is classified as medium, although this assessment is indicative. Standards with low effort are characterized by flexible measurement periods and low methodological dependencies on other references. In contrast, nested and interlinked references increase the time required considerably. Feedback from network operators confirms that the initial costs for implementing the standards are very high. Established, standardized routines could reduce these costs in the long term.

In the regulatory environment, none of the 15 energy-relevant standards examined are mentioned in the EU taxonomy or the CSRD. The survey revealed that there is no evidence of practical application of the standards. According to the BEREC study (BEREC 2023), the ETSI EN 303 472 and ETSI ES 203 228 standards were used by some network operators.

Table 5-1: Overview of the overall results: Energy management

Network segment	Standards	Comparability when using the same standard	Suitability	Effort estimation: Semi-quantitative	Market penetration penetration	Stakeholder interviews
RAN: 2G/3G/4G	ETSI EN 303 472 V1.1.1 (2018-10)	**high**	**high**	medium	• None of these standards are mentioned in the taxonomy or the CSRD. • Survey: Network operators are partially aware of the ETSI standards, but there is no evidence of their practical application • BEREC study (BEREC 2023): ETSI EN 303 472 and ETSI ES 203 228 were used by some network operators	-Initial expenditure: more than 1% of CAPEX, - Subsequently probably <0.1% CAPEX
RAN: technology-independent	ETSI ES 203 228 V1.4.1 (2022-04) / ITU-T L.1331	medium	**high**	low		
RAN: technology-independent	ETSI TR 103 540 V1.1.1 (2018-04)	low	medium	low		
RAN: technology-independent	ITU-T L.1350 (10/2016)	low	low	medium		
RAN: technology-independent	ITU-T L.1351 (08/2018)	low	low	medium		
RAN: technology-independent	ETSI EN 305 200-2-3 V1.1.1 (2018-06)	medium	medium	medium		
RAN: technology-independent	ETSI TS 105 200-2-3 V1.2.1 (2019-12)	medium	medium	medium		
FAN: technology-independent	ETSI EN 305 200-2-2 V1.2.1 (2018-08)	medium	medium	medium		
FAN: technology-independent	ETSI TS 105 200-2-2 V1.3.1 (2019-12)	medium	medium	medium		
CAN: technology-independent	ETSI ES 205 200-2-4 V1.1.1 (2015-06)	low	low	low		
5G mobile network: RAN, core network, end-to-end, NFV, slicing	ETSI TS 128 554 V18.7.0 (2024-10)	low	low	medium		
ICT location: Core network	ETSI EN 305 200-3-1 V1.1.1 (2018-02)	medium	medium	medium		
ICT location: Core network	ETSI TS 105 200-3-1 V1.2.1 (2019-12)	medium	medium	medium		
ICT location: entire network	ITU-T L.1332 (01/2018)	low	low	medium		
Entire access network: NFV	ETSI EN 303 471 V1.1.1 (2019-01)	medium	medium	medium		

Source: Own compilation

5.2 Greenhouse gas emissions

The evaluation of the GHG-related standards shows that the comparability of the results of the calculations when applying a standard for Scope 1 and 2 can be classified as low to medium (see Table 5 2), as both relevant standards have a relatively high degree of freedom with regard to the procedure for primary data collection and the definition of allocation rules. The suitability of the two standards under consideration for Scope 1 & 2 is therefore medium.

In principle, this also applies to Scope 3 (see Table 5-2): Here, too, the degree of freedom in primary data collection and allocation rules is high for three of the standards considered, or there are no specific guidelines. Only the Scope 3 Guidance for Telecommunication Operators offers concrete and sector-specific instructions here. The comparability of this standard is therefore rated as high. Furthermore, its suitability for Scope 3 is also rated as high overall, as the GSMA Guidance contains binding requirements for the disclosure of the indicators and assumptions used. This benefits the credibility and transparency of the GHG reports based on them. However, none of the standards considered require an obligation for independent external validation, although this is seen as a prerequisite for trustworthiness in practice.

Table 5-2: Overview of the overall results: THG

<table>
<tr><th>THG-groups</th><th>Standards</th><th>Comparability of GHG balance applying the same standard</th><th>Suitability</th><th>Cost estimate</th><th>Market penetration penetration</th><th>Interviews wth individual stakeholders</th></tr>
<tr><td rowspan="2">Scope 1 & Scope 2</td><td>GHG Protocol Corporate Accounting and Reporting Standard (2004) & Scope 2 Guidance</td><td>low</td><td>medium</td><td>medium</td><td rowspan="6">• GHG Protocol Corporate: high due to CSRD and practical application (sustainability reports of network operators) (Annex VI)
• ITU 1420 and GSMA: was used by two network operators (Annex VI)</td><td rowspan="6">• Initial expenditure: approx. 1-5% of CAPEX,
• subsequently expected <0.1% CAPEX</td></tr>
<tr><td>ITU-T L.1420 (02/2012)</td><td>medium</td><td>medium</td><td>high</td></tr>
<tr><td rowspan="4">Scope 3</td><td>GHG Protocol Corporate Accounting and Reporting Standard (2004)</td><td>low</td><td>low</td><td>medium</td></tr>
<tr><td>ITU-T L.1420 (02/2012)</td><td>low</td><td>low</td><td>high</td></tr>
<tr><td>Protocol Corporate (Value Chain) Standard (2011)</td><td>medium</td><td>low</td><td>medium</td></tr>
<tr><td>GSMA Scope 3 Guidance for Telecommunication Operators</td><td>high</td><td>high</td><td>medium</td></tr>
</table>

Source: Own compilation

In summary, it can be stated that the GHG Protocol Corporate Accounting and Reporting Standard (2004) including the Scope 2 Amendment (2015) is the most suitable in practice, despite the limited comparability of the GHG reports based on it. This is because this standard is the most widely used worldwide and its methodology is widely known and widely accepted by companies, stakeholders and government bodies. In addition, its application within the EU is already mandatory for companies above a certain size due to the regulatory stipulation in the CSRD. The additional effort required for its application is therefore classified as medium. The application of ITU-T L.1420, on the other hand, is associated with a comparatively higher effort, as this standard provides for a mandatory data quality assessment for Scopes 1&2.

Scope 3 typically requires significantly more effort than Scopes 1&2, as the extent of data collection and evaluation in its 15 categories is many times greater. This applies regardless of the underlying standard. However, the GSMA guidance already shows a prioritization of the materiality of certain categories for the telecommunications sector, so that at least the initial effort can be focused on these essential categories. In contrast, the effort for ITU-T L.1420 is considered to be high, as there are no specific methodological guidelines for the Scope 3 categories.

With regard to the "must-have" indicators named in the JRC study, these standards only cover GHG scopes 1, 2 and 3. Although the results of energy management, in particular energy consumption data, can be used as input data for GHG accounting in the context of scopes 1 to 3, these data sources are not explicitly mentioned in the GHG standards.

5.3 Circular economy

According to the available results, the comparability of the results when applying a standard is limited and the suitability for the Code of Conduct is also classified as severely restricted. This is due to the fact that, with the exception of e-waste quantities, the standards examined do not address any of the "must-have" indicators proposed by the JRC. It is worth mentioning in this context that the JRC study contains "should-have" indicators that relate to the component level. These are understood as functional components that are used in new or revised products. Some of these should-have indicators are addressed in the standards. However, indicators at component level are not the subject of this study.

The effort involved in applying the standards is classified as low to medium, although this estimate should be regarded as indicative. The result of the cost estimate could neither be confirmed nor refuted by the survey of individual stakeholders, as the network operators surveyed are not familiar with the standards examined.

The individual results for comparability when applying the same standards, the overall assessment of suitability and the cost estimate are summarized in Table 5-3.

Table 5-3: Overview of the overall results: Circular economy

<table>
<tr><th>Life cycle phase</th><th>Standards</th><th>Comparability applying the same standard</th><th>Suitability</th><th>Effort estimate</th><th>Market penetration</th><th>Interviews with individual stakeholder</th></tr>
<tr><td rowspan="3">Before use</td><td>ETSI TR 103 476 V1.1.2 (2018-02)</td><td>low</td><td>low</td><td>medium</td><td rowspan="6">• No normative references
• Standards are largely unknown
• Hardly used in practice (exception GRI 306)</td><td rowspan="6">Expenditure Currently not quantifiable</td></tr>
<tr><td>DIN EN 45556 (2020)</td><td>medium</td><td>medium</td><td>medium</td></tr>
<tr><td>DIN EN 45557 (2020)</td><td>medium</td><td>medium</td><td>medium</td></tr>
<tr><td rowspan="3">End-of-Life</td><td>GRI 306</td><td>medium</td><td>low</td><td>low</td></tr>
<tr><td>ETSI EN 305 174-8 V1.1.1 (2018-01)</td><td>medium</td><td>low</td><td>low</td></tr>
<tr><td>ETSI TS 105 174-8 V1.2.1 (2019-12)</td><td>medium</td><td>medium</td><td>low</td></tr>
</table>

Source: Own compilation

6 Conclusions

6.1 Overarching aspects

Reliable and comprehensible comparisons of the must-have indicators generated when applying sustainability standards at different grid operators require the consideration of further aspects in addition to uniform measurement processes, data collection, clear definitions of system boundaries and a uniform methodical allocation in the case of shared grid infrastructure. These include environmental conditions, operating age, technology and generation, differences in connection density between conurbations and rural areas, locations, the grid architecture of the grid segments and load profiles. There is currently no such methodological basis. The standards examined in this study are primarily used for internal trend analysis in order to monitor the company's own performance in terms of energy consumption, GHG and circular economy over time. However, they cannot be used to aggregate measurement results and do not allow analyses at the level of the entire network. However, the standards under consideration do not support the determination of the network-related environmental footprint for the public communication of network operators. For this purpose, standardized measurement methods and allocation rules, definitions, standardized reporting formats and mandatory validation would be required in order to create a sufficiently robust and transparent data basis.

Due to the different network levels (access network and core network), the different network segments (RAN, FAN, CAN) and the associated different network infrastructure and technology, it is recommended that practice-oriented case studies on the relevance of the various influencing factors for the specific standards be carried out together with network operators. On this basis, common guidelines for uniform or comparable measurement environments could be developed, which would facilitate the application of the standards and increase the comparability of the results. The increased involvement of grid operators could also provide a more reliable data basis for the effort estimates (initial and ongoing effort) and the level of effort could be used as a further selection criterion for suitable standards. Standards that cause little effort for the grid operators are likely to be used more. Acceptance by grid operators is necessary to ensure that as many as possible apply the CoC - despite voluntary application. A sufficiently large data basis is required in order to make valid statements on the environmental footprint of telecommunications networks. At the same time, a clear signal would be sent that bureaucratic burdens are limited and that the costs of environmental reporting are adequately taken into account.

6.2 Category-specific conclusions

The aim of the planned EU Code of Conduct is to identify and define best practices based on standards to measure and assess the environmental impact of telecommunications networks. It provides a framework to be taken into account when assessing investments as sustainable investments, if the EU taxonomy is indeed extended to include telecommunications networks. Organizations that comply with this EU Code of Conduct can then report these investments as green investments in their sustainability reporting.

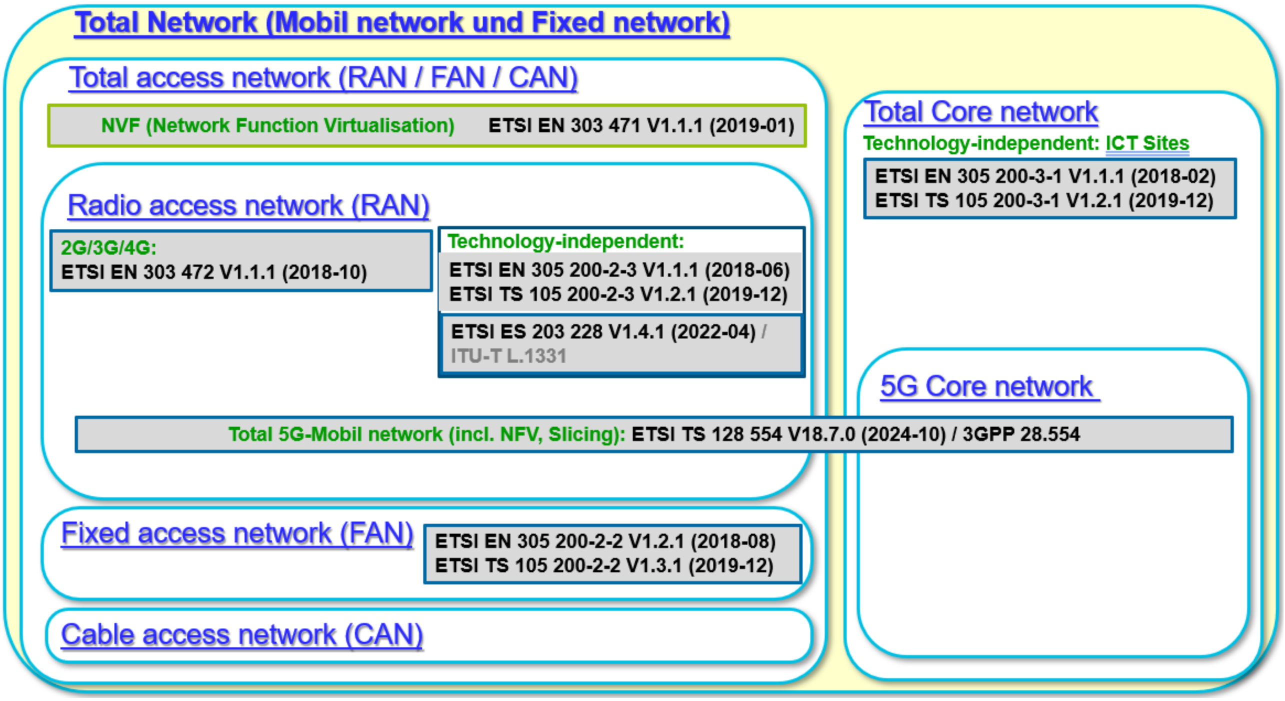
The current draft of the EU Code of Conduct also points to potential gaps in standardization that should be closed by future standardization activities. The study makes recommendations for suitable standards for the CoC based on a science-based approach.

6.2.1 Energy management

It is recommended that the applicability of the proposed standards be discussed with network operators as early as the development phase of the CoC. In this way, potential limitations in practical implementation can be identified at an early stage and necessary adjustments or additions to the standards can be made to ensure broad acceptance in the application of the CoC.

Limited comparability of the results of the measurements does not preclude a standard from being suitable in practice for determining the must-have indicators. Figure 6-1 shows the potential standards that can be used for the must-have indicators, broken down by network segment.

Figure 6-1: Assignment of potential standards that can be used for the must-have indicators



Quelle: Eigene Darstellung

ETSI EN 303 472 (RAN: 2G/3G/4G) and ETSI ES 203 228 (RAN: 2G to 5G) are generally suitable for the CoC. ETSI EN 303 472 provides comparable results if the operating conditions are similar, but according to the standard it is not intended for the comparison of measurement results if these conditions are not met. ETSI ES 203 228 offers flexible measurement periods, which is practical, but makes it difficult to compare results. The extrapolation method of this standard has not yet been proven in practice. Some grid operators determine energy consumption directly via meters, billing or estimates based on installed capacity, as shown in the feedback from the stakeholder survey.

The ETSI EN 305 200-x series defines global KPIs that could support regulatory objectives. However, only the “Objective KPIs” are considered in the study. The associated Technical Specifications (TS) are not always consistent with the EN standards and cannot serve as a sole reference, as they do not define measurement periods, for example. An update of the standards and a legal review for the recognition of renewable energies are necessary.

ETSI ES 205 200-2-4 is currently the only standard for cable access networks, but is not currently recommended due to its low accuracy (e.g. short measurement periods). However, once the standard has been updated, application is possible, so that development from scratch is not necessary.

ETSI EN 303 471 can be used as a complementary standard for access networks in NFV applications, with measurements at site level. ETSI TS 128 554 (based on 3GPP TS 28.554) covers 5G RAN and core network and is future-oriented but technically complex. For the CoC, it should be clearly defined which parts of the standard are relevant; missing measurement specifications (e.g. measurement period) must be added to the CoC in order to ensure uniform application.

In summary, the following recommendation can be derived for determining the energy-relevant must-have indicators for the CoC. The limitations and strengths of the standards are shown in Table 6-1, whereby the technical specifications (TS) are assigned under the respective European standards (EN). These aspects can serve as a basis for discussions with stakeholders on the further development of the CoC.

Table 6-1: Summary of the strengths and limitations of the standards that could potentially be used for the Code of Conduct

Standards	Network segment	Strengths	Limitations
ETSI EN 303 472 V1.1.1 (2018-10)	RAN: 2G/3G/4G	• Includes three must-have indicators • Includes ICT equipment & infrastructure • Clear definition of the measurement method • Detailed reporting requirements	• Does not support 5G technology • Not considering the shared base station locations
ETSI ES 203 228 V1.4.1 (2022-04) / ITU-T L.1331	RAN: 2G/3G/4G/5G	• Coverage 2G to 5G • Includes ICT equipment & infrastructure • Detailed reporting requirements • Provided extrapolation method • Practicable allocation rule for shared locations	• 2 of the 3 must-have indicators (no explicit disclosure of the "renewable energy" indicator, but requires disclosure of the percentage of energy from renewable sources used on site). • Flexibility in measuring period and measuring frequency
• ETSI EN 305 200-2-3 V1.1.1 (2018-06) • ETSI TS 105 200-2-3 V1.2.1 (2019-12)	RAN	• Includes three must-have indicators • Includes ICT equipment & infrastructure • Measurement period: standard 365 days, shorter (at least 7 days) possible if representative of the year • **"Global KPIs": potential for future comparisons**	• Different treatment for shared locations: →EN: Not consideringthe shared base stations →TS: Allocation based on energy costs • Measurement of the data volume: →EN: according to ETSI EN 303 472 normative →TS: informative • 'Green' energy, which is certified as renewable, is not recognised. An update is required
• ETSI EN 305 200-2-2 V1.2.1 (2018-08) • ETSI TS 105 200-2-2 V1.3.1 (2019-12)	FAN	• Includes three must-have indicators • Includes ICT equipment & infrastructure • Measurement period: standard 365 days, shorter (at least 7 days) possible if representative of the year • **"Global KPIs": potential for future comparisons**	• Different treatment for shared sites: see EN 200-2-3 • TS: if direct measurement is not possible, the maximum consumption of the appliances can be used in accordance with the manufacturer's technical specifications • 'Green' energy, which is certified as renewable, is not recognised. An update is required

Standards	Network segment	Strengths	Limitations
• ETSI EN 305 200-3-1 V1.1.1 (2018-02) • ETSI TS 105 200-3-1 V1.2.1 (2019-12)	ICT locations for core network	• Includes ICT equipment & infrastructure • Measurement period: standard 365 days, shorter (min. 7 days) possible if representative for the year • Measuring points are clearly defined • **"Global KPIs": potential for future comparisons**	• 2 of the 3 must-have indicators[10]. Energy efficiency indicators missing • No allocation rule for shared locations An update is required • 'Green' energy, which is certified as renewable, is not recognised. An update is required
ETSI EN 303 471 V1.1.1 (2019-01)	NVF for the access networks	• Holistic approach: Aggregated measurements of the entire NFVI without differentiation at VNF or component level. • As a supplementary standard for RAN and FAN in the NFV application.	• Not taking into account the shared base stations • 'Green' energy, certified as renewable, is not recognised.
ETSI TS 128 554 V18.7.0 (2024-10) / 3GPP TS 28.554 version 18.7.0	5G end-to-end: RAN & core network	• Includes both RAN and core network • **Future-oriented**: →5G NFV at component level, network slicing →Extensive performance indicators.	• 2 of the 3 must-have indicators • No requirement for the "renewable energy" indicator • No information on measuring method, e.g. measuring period and measuring frequency • Energy consumption of the infrastructure is not mentioned • No report template and report requirements. • No allocation rule for shared locations

Source: Own compilation

Cross-standard conclusions on energy management:

The allocation of energy consumption in infrastructure sharing represents a methodological challenge for the calculation of must-have indicators, as there is currently no universal, scientifically based method for distributing the energy consumption of shared grid infrastructures between grid operators. Different allocation approaches lead to varying results and also to possible double counting or lack of counting. The selection and justification of allocation parameters requires in-depth knowledge of telecommunications networks and their environmental assessment as well as case-specific leeway. In the absence of further scientifically sound findings on allocation parameters for telecommunications networks in the CoC development phase, it is suggested that network operators disclose their parameters for calculating energy consumption at shared locations. This promotes transparency, enables practical experience to be gained and supports the further development of the CoC.

6.2.2 Greenhouse gas emissions

As part of the JRC study, it was proposed to summarize the climate-relevant sustainability indicators based on the defined GHG emissions in three scopes as must-have indicators.

[10] Note: There is a deviation compared to other ETSI EN 303 200-2-x series, where the indicator "Task Effectiveness" describes the relationship between data volume and energy consumption. In this standard, the indicator "Task Effectiveness" refers to the ratio between the energy consumption of the IT devices and the total energy consumption including infrastructure (e.g. cooling).

It is recommended that the GHG Protocol Corporate be included in the CoC as a methodological reference for the quantified recording and reporting of an ICT company's greenhouse gas emissions. As a generic standard, the GHG Protocol Corporate is less specific than ITU L.1420, which was developed specifically for the GHG reporting of ICT companies. However, the analysis shows that the latter standard is more complex to apply and has so far been used less frequently than the GHG Protocol. In order to reduce the effort involved, the CoC should therefore specify the GHG Protocol, which should be recommended in the CSRD, as a methodological reference for Scopes 1&2.

For Scope 3 emissions, the GSMA/Gesi/ITU Scope 3 Guidance for Telecommunication Operators has proven to be the methodological guideline with the best comparability of application results. In order to focus the GHG calculations on the aspects considered material for the telecommunications sector, the Scope 3 Guidance prioritises the Scope 3 categories (1, 2, 3, 8, 13 and 15) (see Annex V.a). It is therefore recommended that this standard be cited in the CoC as a reference for Scope 3. In addition, it may be useful to clearly define network-related GHG-relevant aspects within these material categories in the CoC so that network operators can report these separately. E.g. Cat. 1 (i.e. purchased network-related devices, switches, servers, routers, production of fiber optic cables, masts, load balance (see ITU L. 1050)); Cat. 3 (travel for maintenance); Cat. 2. (underground construction for network expansion (laying of cables) (see Table 7-18).

Network operators should also be encouraged to collect industry-specific but average CO_2e emission factors for upstream and downstream processes, e.g. from the manufacturing phase of network components such as servers, switches or routers, together in a central database platform. The aim is to facilitate the calculation of extensive Scope 3 categories and at the same time improve the harmonization and comparability of the results.

6.2.3 Circular economy

As already stated in Chapter 3.4, with the exception of GRI 306 and the indicator for e-waste defined there, none of the standards examined address the “must-have” indicators proposed by the JRC at product level. However, it should be borne in mind that although it makes sense to record the indicators at product level from the perspective of a circular economy, it is difficult to implement in operational practice. This assessment was confirmed by network operators in the stakeholder survey. Against this background, it may make more sense to define the indicators in the “circular economy” category at the material level (recycling) or component level (reuse, refurbishment). One of the main reasons why this is difficult to implement in practice is that products are usually heterogeneously composed of different components and materials sourced worldwide. This makes differentiated analyses and conclusions at component level very difficult. Some indicators already exist at component level (see Table 7-32 and Table 7-33 in Annex IX). However, these were not developed specifically for network infrastructures and are therefore only suitable for the telecommunications sector to a very limited extent. Due to the limited suitability of the existing standards and the limited comparability when using the same standard, there is an obvious need for the development of specific standards at component level for telecommunications network infrastructures in the “circular economy” category. However, it must be borne in mind that new standards cannot be developed in the short term. A prerequisite for the application of such standards would be that the technology suppliers make the corresponding data available to the network operators. This assessment was also shared by the stakeholders surveyed. This applies in particular to the “Before use” group. In the “End-of-life” group, GRI 306 does provide an indicator for determining e-waste quantities; however, the overall assessment of the suitability of this standard is comparatively low due to the excessive scope for implementation.

Furthermore, it should also be noted that the indicators considered in the available standards do not take into account the quality of reused, recycled or refurbished products.

Finally, it should be noted that although the ITU-T L.1050 standard does not contain any quantitative indicators, it does provide a structured identification of the relevant telecommunications equipment broken down by network segment. This includes network devices as well as technical infrastructure equipment in access, backhaul and backbone networks. The devices listed in the standard can be used as a basis for the systematic recording of relevant e-waste in the network area.

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7 Annex -> see seperate document