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Environmental sustainability in telecommunications

Exploring direct impacts of EU-headquartered telecom operators

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This time has been interesting to say the least; though some things took detours, changes, ups and downs; those made the experience more memorable.

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Thanks, Swedish Institute for giving me the opportunity to live this experience

Abstract

The relevance of the ICT sector and telecom operators is predicted to grow rapidly within the next decade, mainly around their direct environmental impacts because of the ongoing expansion of mobile and fixed networks and increasing data traffic. Therefore, it is necessary to explore telecom operators' direct environmental impacts, considering the currently available information in sustainability reports and different reporting standards and frameworks applicable to them. This study, using a mixed methods approach, elicits the direct environmental impacts from the direct environmental of telecom operators by analyzing the sustainability reports of five EU-headquartered telecom operators over a four-year period and considering applicable environmental sustainability reporting frameworks. Insights from practitioners were collected via interviews to determine ongoing trends and challenges in the industry. The results indicate that greenhouse gas emissions, energy, and circularity are the most relevant and addressed topics among the selected telecom operators, with Scope 3 emissions being the most pressing issue for telecom operators. Moreover, trends and challenges around the operator's environmental performance and reporting include data quality issues, lack of standardization for environmental disclosures, and lack of supplier engagement.

Keywords: environmental sustainability; sustainability reporting; telecommunications

Executive summary

Problem definition.

While being a small yet relevant contributor to the overall greenhouse gas emissions, the relevance of the ICT sector and telecom operators is predicted to grow rapidly within the next decade, mainly around their direct environmental impacts. This growth in relevance calls for telecom operators to provide reporting on their impact, allowing for the identification of trends and potential challenges around these aspects. Sustainability-related disclosures are often guided and performed considering voluntary, generic, and industry-specific standards and frameworks, which can result in scattered and heterogeneous information. It is then necessary to explore telecom operators' direct environmental sustainability effects, considering the currently available information and different reporting standards and frameworks applicable to them.

Aim and research questions.

This study aims to elicit the direct environmental effects of telecom operators. This project's scope is narrowed to telecom operators operating in the European Union (EU). To achieve this aim, two main research questions are proposed:

RQ1. What are the reported and under-reported direct environmental effects from EU-headquartered telecom operators considering their sustainability reports and applicable reporting frameworks and standards?

> *RQ1.1. What are the existing relevant reporting frameworks for environmental sustainability in telecom operators?*

A second research question seeks to delve into the trends and challenges towards improving the environmental performance and reporting of TOs:

RQ2. What are the trends and challenges towards the improvement of the environmental performance and its reporting of EU-headquartered telecom operators?

This question seeks to explore the ongoing challenges and trends surrounding telecom operators' direct environmental impacts with practitioners.

Research design.

This study uses an *explanatory sequential mixed methods design* involving a two-stage data collection effort. First, the researcher collects quantitative data from sustainability reports from five selected telecom operators over a four-year period, in alignment with (RQ1); the findings from this stage informed the second qualitative stage (RQ2), where six interviews were conducted with relevant stakeholders from the telecommunications sector.

Research results and conclusions.

The results indicate that the main environmental concerns for telecom operators are greenhouse gas emissions, energy, and circularity in the industry. The biggest concern is Scope 3 emissions, which make up to 90% of the overall emissions from the selected companies. Moreover, the reporting trend in the sector indicates that recent regulations shape the reporting landscape, aiming at increasing the quality of disclosures. However, the sector faces several challenges in improving its environmental performance and reporting, including data quality issues, lack of standardization for environmental disclosures, and lack of supplier engagement.

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1 Introduction

Information and Communications Technologies (ICT), specifically telecommunications, has grown significantly in the past decades as a crucial element of digitalization. ICTs are currently an integral element of nearly every sector and industry worldwide. Digitalization and ICT have been renowned as elements to tackle or mitigate the global economy's environmental pressures, being crucial towards enabling the reduction of carbon emissions and energy consumption (Coroama & Mattern, 2019). As pointed out by Coroama & Mattern (2019), ICT and digital systems can drive optimization in energy and resource-intensive systems and to virtualize or substitute them altogether. As a result, ICT use is closely related not only to organizations' productivity but also to their sustainability efforts (BCG, 2023; Kang et al., 2010; Truant et al., 2023).

Currently, there is an increasing development, deployment, and use of ICT (Roussilhe et al., 2023), coupled with an exponentially growing volume of data storage, processing, and transmission requirements (Santarius et al., 2023). On top of that, recent events, such as the COVID-19 pandemic in 2020, illustrated the ongoing and unprecedented use of ICT and data consumption in different settings. At a business level, this is experienced in practices like e-commerce and cloud computing applications, while at the consumer level, this situation is depicted through practices including remote working and schooling, video streaming, gaming, and social media. Furthermore, emerging data-intensive digital technologies such as blockchain and artificial intelligence is likely to further increase the environmental footprint of the ICT sector (Roussilhe et al., 2023), despite the efficiency gains in equipment enabling its functioning.

The enabler for these activities is the infrastructure provided by telecommunications operators (TOs). These operators provide wireless communications via radio-based cellular networks and operate and maintain transmission facilities. They also operate wireline segments that provide local and long-distance voice, voice over internet protocol, telephone, television and broadband internet services over a an expanding network of fiber-optic or copper-based cables (IFRS Foundation, 2023; León & Salesa, 2023). TOs' infrastructure mainly include equipment such as radio units, cables, servers, and routers (GSMA, 2019a; NGMN, 2021a).

1.1 Problem Definition

According to Hilty & Aebischer (2015) the environmental impacts from ICT, including the ones from telecom operators, can be of a diverse nature. First, there are life-cycle impacts, which consider all the impacts derived from the existence and use of telecom infrastructure and end-user devices; enabling impacts refer to the impacts derived from the use of ICTs, including but not limited to dematerialization and virtualization effects; finally, structural impacts occur when the use of ICT foster changes at the level of societal or economic structures, which in turn can trigger other enabling and life-cycle impacts.

Focusing on the direct impacts of telecom operators' activities, their complexity, ubiquity and constant operation of telecommunication networks make this industry an energy and carbon-intensive one. According to GSMA (2019), the telecommunications industry alone consumes between 2 to 3% of the global energy. Also, within the whole ICT sector, that also encompass data centers and user devices (e.g. smartphones), telecommunications networks are responsible for between 22 to 35% of the sector's global carbon footprint, situated between 1.2 to 2.2 $GtCO_2e$, (Freitag et al., 2021), which is often compared to the carbon footprint of the aviation sector, situated at approximately 1.04 $GtCO_2e$. Other significant, though less covered direct environmental impacts of this industry are, for example, land use and waste electrical and electronic waste (e-waste); the first is related to the ongoing geographical expansion of networks, while the second is highlighted considering the end-of-life and decommissioning of equipment that reached their end of life, including infrastructure elements such as antennas and other networking equipment, as well as end-user-devices like mobile phones and routers (Roussilhe et al., 2023).

A key concern around telecom operators' direct environmental impacts, as pointed out by Roussilhe et al. (2023), is that limited or heterogeneous data availability hinders the understanding of industry's impact, especially for aspects beyond the most scrutinized ones of energy consumption, renewable energy adoption, and greenhouse gasses emissions; for example, information related impacts related to manufacturing or end-of-life processes is either *unavailable, scattered or understudied*, despite several frameworks and standards encouraging operators to disclose or report them. Even widely documented topics such as GHG accounting face difficulties, especially for upstream and downstream activities of telecom operators (Samuel et al., 2024), mainly due to the complex value chain involved in the provision of telecommunication services, which involves equipment, application, and content providers (Yu et al., 2008).

While being a small yet relevant contributor to, for example, the overall greenhouse gas emissions (Belkhir & Elmeligi, 2018), the relevance of the ICT sector and telecom operators is predicted to grow rapidly within the next decade, mainly around their direct impacts (Itten et al., 2020). This growth in relevance calls for telecom operators to provide reporting on their impact, allowing for the identification of trends and potential challenges around these aspects. Sustainability-related disclosures are often guided and performed considering voluntary, generic, and industry-specific standards and frameworks, which can result in scattered and heterogeneous information that hinders comparability within the industry (Famularo, 2023; León & Salesa, 2023). In this sense, it is necessary to explore telecom operators' direct environmental sustainability effects, considering the currently available information and different reporting standards and frameworks applicable to them. It is relevant to know how core players behind the infrastructure supporting the ever-increasing digital lifestyles and practices identify, assess, and address their impacts.

1.2 Aim and Research Questions

The direct environmental effects from telecom operators is not clear and is mainly explored using global data and performed by industry associations like the GSM Association or the Global e-Sustainability Initiative (GeSI). However, there is a lack of uniformity in the reporting at the corporate level, considering that telecom operators have specific priorities and ways of assessing and reporting their impacts related to the concept of materiality, as mentioned by León & Salesa (2023).

This heterogeneity, along with scattered information about their direct environmental effects, paints a blurry picture of telecom operators' impact, especially considering their ongoing efforts towards greener and more sustainable practices. It is then relevant to look at what and how telecom operators are reporting and considering relevant in terms of direct environmental impacts.

Given this, it is relevant to explore these frameworks and their similarities and to identify how the available information from telecom operators (in the form of databases and reports) fits in those. As a result, the aim of this study is to elicit the direct environmental effects of telecom operators. The scope of this project is narrowed down to telecom operators operating in the European Union (EU); this geographical delimitation is further elaborated in the *Scope and Delimitation* section.

To achieve this aim, two main research questions are proposed:

RQ1. What are the reported and under-reported direct environmental effects from EU-headquartered telecom operators considering their sustainability reports and applicable reporting frameworks and standards?

Addressing this question requires identifying different standards and frameworks for the reporting of environmental effects by telecom operators and the required disclosures. For example, for direct effects, several standards and frameworks are available and applicable to these companies, including international standards like the GHG Protocol and Global Reporting Initiative (GRI), Carbon Disclosure Project (CDP), as well as industry-specific standards such as the SASB for Telecommunications services.

A sub-question is also presented to aid the process:

> *RQ1.1. What are the existing relevant reporting frameworks for environmental sustainability in telecom operators?*

A second research question seeks to delve into the trends and challenges towards improving the environmental performance and reporting of TOs; with this

> *RQ2. What are the trends and challenges towards the improvement of the environmental performance and its reporting of EU-headquartered telecom operators?*

This question seeks to explore directly with practitioners the ongoing challenges and trends around the topic of direct environmental impacts of telecom operators.

1.3 Scope and Delimitation

This research focuses on the issue of direct environmental impacts from telecom operators headquartered in the European Union. This delimitation responds to specific factors such as the existence of, for example, tighter sustainability-related regulations such as the already implemented Corporate Sustainability Reporting Directive (CSRD). Moreover, focusing on this region allows for a selection of telecom operators that operate in a wide geographical context, present a significant market share and offer a relevant technology mix. Finally, it obeys the fact that the EU has placed attention to digitalization through specific initiatives, such as the Digital Decade 2030 policy program, which seeks to increase digital skills, digitalization of businesses and public services, and the deployment of digital infrastructure.

1.4 Ethical Considerations

The current study is not externally supported nor funded by an external organization, so there is no potential influence on results or conclusions. The Research design contemplates the use of mixed methods, entailing first a more quantitative component followed by a qualitative one. Regarding confidentiality, the quantitative component of this research project relies on available information around the topic of direct environmental impacts from EU-headquartered TOs; such information is in the form of peer-reviewed and grey literature, including mainly telecom operators' sustainability reports, consultancy reports, databases, and web portals.

On the other hand, the qualitative component requires primary data collection from telecom operators and relevant value chain actors, and other stakeholders such as industry associations and academia. Hence, confidentiality needs to be addressed. For the data collection process, via semi-structured interviews, the interviewees will be participating on a voluntary basis and their answers will be anonymized (unless they request otherwise). All the information generated will be used for the purpose of the current project and will not be shared with others without explicit authorization from the parties involved; the data originated from these data collection process will be stored in One Drive managed by Lund University.

1.5 Audience

This study aims to present a comprehensive overview and description of the direct environmental impacts resulting from selected EU-headquartered telecom operators.. The study's audience is diverse and can be divided into three main categories. First, from a practical standpoint, the study is intended for sustainability practitioners working at telecom operators, both within and outside the study's geographic scope, who are seeking information on effective or suboptimal reporting practices regarding environmental impacts. Second, from an academic perspective, the study provides up-to-date insights into the direct impacts of telecom operators in the current data-intensive environment, utilizing sustainability reports and insights from relevant stakeholders as information sources. Additionally, the study seeks to inform the development of more sustainable practices in the industry and can provide insights for research and academic institutions working on sustainability, telecommunications, and information and communication technology (ICT) topics. Finally, this research can also inform policymakers, both within and outside the study's geographic scope, who are interested in supporting regulations or incentives in the telecom sector.

1.6 Disposition

Chapter 1. Presents the problem definition, research aim, scope and delimitation considerations, and intended audience.

Chapter 2. Introduces the research design and methods for data collection. An explanatory sequential mixed methods approach is selected and guides the process, entailing a quantitative approach, followed by a qualitative one executed via semi-structured interviews.

Chapter 3 provides a literature review in which core concepts are defined and the state of the art is presented. The chapter describes the sector under study and conceptualizations about the different environmental impacts of telecom operators. Moreover, a review of the environmental impacts of telecom operators is presented, as well as a description of the role of sustainability reporting.

Chapter 4 presents the results of the analyzed reports from selected companies over the selected 4-year period. The chapter's structure is guided by the environmental material topics identified by the analyzed companies. Findings from the first stage guide the development of the second stage, qualitative, in which six interviews were conducted with stakeholders from sectors including telecom operators, equipment providers (telecom operators' supply chain), industry associations, and academia. The second stage aims to identify different factors influencing the current and prospective reporting practices of environmental reporting in the industry.

Chapter 5. The discussion chapter offers the interpretation of the results, encompassing both quantitative and qualitative aspects. Furthermore, practical implications, limitations, and future research, the study's outcomes are contrasted with the available literature, and recommendations for the field are put forth based on the examination. The study's limitations are also presented in this section, as well as future work considerations.

Chapter 6. Conclusions of the study.

2 Research design, materials and methods

2.1 Research design

Considering the aim of this study, a pragmatic worldview is used since instead of focusing on the methods, emphasis is placed in the research aim and questions, thus allowing for exploring different methods or a combination of them to understand the problem (Creswell & Creswell, 2018). As a result, a mixed method is contemplated for this study.

According to Creswell & Creswell (2018), mixed methods research involves the collection of both quantitative and qualitative data, with the core assumption that the integration of these provides additional insights beyond the information provided by either quantitative or qualitative data and information alone. Mixed methods are strong in drawing insights from both qualitative and quantitative research while minimizing their shortcomings. The selected approach is suitable for exploring the topic of direct environmental impacts from telecom operators, considering that quantitative information publicly available (reports, databases, and web portals) and qualitative, primary information from practitioners can provide a more comprehensive analysis of the topic.

2.2 Mixed methods: Explanatory sequential mixed methods design

Considering the research questions presented in the section Aim and Research Questions, the study's current study first seeks to identify the environmental aspects reported in sustainability communications and reporting from TOs and their magnitude over the last years while also identifying underreported or underexplored aspects considering existing reporting frameworks and standards. Based on the findings, from the previous step, the study moves on to the collection of primary information from TOs sustainability practitioners, with specific queries around the main trends and challenges towards the improvement of the environmental performance and its reporting of EU-headquartered TOs.

These characteristics fit with the *explanatory sequential mixed methods design*, which involves a two-stage data collection effort. First, the researcher collects quantitative data (RQ1) proceeds to analyze the results, and uses them to build on to the second, qualitative, stage (RQ2). The first phase informs the type of participants to be included in the second phase while highlighting the types of questions to be asked (Creswell & Creswell, 2018).

The following subsections describe the general procedures for conducting the two-stage data collection, and their respective data analyses. A summary of the methodological steps is presented in Figure 1.

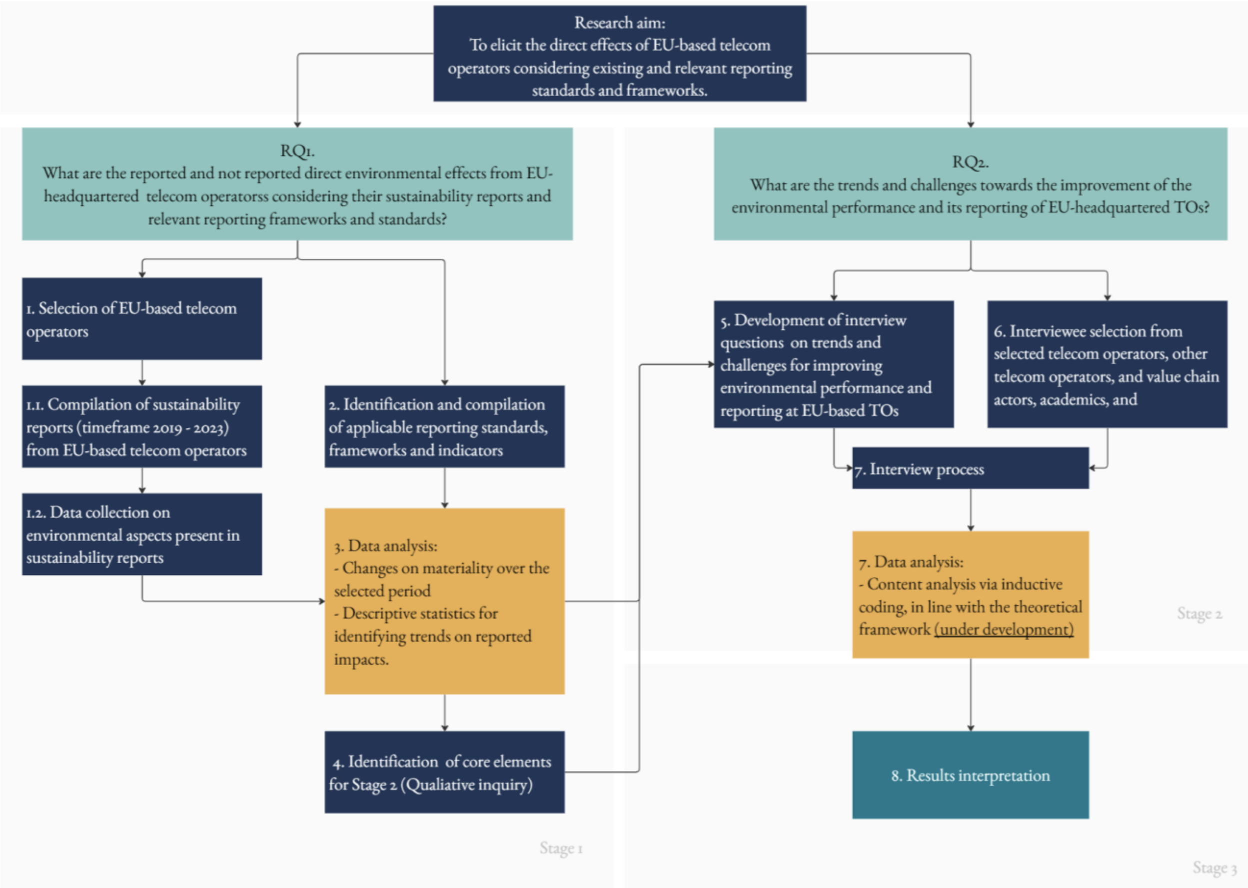

Figure 1 Research design and methodological steps.
Source. Author's own.

2.2.1.1 First stage: quantitative component

RQ1. What are the reported and not reported direct environmental effects from EU-based TOs considering their sustainability reports and relevant reporting frameworks and standards?

1.2. Methods for data collection and analysis

1. *Selection of TOs to be assessed.*

Analyzing all EU-headquartered TOs telecom operators is an ambitious task, thus it is necessary to define selection criteria. Considering the context of this research, relevant criteria for the TOs' selection are ***a) geographic reach, b) technology mix c) number of subscriptions (mobile) d) transparency and reporting***. The last criterion is especially relevant since the main sources of information are telecom operators' sustainability reports. To capture the effects of global events, like the COVID 19 pandemic, reports at least from 2019 onwards are to be considered. Given the time frame, 2019 to 2022 , and the time constraints for this study, the number of selected TOs is set to five, ensuring that the selected companies present the previously mentioned criteria. Considering this, the following telecom operators were selected for the assessment, details about these operators are found in Section 4.1 Description of the selected companies.

- A1 Telekom Austria Group
- Deutsch Telekom
- Orange SA
- Telefonica
- Telia Company

1.3. Data collection on environmental aspects present on sustainability reports

With the telecom operators selected, the next step is to review their corresponding sustainability reports (2019 to 2022) and compile the information related to their direct environmental impacts. The time scope allows for a longitudinal analysis that can capture trends and changes in but the environmental performance and reporting practices of the selected companies.

2. Identification of reporting standards and frameworks applicable to TOs.

For the telecommunications industry there are several frameworks and standards applicable for assessing and reporting their direct environmental impacts. Such frameworks are of a voluntary nature, proposed by different industry associations and internationally recognized entities. The available standards and frameworks and their respective metrics can either differ significantly in their scope or can be applied by the adopted by telecom operators considering the relevance of the environmental impacts in function of their materiality assessments.

Identified standards and frameworks entail:

- Greenhouse Gas Protocol (GHG).
- Global Reporting Initiative (GRI).
- SASB Reporting standards for Telecommunications.
- GSM Association Metrics for Mobile.
- International Telecommunications Union (ITU) L-series recommendations for environment and Information and Communication Technologies (ICTs).

This study only focused on frameworks and standards, or parts of them, that pertain exclusively to direct environmental impacts; thus, frameworks and disclosures integrating financial considerations are excluded, such as the framework provided by the Taskforce on Climate-Related Financial Disclosures (TCFD), as well as regional standards and regulations such as the European Sustainability Reporting Standards (ESRS), the EU Corporate Sustainability Reporting Directive (CSRD), and the EU Taxonomy Regulation.

3. Data analysis

a. Examination of the evolution of environmental material topics in reviewed sustainability reports.
b. Identification of trends among reported direct effects in the selected telecom operators, covering aspects such as absolute GHG emissions, absolute energy consumption, waste generation, among others.
c. Hotspot identification: This entails identifying topics that are frequently reported and those that are not, considering the selected standards and frameworks.

4. *Identification of core elements for Stage 2 (Qualitative inquiry)*

2.2.1.2 Second stage: Qualitative component

What are the trends and challenges towards the improvement of the environmental performance and its reporting of EU-headquartered TOs?

The qualitative follow-up builds up on the quantitative data collection stage. The second stage considers significant variables or topics addressed quantitatively. Also, the first stage informs the sampling procedure but it can also envision the types of qualitative questions to ask the participants (Creswell & Creswell, 2018)

1.4. Methods for data collection and analysis

1. *Development of interview questions*
    a. Assessing the findings from the first stage to identify relevant topics of inquiry around reported and underreported direct environmental impacts. The interview guide and questionnaire prepared is presented in Appendix 1.
2. *Interviewee selection*
    a. Considering the topics, the selection of interviewees (mainly sustainability-related personnel) was conducted; the list of interviewees encompassed sustainability analysts at the selected telecom operators, upstream value chain actors, industry associations, and academic experts. Interviewees were identified through the selected sustainability reports, industry and policy reports, and research articles. Contact was established via email and LinkedIn.
3. *Interview process and analysis.*
    a. Six interviews were conducted online between March 29th and April 17th, 2024. Depending on the interviewees' availability, each interview took 45 to 60 minutes. Table 2 presents general details about the interviewees and interviews.

    b. Each interview was transcribed using Microsoft Word and inspected for consistency and language corrections prior to their analysis.
    c. The analysis of the information was conducted in alignment with the research aim and the specific research question. The analysis mainly considered the LES framework of ICT impacts on sustainability (Hilty & Aebischer, 2015) focusing on the life-cycle impacts.
    d. The thematic analysis was conducted using ATLAS.ti 24 using an inductive coding approach (Creswell & Creswell, 2018).

Table 1. List of interviewees

Interviewee Code	Industry	Position description
EP	Manufacture of communication equipment	Sustainability analyst
R1	Academia	Academic researcher on sustainable ICT
PA	Industry Association	Policy analyst

FR	Standards organization	Analyst. Former researcher on environmental impacts of ICT
TO	Telecom operator	Sustainability analyst
R2	Academia	Academic researcher on sustainable ICT

3 Literature review

This chapter provides a comprehensive overview of the existing literature on environmental sustainability and the telecommunications industry. Before examining the state of the art around the research topic, key concepts are presented to contextualize the industry under research. Key concepts and descriptions

3.1.1.1 Role of telecom operators in society

Telecom operators play a crucial role in modern society, being instrumental in driving development, societal transformation, and economic growth. The industry has played a crucial role in influencing the way consumers interact with technologies covering a vast range of applications, including but not limited to businesses, banking, education, social media in entertainment (NGMN, 2021b). Over the past decades, telecommunications technologies, and thus telecom services, have become more and more essential for everyday activities, and for the adoption of new technologies such Internet of Things (IoT) or artificial intelligence (AI) (BCG, 2023; NGMN, 2021b)

Telecom operators aid the deployment of and adoption of connectivity solutions; according to ITU, the number of individuals connected to the Internet has only grown. Around 67% of the world's population is now connected to the internet; that adoption percentage is way higher in regions like Europe, where around 91% of the population is connected to the internet, approaching universal use. The last figure is starkly different from regions like Africa, where only one-third (37%) of the population is connected to the internet. This constant growth in the number of connected individuals is reflected in the number of mobile and fixed broadband subscriptions; ITU indicates that in 2023 on average, there are 87 mobile broadband subscriptions per 100 inhabitants, a 27% increase compared to 2022 (ITU, 2023). Moreover, fixed-broadband subscriptions have reached 19 subscriptions per 100 inhabitants, with a consistent annual growth rate of 6.7%.

To sustain and cope with this increasing adoption, operators need to invest and continually deploy and update their networks. Currently, around 52% of the world is covered by fourth-generation (4G) networks and 38% by fifth-generation (5G) networks; the remaining percentages correspond to legacy networks (3G and 2G), which are mainly used in low-income countries. Both 2G and 3G are continuously being decommissioned in favor of more modern networks (Rouphael et al., 2023)

3.1.1.2 Overview of telecom operators

According to ITU, telecom operators are part of the Information and Communication Technologies (ICT) sector, which represents economic activities that include industries intended to fulfill or enable information processing and communication via electronic means, including their transmission and display (ITU, 2020). The ICT sector is comprised of different industries, with telecom operators being part of the ICT service industries, presented in Table 3.

Table 2 ICT sector breakdown (ITU segmentation)
Source: ITU (2022)

Type of industry	Industries
ICT Manufacturing Industries	Manufacture of electronic components and boards
	Manufacture of computers and peripheral equipment
	Manufacture of communication equipment
	Manufacture of consumer electronics
	Manufacture of magnetic and optical media
ICT Trade industries	Wholesale of computers, computer peripheral equipment and software

Type of industry	Industries
	Wholesale of electronic and telecommunications equipment and parts
ICT Service Industries	Software publishing
	Wired Telecommunication activities
	Wireless Telecommunications activities
	Satellite Telecommunication activities
	Other Telecommunications activities
	Computer programming activities
	Computer consultancy activities
	Computer facilities management activities
	Other information technology and computer service activities
	Data processing, hosting and related activities
	Web portals
	Repair of computers and peripheral equipment
	Repair of communication equipment

ITU's segmentation of telecommunications includes the provision of telecommunications and related service activities; such as the transmission of voice, data, text, sound and video, based on a single technology or the combination of technologies; the convergence point of telecommunication activities is that industries providing this service are dedicated to the transmission of content and not its creation (ITU, 2020). Under these considerations, the IFRS Foundation (2023), provides a thorough definition that encompasses the previous considerations, defining telecom operators as providers of wired or wireless communication services. The wireless segment provides direct communication via radio-based cellular networks and operates all the required facilities associated with routing and switching. Moreover, the wireline segment provides local and long-distance voice communication, voice over internet protocol telephone, television, and broadband internet services over expanding networks of copper or fiber optics (IFRS Foundation, 2023). Through their operations of fixed and wireless (mobile) data transmission, telecom operators provide the required infrastructure and connectivity services to support the current highly digitalized economy and life. All types of digital communications are reliant on the stability and services of these operators (NGMN, 2021b), including media and entertainment, banking, transportation, and others.

3.1.1.3 Telecom operators' supply chain

To provide their services, telecom operators rely on interactions with an ample spectrum of the ICT sector industries. As pointed out by Çanakoğlu & Bilgiç, (2007), telecommunications is a complex industry, characterized by the outsourcing of functions such as manufacturing and research and development to suppliers, as well as intense competition. Modern telecommunications are the convergence point of different technologies like telecommunications, information technology, media, and the internet; as pointed out by Yu et al. (2008), the development of newer generations of broadband cellular networks involves not only system equipment or basic services, such as voice, but also incorporates a multitude of links into an already complex supply chain encompassing content, applications, software, hardware, and other elements (Yu et al., 2008).

Telecom operators' supply chain thus involves different actors, focused on the provision of hardware and software solutions (e.g., handsets, antennas, switches, servers, base stations) while the roles of operators consists of installing the required capacity to provide the services to their consumers in either the wired or wireless segments (Çanakoğlu & Bilgiç, 2007).

A detailed overview of this supply chain is presented by Patil & Karnam (2022), who compile and define it, considering inputs from Yu et al. (2008), Cassivi (2005), and Pasadilla (2016). This multi-tier supply chain brings together the following actors:

- **Equipment providers or vendors**: specialized in providing the hardware and software that constitutes the network infrastructure and provide required handsets as per requirements of the operators. Equipment providers include system integrators (Patil & Karnam, 2022) such as companies like Ericsson, Nokia, and Huawei, and electronic manufacturing specialists (EMS) also called contract manufacturers. The first are the ones mostly devoted to the knowledge-based component of the value chain, while the manufacturing part is outsourced to the EMS.
- **Application providers:** are responsible for providing software solutions depending on the telecom operators' requirements.
- **Service providers:** provide platforms that allow consumers to access specific services; they can simultaneously act as content providers.

The multi-tiered supply chain is depicted in Figure 2.

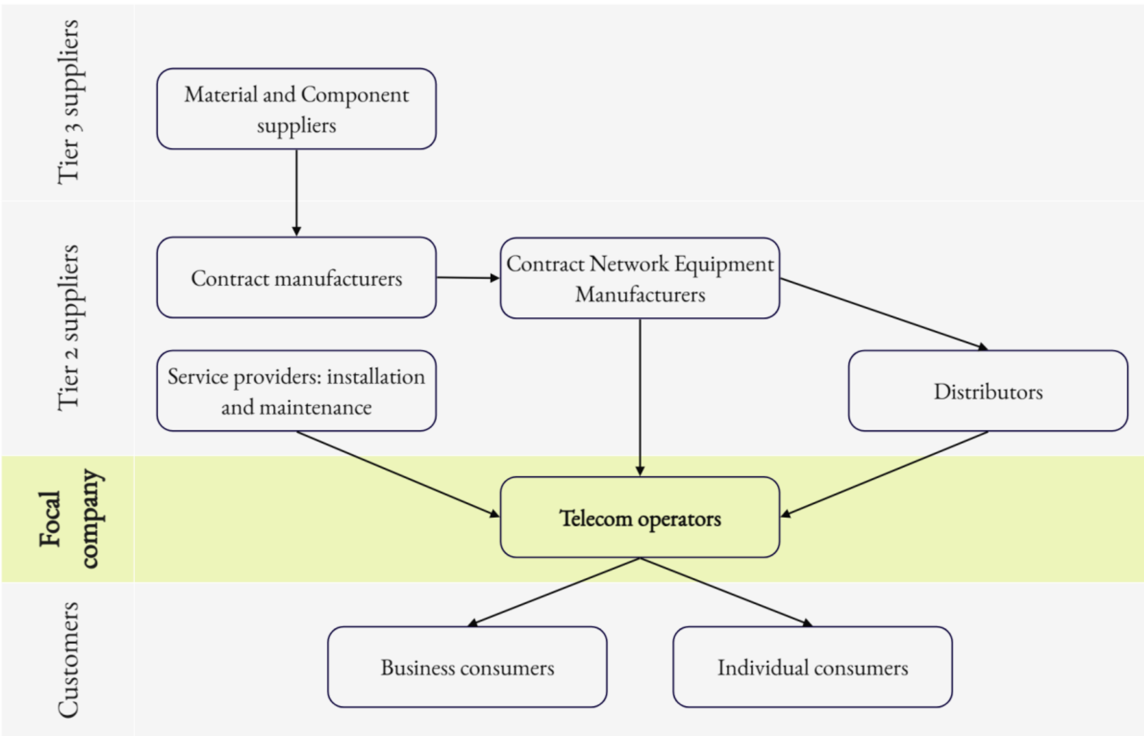

Figure 2 The Telecom Operators' value chain.
Source: Adapted from Yu et al., (2008) (BCG, 2023; Mickoleit, 2010; NGMN, 2021b)

3.1.1.4 ICT, telecom operators and environmental sustainability

Environmental sustainability of the ICT sector and telecom operators has been addressed mainly in gray literature from telecommunications-related organizations like GSMA, ITU, the European Telecommunications Network Operators' Association (ETNO), and the Next Generation Mobile Networks alliance (NGMN) and by telecom operators through their sustainability reports. The environmental impacts of telecom operators can be wide in nature, though the most covered aspects include on Greenhouse Gases (GHG) emissions (Freitag et al., 2021; Malmodin & Lundén, 2018;

Rouphael et al., 2023) and energy consumption and efficiency (GSMA, 2019a; ITU & World Bank, 2024).

As previously mentioned, the impact of ICT, including telecom operators, is diverse. Mickoleit (2010) indicates that ICTs present positive and negative impacts on the environment and that their net environmental impact corresponds to the sum of all interactions of ICTs with the environment, considering all potential reductions achieved due to the use of such technologies. Moreover, ICTs also influence how people live and work and the way goods and services are produced and delivered. Acknowledging the complexity and the far-reaching implications of these impacts that extend beyond the environmental dimension of sustainability to broader socioeconomic contexts, Köhler & Erdmann (2004) and Mickoleit (2010) provide a three-level description of the environmental impacts from ICTs, according to their order of impact.

Direct impacts (Mickoleit, 2010) or first-order effects (Hankel et al., 2018; Köhler & Erdmann, 2004), include both positive and negative impacts attributed to the physical existence of ICT products in the form of goods and services. Such impacts result from the production, use and end-of-life management of all hardware involved in the provision of, in the case of telecom operators, a service. In the case of operators, such hardware can include antennas, routers and switches, and base stations (Rouphael et al., 2023)

Enabling impacts (Mickoleit, 2010), second order or secondary effects (Hankel et al., 2018; Köhler & Erdmann, 2004) are impacts derived from the use of ICTs that aid the reduction of environmental impacts across sectors due to ICTs' potential to change, modify or optimize processes; however, such changes may also lead to negative effects that need to be considered, such as the higher energy consumption from ICT-enabled systems in comparison to conventional systems (Mickoleit, 2010; Radonjič & Tompa, 2018).

Elaborating on enabling impacts, Mickoleit (2010) mentions four ways these enabling impacts can be achieved:

- *Optimization:* ICTs can help reduce another product's environmental footprint. This is exemplified in smart energy distribution systems, where ICTs enable fewer transmission and distribution losses.
- *Dematerialization and substitution:* ICTs and their related advances can drive the replacement of physical products or processes by digital ones. Examples of this include teleconferencing, which can reduce the need for business travel, and the replacement of physical media in favor of digital versions, such is the case of music or printed media.
- *Induction:* these impacts occur when ICTs help increase the demand for other products; for example, in the case of teleconferencing, this could lead to an increase in the demand for improved video or sound systems.
- *Degradation:* the embedding of ICTs in products can create complications for that specific product during its life cycle; for example, during end-of-life treatments, where embedded ICTs may require additional steps for product recycling or material recovery processes.

Finally**,** Mickoleit (2010) describes *systemic or third-order impacts* (Köhler & Erdmann, 2004) of ICTs as those involving behavioral shifts and non-technological factors, including intended or non-intended consequences, arising from ICT application. Expanding on this, Hankel et al. (2018) characterize these impacts as the environmental effects stemming from medium and long-term behavior and reconfigurations of economic structures due to the widespread availability of ICT products and services. These systemic impacts can have an indirect impact on ICT hardware (direct impacts) and permeate other processes and industries (enabling impacts). An example of this is access to information, which, while bridging gaps across sectors or individuals, fosters technology adoption that, in turn, can lead to behavioral changes in consumption patterns that can result in additional direct and indirect impacts (Mickoleit, 2010).

Systemic impacts can lead to rebound effects, where improved access to information or energy efficiency gains can reverse or reduce the positive impact of the use of ICTs (Hankel et al., 2018). Coroama & Mattern (2019) describe rebound effects as varied mechanisms that could reduce the potential resource and energy savings brought by, for example, energy and resource efficiency gains in ICT products. These rebound effects take place when initial positive effects make a good or service more attractive, increasing their demand and thus leading to greater consumption of energy and materials potentially offsetting initial positive outcomes (Plepys, 2002).

3.1.1.4.1 The LES framework

This classification of the environmental effects of ICT is further detailed and operationalized by Hilty & Aebischer (2015) in their descriptive *"LES Model"*. This model also comprises three levels of impact, namely: life-cycle impact (L, level 1), Enabling Impact (E, level 2), and Structural impact (S, level 3).

Life-cycle impacts (level 1) reflect the definitions previously mentioned by Köhler & Erdmann, (2004) and Mickoleit (2010)highlighting that the total impact should be allocated to a functional unit of the service it produces during the use stage. The authors mention life cycle assessment (LCA) as the method of choice for assessing these impacts since they connect the action of providing ICT or telecommunications services to the use of natural resources.

The enabling impacts (level 2) reflect previous research and on top of the enabling mechanisms mentioned (optimization, dematerialization and substitution, induction and degradation), Hilty & Aebischer (2015) add the externalization of control as an enabling impact; indicating that if a process requires information as an input, the control over that process can be externalized. Problems like obsolescence and emerging risks can be explained by the externalization of control; the former can occur if a provider of information resources stops providing it (e.g. decommissioning of 3G infrastructure would leave 3G devices out of use), while the latter can happen since ICTs and networks have a factual vulnerability that can be exploited externally.

Finally, the Structural Impacts (level 3), also resemble third-order effects; though Hilty & Aebischer (2015) provides a more comprehensive view of these impacts, highlighting the far-reaching consequences of digitalization and ICT. These impacts are referred to as the ICT impacts that drive persistent changes noticeable at the macro level leading to structures changing from the actions performed at the micro level (life cycle of ICTs and their use). The authors point to two structural impacts over which ICT has a significant influence. The first is the structural change, defined by the authors as any transition of economic structures, where dematerialization (the aggregate result of life-cycle and enabling impacts) and the networked economy (mainly enabled by the Internet) are crucial in driving changes in resource use and consumption. The second change influenced by ICT mentioned in this framework is related to institutions (defined by the authors as anything immaterial that shapes actions, such as policies or social norms), over which ICT can have a role in their evolution, citing positive impacts like accessibility to banking, or enhanced environmental monitoring (Hilty & Aebischer, 2015).

The authors point out that the presented framework is not meant to be exhaustive, highlighting that level 2 and 3 impacts present several complexities and challenges, such as the lack of a comprehensive methodology for their assessment, unlike the case of level 1 impacts.; thus additional, potential changes are included in the framework as "other changes" encompassing different technological, organizational, behavioral, structural, and institutional changes. A graphical representation of the LES framework is provided in Figure 3, and it is worth noting the lack of a direct connection between Level 1 and Level 3 impacts since Level 2 impacts constitute the bridge between those two levels.

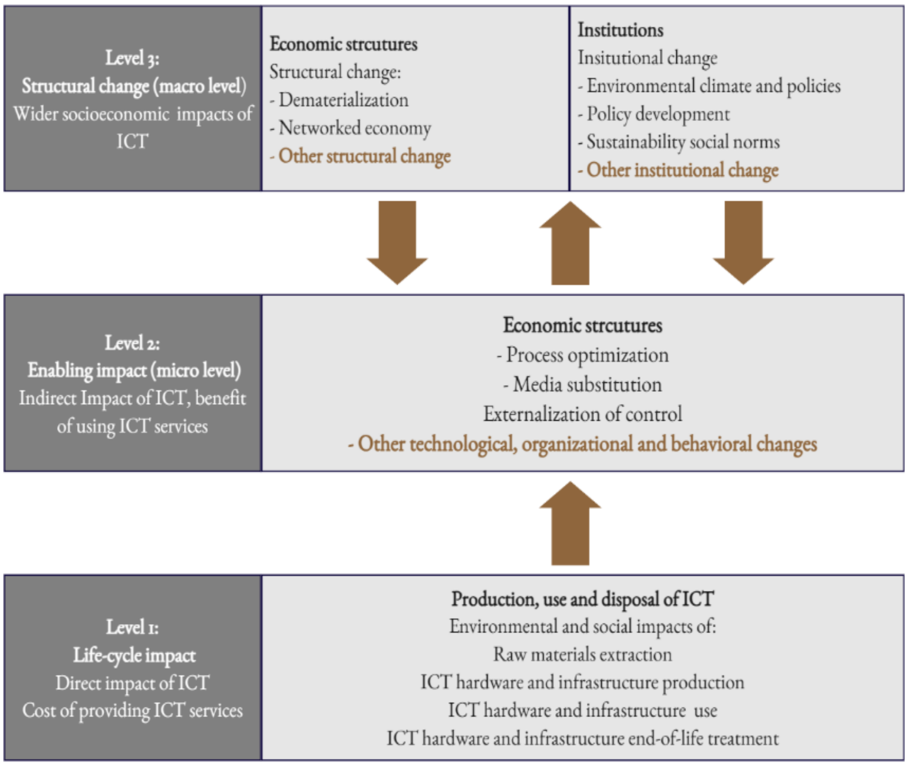

Figure 3 The LES framework for assessing ICT's environmental sustainability
Source: Adapted from Hilty & Aebischer (2015)

3.1.1.5 ICT and Telecom operators: their direct environmental impacts

The telecommunications sector is comprised of several layers of complexity, and so does their environmental impact assessment. Research around the direct environmental impacts has been rather complex, often carried out focusing on the whole ICT sector, which includes networks (telecom operators), data centers, and user devices (Freitag et al., 2021). ICT's direct impacts occur throughout the whole life cycle of all devices involved in the telecommunications service provision, meaning that these impacts can have repercussions on several impact categories such as global warming, primary energy use, toxicity, resource depletion, land use, water use, ozone layer depletion, and biodiversity (Mickoleit, 2010).

Direct environmental impacts are key to understanding the environmental impact of the ICT sector and telecom operators, the latter being critical for the ongoing digitalization as it provides the infrastructure required for all modern communications through which digital services and products can be delivered and consumed (NGMN, 2021b; Radonjič & Tompa, 2018). Year after year, the demand for computing power, storage capacities, data transmission, and devices has deemed digital consumption unsustainable, mainly in terms of energy and materials consumption. Although the sector has made significant progress in terms of energy efficiency, in terms of hardware or software, the demand and consumption are expected to even outweigh such gains (Itten et al., 2020). In fact, according to Itten et al. (2020), the exponential growth of devices, network traffic, and stored data is responsible for the increasing carbon footprint of ICT, estimated by the authors at an 8% annual rate.

Direct environmental impacts have been of relevance to scientific research, and in the past decades prominent works on ICT environmental sustainability have mainly focused on two core aspects: GHG emissions and energy consumption, since these are depicted as the most critical aspects of environmental performance from an environmental perspective (Scheck & Kallio, 2013). Such studies analyze telecom operators individually, as a component of the ICT sector, or coupled with other sectors like entertainment and media (Malmodin & Bergmark, 2015; Malmodin & Lundén, 2018, 2018), highlighting the interdependencies telecom operators have with other sectors.

Telecom operators: their GHG emissions and energy consumption.

Although the ICT sector, and TOs as part of it, is currently as small contributor to global GHG emissions, the sector is expanding along with its impact this and the following decade (Freitag et al., 2021; Itten et al., 2020). Research focusing on telecom operators is addressed by (Malmodin et al., 2014; Malmodin & Lundén, 2018). From a top-down approach, (Malmodin & Lundén, 2018)assessed operational electricity consumption and GHG emissions of telecom operators between 2010 and 2015, considering the fixed and mobile telecom networks, excluding data centers and end-user equipment. The authors collected data from approximately 15% of the global fixed subscriptions and around 40% of the global mobile subscriptions and conducted extrapolations to global levels. Their findings revealed that for 2015 the global energy consumption from telecom operators was estimated at 242 TWh, corresponding to 1.15% of the total electricity grid supply. Additionally, the operational carbon emissions were estimated at 169 $MtCO_2e$ for 2015, representing around 0.34% of global carbon emissions, estimated at around 50 $GtCO_2e$. During the period analyzed, electricity consumption from telecom operators increased by 31%, and GHG emissions experienced a 17% growth. From the two segments analyzed, mobile networks are the ones experiencing the most increases in both energy consumption and GHG emissions due to increasing number of subscriptions. A key aspect mentioned by the authors is that voluntarily provided data from operators allowed a more granular analysis, which could have been more difficult to perform based on data available in annual reports (Malmodin & Lundén, 2018). The previous study follows the approach presented in (Malmodin et al., 2014) where they conducted and LCA-based study on the life-cycle-based carbon footprint from ICT in Sweden, using detailed inventory data provided by Ericsson and Telia Sonera and user-behavior information. In this study, data pertaining to user equipment (e.g., mobile phones, desktop computers), networks, telecom operators' own activities (e.g., business travel, vehicle fleet), and data centers were analyzed. The authors estimate the carbon footprint of ICT in Sweden at 1.5 M, from which 0.65 Mt can be attributable to the telecom operators and their consumers. The largest share of the footprint is attributed to end-user equipment (mainly during the manufacturing stage), followed by data centers and networks.

More recent research is provided in Freitag et al. (2021) which analyzes several studies on the whole ICT sector's climate impact. The authors mention that the scientific debate on ICT's carbon footprint intensified around 2015, and focuses on analyzing relevant literature, including the work of Andrae & Edler (2015), Belkhir & Elmeligi (2018) and Malmodin & Lundén, 2018). The analysis confronts the different results obtained by previous research; for example, the literature analyzed indicate that ICT is responsible for between 1.8% to 2.8% of global GHG emissions for 2020; it is estimated that networks (telecom operators) are responsible of 22% - 35% of the ICT sector GHG emissions. Moreover, the authors claim, that the GHG emissions from the ICT sector can be up to 3.9% of global emissions by including all supply chain pathways This study also notes that available studies tend to make omissions around growth trends in areas such as embodied emissions, Internet of things (IoT), artificial intelligence (AI) and blockchain technologies, which are likely to significantly contribute to an increase in energy consumption and emissions. Also, it is noted that the ICT sector has improved significantly its energy efficiency, but there is a the need to constrain the ICT consumption so the current efficiency gains translate into actual emissions reductions; this is currently not the case since the demand for ICT-enabled devices, subscriptions, and number of devices per person have outpaced the energy efficiency gains improvements, and thus increased the ICT sector's energy consumption and GHG emissions. Concerning telecom operators, the authors highlight that while the deployment of next-generation networks has improved efficiency, it does not necessarily guarantee the replacement of outdated legacy equipment. Furthermore, as new user habits and devices emerge, they may counteract the benefits of replacement (Freitag et al., 2021).

Circularity within the telecommunications industry, understanding the circular economy as a system where materials and products are kept in use and circulation via processes such as maintenance, reuse, refurbishment, remanufacture, and recycling (Ellen MacArthur Foundation, 2017), has been mainly focused on end-user devices (GSMA et al., 2022), and limited literature covers network infrastructure. On this, a study from Andrae (2023) touches on the topic of circularity for large ICT network infrastructure and highlights that circularity paths must be different for different product groups. With that, the author mentions that the reuse and refurbishment of large ICT network Infrastructure may not always be environmentally beneficial, especially considering if there are energy efficiency (higher than 10%) improvements in new equipment. The author further indicates that circular economy initiatives do not always benefit sustainability, especially in business-to-business equipment like network infrastructure, whose life cycle differs vastly from consumer goods like routers or mobile phones (Andrae, 2023).

Telecom operators and (environmental) sustainability reporting

The progress around sustainability matters is documented via corporate sustainability reports, which, in addition to financial reporting, integrate information about environmental, social, and economic aspects relevant to the companies, their stakeholders, and society (Dincer et al., 2023). This type of reporting depicts the companies' capacity for self-regulation, providing a mechanism for the improvement of their environmental and social performance (León & Salesa, 2023). A company reporting on its sustainability performance can do so as part of a signaling effort that seeks to reduce information asymmetry among the firm and its stakeholders about specific aspects, positive or negative, that would otherwise be unknown (Famularo, 2023; León & Salesa, 2023). Also, sustainability reporting can be part of companies' efforts to achieve legitimacy by responding to stakeholders' and society's transparency claims, justifying their corporate activities, and improving their relationship with them (Dincer et al., 2023; León & Salesa, 2023). For a specific aspect to be included in a sustainability report, it needs to be considered material: that is, it must have a direct or indirect impact on the companies' economic, social, and economic performance, with relevance to the companies' stakeholders and society at large (León & Salesa, 2023).

Radonjič & Tompa, (2018) highlight the relevance of assessing telecom operators' environmental performance at the organizational level in response to rising energy and carbon footprints, increased stakeholder scrutiny, stricter regulations, and voluntary commitments to improve their environmental performance. As seen in previous sections, company data is relevant for conducting industry-level assessments, and telecom operators play a relevant role in identifying problems and challenges within the sector. Moreover, telecom operators are expected to disclose their sustainability performance, usually guided by standards or frameworks such as the Global Reporting Initiative (GRI) or the GHG Protocol. The GRI standards are a set of sustainability standards that aid organizations to disclose information on economic, social and environmental aspects. On the environmental aspects, these standards cover topics such as materials, energy, emissions, waste, water and biodiversity (GRI, 2020). In the case of the GHG Protocol, is a standard for measuring, managing, and reporting GHG emissions. Under the GHG protocol emissions are categorized direct emissions (Scope 1), indirect emissions from purchased energy (Scope 2), and other indirect emissions from upstream and downstream in the value chain (Scope 3) (Bieser et al., 2023; Greenhouse Gas Protocol, 2011). The GHG Protocol has been widely recognized worldwide as a template for organizations to assess and disclose their GHG emissions (Patchell, 2018).

The voluntary nature of these two main standards (GRI standards and GHG Protocol) can lead to underreporting from companies; for example, in the case of telecom operators, most of their GHG emissions correspond to Scope 3 emissions, yet this figure is often presented as an aggregated figure, hampering the identification of specific areas of concern, considering that the GHG protocol entails 15 subcategories (8 upstream and 7 downstream). In this case, emphasis is placed on the GHG protocol since it is the base for different frameworks, like GRI and other environmental, social, and governance ratings, such as CDP (formerly Carbon Disclosure Project).

As a result, the varied ways of approaching the reporting in telecom operators can lead to unclear assertions of their impact, performance, and trends; as a result, several efforts have been placed to bring uniformity to sustainability disclosures in the form of new frameworks or sets of key metrics, such as GSMA's ESG metric for mobile (GSMA, 2022), or the more recently proposed set of indicators for telecommunications networks' environmental footprint arranged by the European Commission (Baldini et al., 2024), in response to the continuous growth of data traffic and the required expansion of network infrastructure to cope with that demand.

This literature review combines aspects that pertain to the direct environmental impacts of telecom operators. Starting with the conceptualizations of the environmental impacts in the LES framework, it further explores how research has been directed on the topic of direct environmental impacts on telecom operators, where it is possible to see that there is not abundant literature that examines exclusively telecom operators and that most evidence points towards energy and emissions since those are the hotspots of the industry; limited research is neither found for other aspects. Finally, sustainability reporting is presented as a key instrument for companies to communicate and track their progress, but at the same time, those disclosures risk being incomplete or inaccurate due to a lack of standardization of metrics and procedures, which can make it difficult to comprehensively evaluate the impact of the sector. Considering the relevance of company-level data for understanding the overall impact of the sector, this study examines corporate sustainability reports from selected companies headquartered in the European Union in order to understand further the current status of their direct environmental impacts, as well as the trends and challenges surrounding the environmental performance and reporting in accordance to applicable frameworks and standards.

A visual representation is presented below.

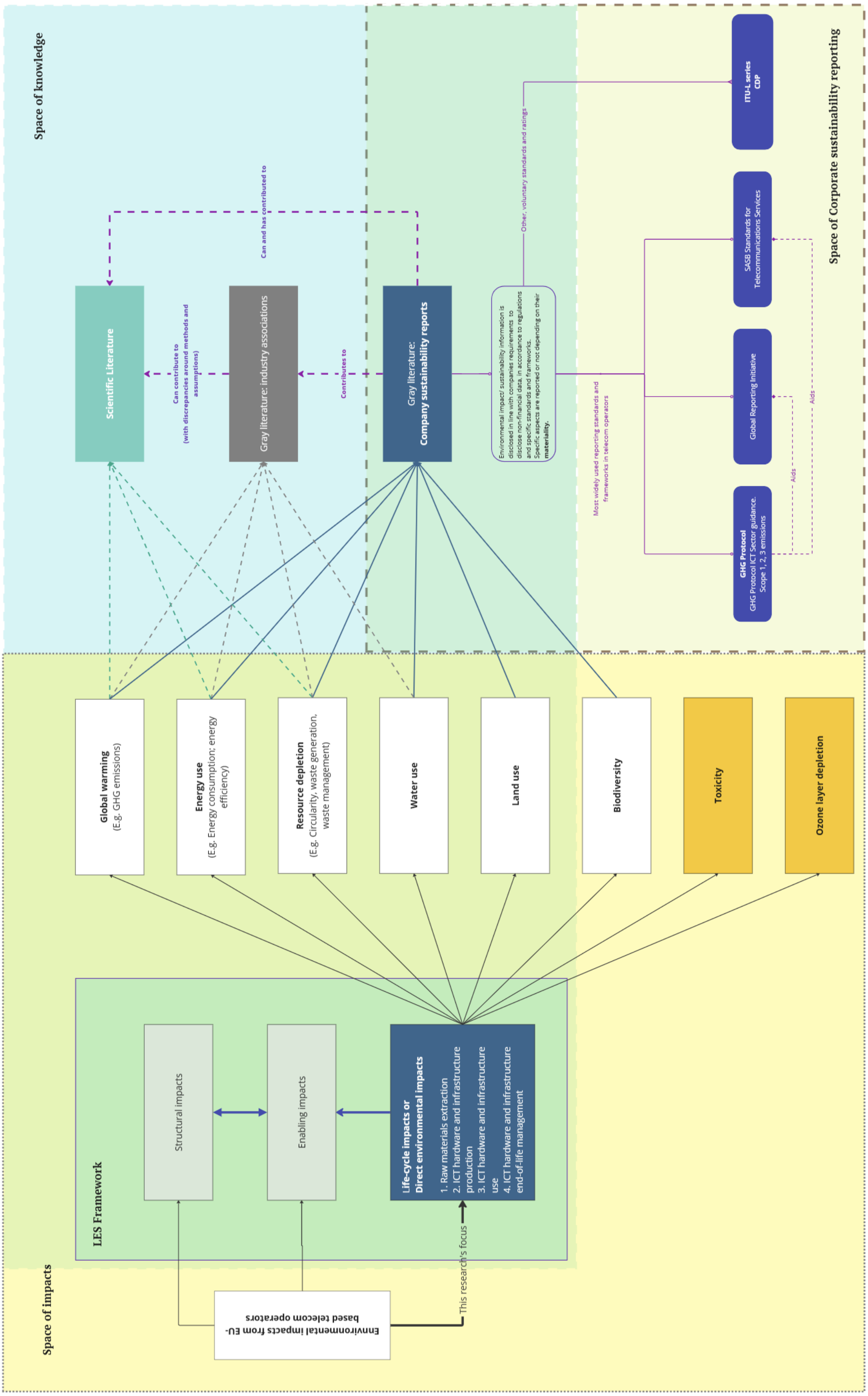

Figure 4 Visual representation of the core aspects of the conducted literature review
Source: Author's own

4 Results and findings

This section provides insights into the environmental performance of selected telecom operators headquartered in the EU and is guided by the LES conceptual framework explained in Figure 3, focusing in the direct environmental impacts. The first stage of this study identifies the environmentally relevant and material topics from these selected operators and identifies trends in these environmental topics over a four-year period. Finally, it presents an overview of the different reporting standards and frameworks the selected operators adhere to. The second stage builds upon findings from Stage 1. Through semi-structured interviews, six practitioners provide a broader perspective on the different trends and challenges the telecom operators face as part of the digital revolution. Before detailing the results from these two stages, a description of the selected companies is presented below.

4.1 Description of the selected companies

The selected four companies, A1 Telekom Austria Group, Deutsche Telekom, Orange SA, Telefonica, and Telia Company present an interesting case for exploring direct environmental impacts from telecom operators; these companies share common attributes, such as their wide coverage, provision of a technology mix that encompasses both fixed and mobile broadband, and available sustainability reporting. Moreover, the five companies operate in an ample geographical scope, in some cases beyond Europe, so the results can also integrate a broader market context. The four-year period selected allows for capturing any significant changes in trends of the selected operators' environmental impacts.

A1 Telekom Austria Group is a leading telecommunications provider in Austria, and Central and Eastern Europe, serving over 24 million customers in 7 countries. It offers fixed and mobile telephony, broadband internet, multimedia services, IT solutions, and wholesale services. As of 2021, A1 had around 5 million mobile and 3 million fixed-line subscribers in Austria, with a 49.2% market share in broadband and 38.6% in mobile voice. The group is majority-owned by América Móvil and has over 17,500 employees (A1 Group, 2023). Deutsche Telekom is one of the world's leading integrated telecommunications companies, with around 242 million mobile customers, 27 million fixed-network lines, and 21 million broadband lines. The company provides fixed-network/broadband, mobile communications, Internet of Things, and information and communication technology solutions for business customers. Deutsche Telekom is present in more than 50 countries worldwide and has over 200,000 employees (Deutsche Telekom, 2023). Orange SA is a French multinational telecommunications corporation present in 26 countries. It provides fixed and mobile telecommunications services, including voice, data, and other value-added services. As of 2021, Orange had 11 million fixed broadband customers and 224 million mobile customers globally (Orange, 2022).

Telefónica is a major global telecommunications company headquartered in Madrid, Spain, and it is one of the world's largest telephone operators and mobile network providers, with operations in Europe and the Americas. It offers various telecommunications services, including fixed and mobile telephony, broadband internet, subscription television, and digital services. The company has 383 million customers worldwide in the 12 countries it operates in. Telefonica has around 113,182 employees globally. Its principal subsidiaries and brands include Movistar, O2, and Vivo (Telefonica, 2023) . Telia Company is the dominant mobile network operator in Sweden and Finland, with a strong presence in Norway, Denmark, Estonia, and Lithuania. The company provides consumers and businesses mobile, broadband, and TV services. As of 2021, Telia had 17 million mobile subscriptions and 2.5 million fixed broadband subscriptions in the Nordic and Baltic regions (Telia Company, 2023).

4.2 Results towards RQ1: main trends from numeric analysis

4.2.1.1 Environmental Material Topics

The selection of material topics, including environmental ones, depends on the approach the reporting companies consider. The reports analyzed indicate stakeholder engagement and dialogue as the main approaches for identifying material topics. Apart from that shared characteristic, the companies under analysis show differences in their specific approaches and outcomes of their materiality assessments. Two companies provide more detailed descriptions of their materiality assessments: Deutsche Telekom and Telefonica; both indicate using a scoring system to determine the most material topics, and Telefonica provides an in-depth analysis of the materiality matrix. These two companies mention taking initiatives to align their reporting with yet-to-be-implemented regulations (by 2022) like the EU CSRD and the ESRS, contributing to changes in the wording of material topics to show the alignment. Only one company, Orange, presents a materiality matrix/assessment for only the years 2021 and 2022. Moreover, Telia discloses a list of relevant matters grouped by stakeholders during the same period.

Despite the differences in their approach to materiality, environmental aspects are consistently reported as material by the selected companies in the four years. Although there are differences in their wording, the material aspects can be grouped into eight categories, presented in alphabetical order below:

- Air quality: referred to as noise pollution.
- Biodiversity and other environmental impacts: Biodiversity aspects and land use.
- Circular economy: Including materials, waste, and water.
- Climate change: Including GHG emissions, and energy consumption.
- Energy: Proposed by Deutsche Telekom, this provides a more detailed overview of energy and electricity consumption but is covered within the climate change category.
- Environmental responsibility.
- ICT solutions for a low-carbon economy: Referred to the enablement impact at the societal level.
- Solutions to reduce client's environmental footprints: Enablement effect at consumer scale.

Figure 5 Illustrates the material topics identified by the reporting companies. Note that a materiality matrix summarizing these points could not be provided since the companies follow their own approaches to materiality as described previously.

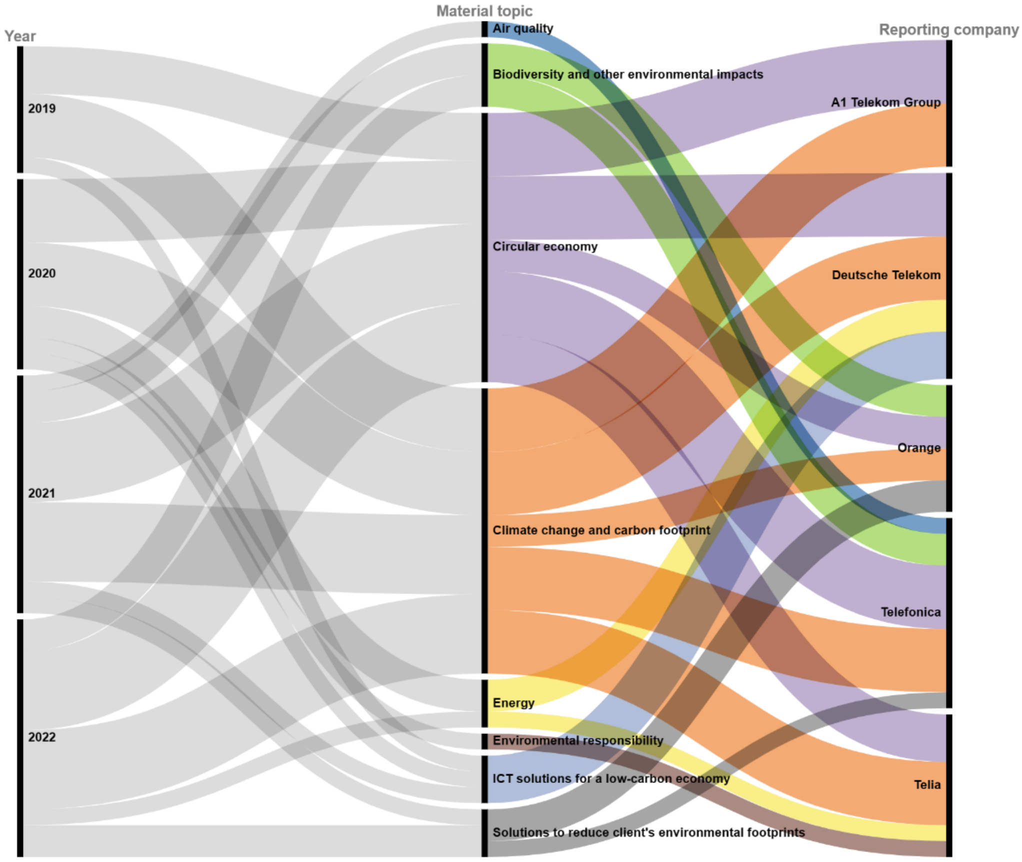

Figure 5 Categorization of material topics identified by the reporting companies in the 4-year period.

The data from Figure 5 shows climate change and carbon footprint are the foremost environmental aspects for the selected companies, and this category is consistently highlighted in reports throughout the four-year period. Circular Economy, encompassing resource management, waste management, e-waste management, and wastewater management, ranks as the companies' second most frequently addressed topic. Moreover, specific aspects such as biodiversity and other environmental impacts (Orange and Telefonica), energy (Deutsche Telekom), air quality (as reported by Telefonica), and environmental responsibility (Telia) illustrate that these specific aspects are of sufficient importance for the companies to warrant individual analysis by the reporting companies. All these material aspects are part of the life-cycle impacts of ICT; moreover, enabling effects are also identified as material by Telefonica and Orange (Solutions to reduce client's environmental footprints) and by Deutsche Telekom (ICT solutions for a low-carbon economy).

Having established the environmental topics prioritized by the reporting companies, the following subsections analyze how and what is reported in the telecom operators' sustainability reports. These subsections allow for a comprehensive exploration of the companies' disclosure practices, offering insights into the depth, quality, and evolution of reporting on each environmental aspect.

4.2.1.2 Climate change and carbon footprint and energy considerations

Climate change and carbon footprint

As seen in the Literature review chapter, climate change considerations are of great relevance to the telecommunications industry. From a corporate point of view, these considerations have been widely covered, with operators monitoring these aspects closely.

All the reporting companies report their GHG emissions following GHG Protocol for all Scope 1, 2, 3 emissions. However, there is no mention in these reports of whether these or not this is conducted following the ICT sector Guidance built on the GHG Protocol Life Cycle Accounting and Reporting Standard proposed by Carbon Trust & GeSI (2017) in 2017, which sets specific aspects for conducting carbon accounting within the ICT sector.

Within this assessment of GHG emissions from the selected companies, Scope 1 emissions (direct emissions from owned or controlled sources) show to be consistently the smallest share of the companies' overall emissions profile. These emissions include and are not limited to the combustion of fuels for heating and vehicle operations; only two companies present disaggregated results covering those aspects, Deutsche Telekom and Orange, with Orange being more specific by adding the emissions attributed to the use of refrigerants. The remaining companies report these emissions as an absolute value. The behavior of these emissions is different for each company over the four year period; where increases are found (6% for A1 Telekom, 14% for Orange); on the other hand, different levels of decrease are evident for the remaining companies: 16%, Deutsche Telekom; 45%, Telefonica; and 14%, Telia.

In the case of Scope 2 emissions resulting from the generation of purchased electricity, in the analyzed 4-year period, all companies present a downward trend; this reflects the companies' strategic shifts towards energy efficiency and renewable energy sourcing for reducing their GHG emissions. Over the period analyzed, the most drastic reduction of Scope 2 emissions is presented by Deutsche Telekom, managing a 99% reduction, seeing a drop in Scope 2 emissions from 2276607t$CO2_e$ in 2020 to 27290 t$CO2_e$ in 2021; a similar case is presented by Telia, showing a 94% reduction, going from 47000t$CO2_e$ in 2019 to 3000 tCO_2e in 2022. The remaining companies show reductions of 69% (Telefonica), 40% (A1 Telekom), and 10% (Orange). Scope 2 are the second largest share of GHG emissions in the analyzed companies.

Finally, the reporting of Scope 3 emissions presents the most variety among the three scopes. These emissions occur both upstream and downstream along the value chain, as established by the GHG Protocol, which covers 15 categories of supply chain activities. While there are less pronounced trends in the changes for these emissions, all reporting companies have reported reductions of 5% for Deutsche Telekom, 7% for A1 Telekom, and 9% for Telefonica. However, the reports for Orange and Telia do not specify the Scope 3 emissions for 2022, so the reductions are calculated for 2019 to 2021. During this period, Orange decreased its emissions by 3% and Telia by 9%. Reporting-wise, the companies present varied approaches to this type of emissions (See Table 3). The analyzed companies disclosed the information covering most of the 15 emissions categories. For instance, Orange reported 11 categories, including seven upstream and four downstream, while A1 Telekom has reported on ten categories, including six upstream and four downstream. On the other hand, Deutsche Telekom has reported on 11 categories, including seven upstream and four downstream. Telefonica and Telia, however, present aggregated figures for their entire Scope 3 emissions. It is worth noting that reports from the latter two companies indicate that data collection is conducted for specific categories; Telefonica, in its 2022 report, presents data on five categories (four upstream and one upstream). From the reported data on specific Scope 3 categories, "Purchased goods and services" is the most emitting upstream activity, while "Use of sold goods" is the most emitting activity downstream; moreover, the former is the largest GHG-contributing activity. Scope 3 emissions comprise the largest GHG emissions in the analyzed companies; as of the available 2022 reports, Scope 3 emissions are responsible for 84% to 99% of the total emissions. A visual representation of this finding is presented in Figure 5.

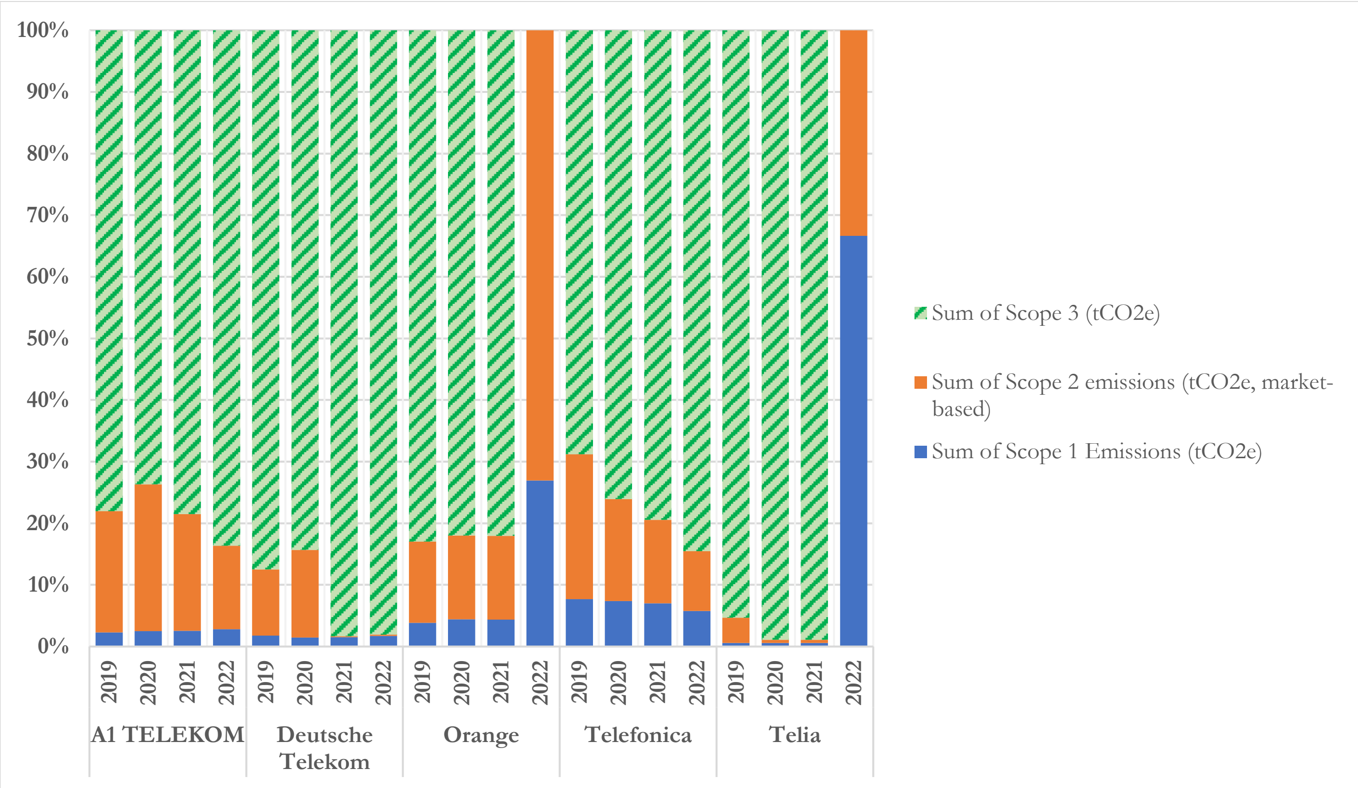

Figure 6 Breakdown of Scope 1, 2 and 3 emissions of the selected companies.
Source: Auhtor's own

Table 3 Breakdown of Scope 3 emissions of the analyzed companies. The one with the "Reported" label indicated that a company has considered a specific category for calculating the total Scope 3 emissions.

Company	Year	1. Purchased goods and services (tCO2e)	2. Capital goods (tCO2e)	3. Fuel and energy-related activities (tCO2e)	4. Transportation and distribution (tCO2e)	5. Waste generated in operations (tCO2e)	6. Business travel (tCO2e)	7. Employee commuting (tCO2e)	8. Leased assets (tCO2e)	9. Transportation and distribution (tCO2e)	10. Processing of sold products (tCO2e)	11. Use of sold products (tCO2e)	12. End-of-life treatment of sold products (tCO2e)	13. Leased assets (tCO2e)	14. Franchises (tCO2e)	15. Investments (tCO2e)	Total Scope 3 emissions (tCO2e)
A1 TELEKOM	2019	473945		50584	76664	572	1519	20400		25809		144148	48	657			794347
	2020	387705		43405	76664	352	414	20400		25809		167126	48	657			722580
	2021	420675		41579	76664	419	201	20400		25809		169786	48	657			756238
	2022	423043		41617	76664	423	880	20400		25809		148163	48	657			737705
Deutsche Telekom	2019	4699181	1797875	643215	259363	57271	88355	517215				3425357	19013	1062692			12569537
	2020	3627576	2279043	854387	1167527	30130	25046	237443				4202247	20538	1053875			13497812
	2021	4404506	2852758	613480	935520	67752	30845	192215				4250576	51857	1003448		0	14402957
	2022	3903545	3897133	546771	996482	58027	28726	218567				1347915	39575	891667		32616	11961024
Orange	2019	3277000	1749000	315000	66000	33000	38000	143000		143000		588000					6352000
	2020	3004000	1839000	352000	62000	30000	11000	139000		14000		528000					5979000
	2021	3034000	1884000	357000	62000	34000	6000	128000		12000		555000					6072000
	2022																
Telefonica	2019																2124279
	2020																2146226
	2021																2072159
	2022	1012000	226000	120000			21000					551000					1930051
Telia	2019	Reported	Reported									Reported		Reported			1105000
	2020																1150000
	2021	Reported	Reported	Reported	Reported	Reported	Reported	Reported				Reported	Reported	Reported		Reported	1006000
	2022																

As previously mentioned all the companies disclose this information considering the GHG protocol; moreover, these emissions are reported in adherence to the GRI Disclosure “305: Emissions”, as per their 2022 reports, by A1 Telekom, Deutsche Telekom, and Telefonica. For its part, Telia does not indicate specific adherence to GRI disclosures since the company has its own sustainability reporting framework that includes elements from GRI and other reporting initiatives. Orange does not present specific GRI disclosures in their reports but indicates their reports are performed following GRI reporting recommendations.

Energy considerations

Energy consumption is a crucial factor in the context of climate change for telecom operators since the majority of their operational impact arises from energy use. Consequently, these operators have placed considerable attention to this aspect of their operations. As previously mentioned, the greenhouse gas emissions related to energy consumption (Scope 2) exhibit consistent reductions across the selected companies. The primary reasons for these reductions, according to the analyzed reports, are the adoption of renewable energy sources and the implementation of energy efficiency measures and equipment. The reporting is, again, varied from company to company, being more granular by companies like A1 Telekom, Deutsche Telekom, Telefonica, and Telia, while Orange provides only aggregated energy-related data; yet all companies report on their absolute energy consumption and renewable energy adoption.

Reductions in energy-related greenhouse gas emissions do not always result in reductions in energy usage. The energy consumption profiles of the companies varied over the four-year period. In terms of absolute energy consumption, Telefonica was the only telecom operator analyzed to achieve a decrease (12%) in energy consumption. Conversely, Orange saw a slight increase of 0.4%, while Telia's increase was 1.3%. A1 Telekom experienced a more significant rise of 11.2%, and Deutsche Telekom recorded the highest increase at 42.1%.

Telecom operators have actively prioritized the adoption of clean energy, with all firms making substantial advancements in this area over the span of four years. As of 2022, Orange has increased its renewable energy use to 38%, A1 Telekom to 68%, and Telefonica to 82%. Additionally, Deutsche Telekom's reports indicate it reached 100% use of renewables by 2021, while Telia’s data reflects it operated entirely on renewables throughout the examined period. Furthermore, the increased adoption of renewable energy and improvements in energy efficiency have had positive effects on the energy intensity (energy used for transmitting one unit of information, kWh/Terabyte) among reporting companies on this aspect (A1 Telekom, Deutsche Telekom, and Telefonica). All three companies demonstrated notable reductions in this regard, with A1 Telekom making the most substantial improvements.

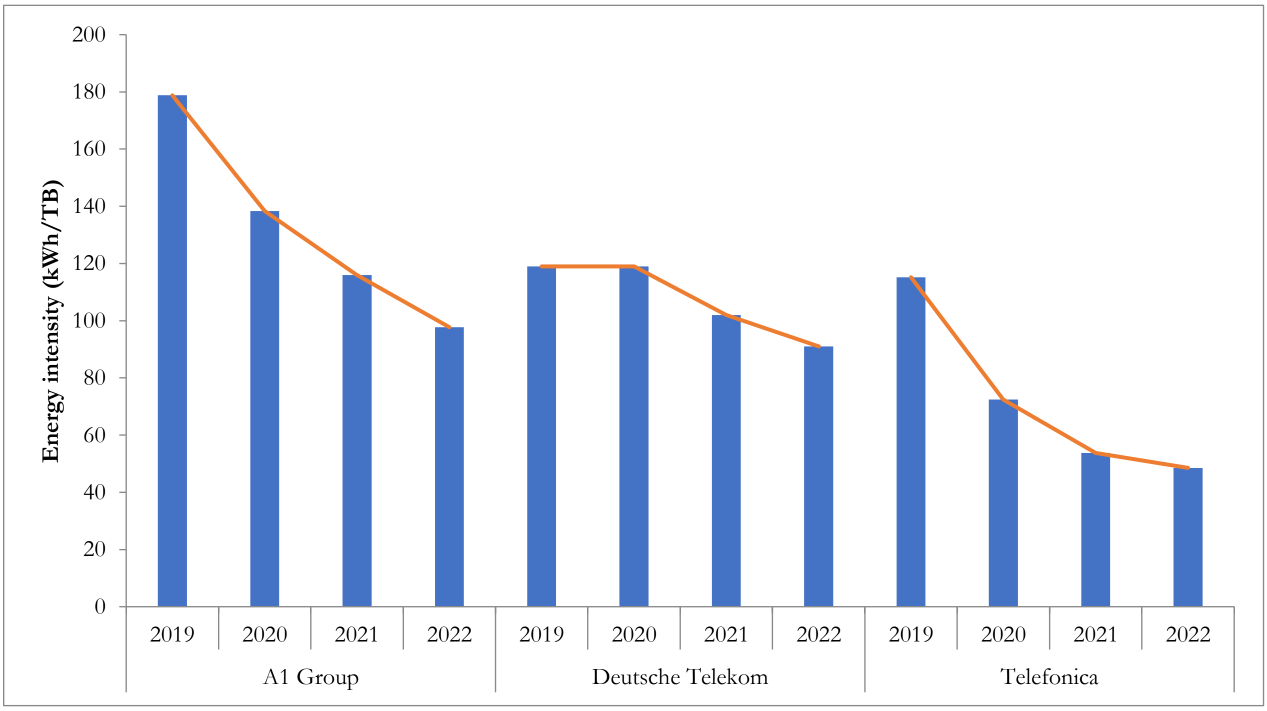

Figure 7 Energy intensity evolution of reporting companies
Source: Author's own

Circular economy: waste, waste management, water and other resources

The circular economy has become a significant part of telecom operators' operations. The most addressed and reported-on element of the circular economy is the management of end-of-life infrastructure and end-user devices, such as antennas, network equipment, mobile phones, routers, and set-top boxes. While all of the companies under examination report on the waste generated and managed, they perform this reporting using their own waste categorizations. Given this lack of homogeneity, individual summaries of waste management are presented for each company. In general, their approach to circularity is gradually shifting towards waste prevention, incorporating reused and refurbished devices as part of their product lineup. Each company has established targets for the collection of end-of-life devices; moreover, when it comes to network equipment, Orange and Telefonica have established reuse targets.

A1 Telekom reports considering higher-level waste categorization of recyclable (paper, metal, and others) and non-recyclable (including electronic waste, batteries, and mobile phones) waste. Over the analyzed period, the non-recyclable fraction generated the most waste. Moreover, the reports do not mention the end-of-life treatments provided for each reported fraction.

Orange categorizes waste into hazardous and non-hazardous categories. The first category integrates network waste electric and electronic equipment (WEEE), household WEEE, wooden poles, batteries, and other hazardous waste; the non-hazardous fraction includes cables, metal poles, paper and cardboard, and other non-hazardous waste. Waste generation fluctuates between reductions and increases for the two waste categories over the 4-year period. A closer look at the hazardous fraction indicates that the most generated fraction corresponds to wooden poles (infrastructure), followed by household WEEE and network equipment. Orange considers waste as recovered when it is entrusted to a service provider that can provide all the documents needed to ensure its traceability from recovery to processing (Orange, 2022) This company provides recovery rates for all reported waste streams; for the year 2022, the recovery rates ranged from 43% to 87% for Household WEEE.

Telia reports from 2020 to 2022 and considers two main categories: construction waste and hazardous waste. For its part, Telia considers construction waste, electronic waste (hazardous waste), hazardous (electronic waste, batteries), and office waste. Construction waste constitutes the largest amount generated by this operator.

Deutsche Telekom presents a more detailed categorization entailing hazardous waste, technical waste (nonhazardous), paper waste, residual waste, and other waste; the largest share of waste generated is nonhazardous waste, which has consistently been this operator's largest waste generator.

Other materials aspects

Despite being considered material; land use and biodiversity concerns are only described via claims in the report. Both Orange and Telefonica mention these aspects that their activities and current deployments do not conflict with biodiversity issues or land use.

Moreover, the enablement impacts from their connectivity solutions are presented by Deutsche Telekom and Telia Company; both operators do not disclose the methodologies for their claims of enablement but indicate achieving enablement in aspects such as transportation, remote work, and smart cities.

General findings on reported aspects.

GHG emissions and energy:

The companies under analysis have managed to reduce their GHG emissions during the analyzed four-year period. Scope 1 emissions have experienced varied changes in the reporting companies; three of the five companies have reduced their direct emissions, with Telefonica making the most significant reduction between 2019 and 2022; on the other hand, Orange presented a 14% increase. Scope 2 emissions are where the analyzed companies have made the most noticeable progress since they all present reductions between 10% (Orange) and 99% (Deutsche Telekom).

The significant reductions in energy-related emissions do not mean that the energy footprint of the companies has also reduced; in fact, only Telefonica's data has managed to reduce its total energy consumption (12%). Also, an effect of the use of energy-efficient equipment is the drop in the energy intensity, considering that the companies reporting this metric have managed to reduce this intensity by between 21% and 45%. for the company with the most improvements.

Finally, Scope 3 emissions remain the biggest challenges for telecom operators in terms of their climate impact, and the analyzed companies have made the least progress on this aspect, with upstream emissions representing the highest share of GHG emissions for all companies.

Reporting:

The GHG Protocol is widely used and accepted by the analyzed companies, but it is up to them to disclose specific information at a more granular level. Despite some companies reporting on many of the 15 categories for Scope 3 emissions, nothing is mentioned about data quality or collection methods. The Carbon Disclosure Project (CDP) is highly relevant for some of the reporting companies; it requires more extensive data provision on climate impacts, and all companies have reported to this disclosure. Moreover, the SASB standards for telecommunications are only mentioned by 2 companies. Also, the GSMA metrics for mobile are only mentioned by one company, and the ITU recommendations are not mentioned by any of the companies under study.

Circularity, materials and waste:

Waste and waste management have been the proxy for a circular economy in the selected companies. The main aspects of circularity are related to product reuse and recycling. End-of-life treatments are not documented for all waste streams. It is not possible to define a trend in waste generation since this could depend on product life cycles; furthermore, each company has its own waste classification, making comparisons difficult. Similarly, this happens with different, if mentioned, end-of-life treatments. Shifts from end-of-life management towards a more comprehensive approach, including device collection and sale of reused devices, are the main strategies mentioned by the companies during the 4-year period.

Apart from GRI disclosure 306 on waste, no specific standard is mentioned. Even though the SASB standards, ITU recommendations, and GSMA ESG metrics cover aspects of circularity. With the lack of guidelines around these, companies tend to back up their actions with specific claims.

4.3 Qualitative analysis on trends and challenges:

As evidenced in the preceding sections, the emphasis on environmental sustainability reporting in the chosen companies is predominantly concentrated on the areas of climate change, GHG emissions, and energy consumption and efficiency. Although less prominent, there is a growing focus on topics like circularity, materials, and waste management. It is worth noting that the reporting practices for these topics vary from one company to another, with some providing more detailed and specific information, while others adopt a more general approach. Examples of these discrepancies may include differences in the specificity of the information provided or variations in the interpretation of concepts established in widely adopted frameworks.

The voluntary nature of reporting and the adoption of specific frameworks and standards lead to variations, which frequently result in challenges when comparing reporting companies' performance due to differing aggregation levels or missing data. As a result, even when a topic is reported, it may not be thoroughly examined. The lack of uniformity or standardization has fueled discussions within the sector to address this situation. In addition to well-known standards and frameworks, such as the GHG protocol and the GRI and SASB Standards, some specific frameworks and metrics are suggested for the purpose of harmonizing these disclosures, aiming for comparability within the sector, alignment with stakeholders' interests and regulations, and for the promotion of transparency in the sector. Examples of these efforts towards standardization include the ITU L series recommendations and the GSMA's Environmental, Social, and Governance (ESG) metrics for mobile (GSMA, 2022) , which builds upon GHG protocol, GRI, and SASB standards. None of the analyzed companies indicate adherence to the ITU's recommendations in their reports, and limited adoption of GSMA's metrics is seen with only one company reporting on it, although all the companies have been part of developing such metrics (GSMA, 2022). More recent efforts towards harmonized metrics, specific to telecom operators are presented in the European Commission's Common Indicators for ICT environmental performance (Baldini et al., 2024).

According to Creswell & Creswell (2018), in an exploratory mixed methods design, the quantitative exploration informs on aspects to be covered through a qualitative inquiry, as a means to explore the initial quantitative results further. Considering the findings, such as trends on reported aspects, challenges in comparisons, and the variety of reporting frameworks and their adoption (which can also be limited), six interviews were conducted to further elicit trends and challenges around telecom operators and their environmental performance and reporting (See Interview guide in Appendix 1). The interviewees comprise a variety of stakeholders related to the telecommunications industry, which allows for a broader perspective on the research topic.

The identified themes are presented and described on the following subsections.

4.3.1.1 Confirming and eliciting trends and challenges on environmental performance and reporting.

4.3.1.2 Climate change, carbon emissions and energy

When talking about the environmental performance of telecom operators, all respondents indicate the sector has made significant progress There is consensus that the use of improved infrastructure, for example, fiber optics instead of copper wire for fixed broadband, coupled with less energy-intensive transmission technologies (5G replacing legacy technologies like 3G) and increased adoption of renewable energy, have been essential for achieving improvements in terms of the industry's overall environmental performance. From the equipment provider side, there is ongoing work in decoupling energy from data consumption (meaning despite increased data consumption, the same or less energy is demanded) by increasing the energy efficiency of networking equipment, which can be translated later into reduced emissions and energy consumption from telecom operators. Moreover, FR indicates that network infrastructure has also seen gains in material efficiency with each generation of technologies. The multiple efficiency gains, according to R2, have positively impacted relative indicators (e.g., tCO_2e/GB) from telecom operators, showing partial or substantial improvements, but in terms of absolute emissions or energy consumption, that is not necessarily the case.

On the latter point, although technological advances have led to improvements, the ongoing expansion of both fixed and broadband networks and increasing data traffic are set to increase telecom operator's emissions (mainly Scope 3 emissions) and energy consumption (EP, R1). Particularly, the need for increased coverage, as operators are required to install new stations, is likely to offset any potential gains from energy-efficient equipment. Elaborating on this, R1 emphasizes that the increase in emissions is not directly attributable to the increase in data traffic but rather the requirements placed on operators (referring to the case of France), which are required to provide the same level of connectivity even in areas where there is no such demand.

Climate change has also posed risks on network infrastructure, says R1, with climate-related service disruptions growing in frequency and demanding more maintenance to keep the service quality optimal; in this sense, maintenance procedures are set to increase the operators' environmental footprint, although maintenance is currently excluded from certain industry-level assessments. R1 also mentions that both data traffic stabilization and decreased infrastructure deployment are necessary for telecom operators to stay on track with their SBTs, at least in France.

4.3.1.3 Circularity

As seen in the reviewed sustainability reports, and other industry-level documentation, the implementation and reporting of circularity have been consolidated as a crucial aspect of the industry's environmental performance. This is exemplified in the approaches to circularity taken by operators, which have mainly focused on aspects of product and infrastructure end-of-life management, and continuously evolved towards more comprehensive approaches, covering aspects such as eco-design, reverse logistics, and product design (EP). At the operational level, circularity practices such as equipment reuse (FR) and the use of low-carbon concrete in base stations (R1) in network infrastructure are seen as relevant in both environmental and financial terms by telecom operators, and significantly less complex, in terms of logistics and supplier engagement, than actions over aspects beyond the operators' own operations.

Moreover, there is increasing interest in embedding circularity as a core element of the operators' business model, such as the adoption of a device-as-a-service and the sale of reused or refurbished equipment. In this case, TO indicates that these actions can have different results, depending on the specific needs or demands of customers or markets where these actions are implemented. Also, R1 mentions that business model innovations are being explored by operators for their network infrastructure. For instance, increased interest is being placed in the lease of network equipment, which can lead to increased longevity of equipment, although R1 notes that this would shift the burden of maintenance to equipment providers and that, currently, this model might not be of interest for current equipment providers.

Furthermore, TO adds that for telecom operators, circularity is complex mainly upstream in the value chain, in terms of materials and design, as these are aspects where operators have less control compared to end-user devices where, despite complexities, there are already established mechanisms for their management, such as take-back systems. Both TO and EP agree that, in general, circularity has reached a wide relevance, and scrutiny over it is expanding to the whole life cycle of network equipment and end-user devices, unlike current practices restricted only to waste management and recycling.

4.3.1.4 Additional trends

Additional trends regarding the direct environmental impact from telecom operators have come to light because of stakeholder scrutiny. This includes the emergence of water and biodiversity-related impacts. According to TO, this scrutiny often arises in response to direct inquiries from stakeholders regarding aspects that may not be directly attributable to telecom activities but rather to their supply chain.

4.3.1.5 Enablement effect

Apart from their direct environmental impacts, the ICT sector, and thus telecom operators, have the unique characteristic of enabling savings in the emissions from different sectors (described in the section *ICT, telecom operators and environmental sustainability).* This enablement impact, avoided emissions as claimed by some companies in their reports, tends to cover and estimate the savings enabled by their solutions (e.g. IoT services) on areas such as smart buildings, smart transportation, smart cities, and remote work; such enablement has been claimed consistently by operators, vendors and industry associations (R1, R2, FR). Although interviewees agree that the enablement impact from telecom operators could be indeed significant, there is uncertainty about it; this is a reason why operators mention this with a certain caution. As pointed out by several interviewees (R1, R2, FR, TO), the main aspect driving uncertainty about the enablement effect is the lack of standardized methodologies and metrics for its assessment.

4.3.1.6 Reporting focus and main reporting frameworks and standards

4.3.1.7 Main frameworks

The adoption and adherence to different frameworks, standards, or even ESG ratings is mainly addressed by TO and EP. These practitioners highlight that the reporting landscape on environmental impacts and sustainability is constantly changing; highlighting that the biggest wave of changes is currently driven by the recently implemented European Sustainability Reporting Standards (ESRS) and the EU Corporate Sustainability Reporting Directive (CSRD); these two have been crucial in shaping ongoing corporate reporting processes. According to FR, the evolution and adoption of these regulations is expected to help increase the transparency of environmental sustainability reporting; particularly, under the CSRD companies are now required to justify the selection or omission of material topics.

Moreover, FR notes that sustainability reporting is getting stricter, and despite this, it is not as mature nor as regulated as financial reporting, which allows the current flexibility with which the operators adhere, fully or partially, to specific reporting frameworks and standards and enables the way this is communicated. But despite this, the evolution of reporting is an opportunity to raise the quality of disclosures for all sectors (pointing at the CSRD, which applies to every sector). Moreover, sector-specific standards can raise the quality of disclosures even more. FR emphasizes that increasing requirements from industry-specific standards might not lead directly to accurate figures (considering value chain complexity) but can provide the same rigor and eventually allow reporting to be more accurate.

EP and TO indicate the most relevant frameworks for reporting direct environmental impacts are the GHG Protocol for GHG emissions and the GRI Standards (for all material disclosures, including GHG emissions) and that currently most reporting efforts are performed to be compliant with the ESRS and CSRD. TO further mentions that the disclosures required by the CSRD are more stringent compared to other disclosures; nonetheless, recognizes significant overlaps among them, with the main difference being specific shifts in perspective. Another element underscored by practitioners TO and EP is the voluntary disclosure to ESG ratings. In both cases, they mention their companies voluntarily report to CDP, a global non-profit organization that rates companies, cities, and states on aspects like climate change, biodiversity, and water use via comprehensive disclosures. TO highlights that compared to other ESG ratings, CDP requires a more thorough approach, and that the accounting method is mostly reliant on the GHG protocol. EP also indicates the equipment provider also reports to CDP, suggesting that adherence to such disclosure has become indicative of an industry benchmark for some companies. In general, this reporting practice mainly responds to expectations from customers (EP, TO) and mainly investors, who are the ones also interested in other ESG ratings (TO).

In addition to stakeholder expectations or requests, the reporting landscape for telecom operators is heavily influenced by national regulations. R1 presents the case of ARCEP, the French regulator, which has implemented the Chaize Act in 2022 (ARCEP, 2022) which gives the operator the faculty to collect data annually on the environmental performance of the ICT sector, including telecom operators. R1 notes that this can improve reporting significantly, although challenges remain with the level of data granularity and resistance from certain operators both for disclosing information and for not adhering to specific frameworks but rather creating their own reporting standards (R1).

> *"I'm not sure if all the numbers are good for now, but [The Chaize Act] it's a huge leap forward for transparency because you have a sequence: first you look for transparency and then you look for quality. Having transparent and high-quality simultaneously is hard to get" (R1).*

Connected to this, TO acknowledges the complexity of reporting can lead to considering stakeholder requirements and regulations at different levels. Accordingly, this interviewee mentions that a best practice is to prioritize which frameworks, standards, disclosures, and ratings are the ones most relevant to compliance with regulations and stakeholders' expectations.

4.3.1.8 Challenges with reporting direct environmental impacts: frameworks, methods, and data (access and quality)

Adherence to different frameworks and standards: Coping with evolving frameworks and reporting practices

According to FR, numerous organizations strive to fulfill sustainability reporting requirements; however, there exists a prominent issue concerning the allocation and prioritization of resources. Some companies express concerns over the growing complexity of sustainability reporting, including the time and learning curve required. On this, TO adds that the complexity of sustainability reporting requires constant revisiting of the standards guiding the disclosures, especially for relatively new topics such as circularity. In this regard, PA shares that at the level of industry association the lack of clarity of new disclosures is a recurrent topic in knowledge exchange sessions.

Additionally, TO mentions that a prevailing struggle across companies lies in balancing resources between reporting activities and substantive, underlying sustainability actions. Although reporting is undeniably critical, there is a dilemma in managing the day-to-day operational activities that form the basis of year-end reports. This tension poses a significant constraint, as numerous companies lack specialized reporting teams capable of integrating new responsibilities without detracting from ongoing sustainability efforts. Furthermore, complying with multiple frameworks and ratings necessitates substantial time investments from operators to report on the specifics required for each disclosure, despite existing overlaps (TO).

Additionally, FR considers that allocating more resources to sustainability teams could yield significant advancements and improved reporting; on this EP and FR agree that sustainability reporting needs to transition to the level of development and emphasis of that of financial reporting. It is difficult to tell whether a company adheres (partially or completely) or not to specific reporting standards or frameworks if that is not mentioned in the reports, considering the way those are written (FR). FR specifically mentions ITU L Series standards, which aim to raise the transparency bar for the whole ICT sector, but an issue arising from these recommendations and other frameworks and standards used for reporting is their voluntary nature and that companies might not be willing to be extremely granular on their disclosures.

Referring to the ITU recommendations, EP indicates that these have been used for product design and development and to report on industry-specific data points. Moreover, R1 indicates that telecom operators are also involved in developing standards and methodologies for assessing, for example, the enablement effect of digital solutions, mentioning that a French telecom operator has actively participated in the development of ITU recommendations.

GHG emissions accounting and energy

EP states that the collection and processing of operational information depend on the chosen reporting methods or frameworks for each annual sustainability report. These changes, often related to methodologies, can lead to variations in reported environmental impact by telecom operators. Despite this, TO asserts that operational data is easily accessible since it is within the company's control unlike Scope 2 or Scope 3 emissions; however, changes in requirements may necessitate recalculations for annual reporting or target setting (observed in analyzed reports). While EP only mentions it briefly,

manual data collection and analysis are prevalent in the industry, highlighting potential human errors and potential concerns about data quality. To address these challenges, EP notes a gradual shift towards outsourcing these processes to software solutions for calculations while also exploring on-site monitoring via sensors capable of measuring aspects such as fuel and energy consumption and production and their environmental impact.

Scope 2 emissions

The calculation of Scope 2 emissions also presents challenges in the reporting. Particularly, access to energy consumption data is a constraint that could affect several telecom operators (R1). In the French case, R1 elaborates on this, access to energy-related data is, depending on the energy provider, provided with a one-year delay, compromising the reporting. Another factor is that despite having real-time access to energy data (depending on the energy provider) access to this might be lost during contract renegotiation processes, making the telecom operators lose information from that period (R1). Given these circumstances, energy modeling has been a critical activity for some telecom operators to estimate their energy consumption and GHG emissions; while this is the case for French telecom operators in other countries this is not necessarily an issue; for example, R1 mentions the case of a Belgian telecom operator that does not face any of the previously mentioned constraints related to energy consumption data.

Scope 3 emissions

Scope 3 emissions and activities are depicted as the most pressing issue for sustainability reporting in the telecommunications industry. Their assessment and reporting are crucial, especially for companies that have committed or set their SBTs. Thus, telecom operators put requirements on companies such as equipment providers to reach specific performance levels, in terms of emissions and materials, that can be translated into reductions in the operators' own operations and value chain emissions (TO, EP). TO indicates that given the relevance of Scope 3 emissions in the telecommunications industry, this aspect has received more scrutiny over the last years; as a result, to improve operators' performance and disclosures on supply chain-related aspects, these companies have taken several actions mainly related to engaging suppliers. TO further emphasizes that it is challenging to match disclosure requests and the corporate reality when faced with difficulties in engaging suppliers.

Engaging suppliers

On the supply chain side, EP and TO agree that collaboration is essential for requesting and managing suppliers to establish environmental targets; a first step after which more granular requirements can be made. Both EP and TO indicate that the engagement process with suppliers does not end with the supplier committing to setting targets, but rather, this implies a follow-up process for telecom operators to push the suppliers into more sustainable practices and transparent reporting (TO).

Data considerations and implications

Scope 3 emissions and their reporting are heavily reliant on financial data for their estimation; R1 points out the uncertainty brought by this method compared with other methods that require supplier or product-specific information. An example emerges, mentioning that deployment and maintenance of mobile and fixed networks are often outsourced to contractors, with cheaper labor costs, which could be translated into lower emissions, potentially concealing the true magnitude of the impact (R1).

Despite issues with data for estimating the direct impacts from telecom operators, industry data is more reliable than other sources like industry-wide estimates from industry associations (R2), and addressing such issues requires a gradual shift from financial flows to physical (supplier or product-level) flows or taking a mixed (hybrid) approach as in the case of some telecom operators in France (R1). R1 also indicates that even data provided by suppliers can be questionable due to the lack of clarity of the methods used and the uncertainty associated with data provided by the suppliers' own supply chain; both aspects over which EP and TO agree.

Enablement impact and its measurement

The enablement impact from telecom operators has been reported continuously, but its measurement has faced criticism due to methodological aspects (FR, R1). When reporting on this type of impact, telecom operators acknowledge the limitations of such calculations and indicate basing these on methods from industry associations such as GSMA and GeSI. Moreover, R1, R2, and FR indicate that the enablement impact reports from industry associations should be taken with caution due to the simplified approaches used for these calculations. R2 exemplifies this by mentioning the GeSI's Smarter 2020 and 2030 reports, which have estimated the potential emissions savings from the ICT sector, indicating that no validations of those claims have been conducted. Furthermore, R2 critiques the approach of such reports since those limit their focus solely on positive impacts but overlook other negative impacts leading to more consumption within and beyond the ICT sector and the telecommunications industry. In R2's view, there has been much discussion about how ICT and telecommunications could potentially reduce emissions., but little has been done in assessing what has been achieved through digitalization. R2 and FR indicate that the ITU recommendation L1480 was developed to assist the transparency around the claims of enablement, especially around the assumptions; although R2 adds that despite the more strict and rigorous nature of this recommendation (and another upcoming standard from the European Green Digital Coalition), there is the tendency to emphasize the positive aspects, stating that this might be in response to interests from participating and funding institutions. R2 criticizes estimates from industry associations, citing a lack of understanding of how communications networks work and wrongful assumptions about network behavior, consumer dynamics, and study boundaries.

Influence of certain developments and trends

The interviewees provided several perspectives on the impact of current developments, such as AI and 5G deployment or 6G development, on the environmental performance of telecom operators. In the past, the telecom industry and the ICT sector utilized improved connectivity and digitalization to claim potential and enablement. Now, these claims are being supported by new technologies, such as AI. According to FR, this implies more of a marketing move from operators rather than a reorientation towards sustainability based on technology availability. FR also notes that changes in sustainability perspectives and narratives have been driven by increased sustainability awareness and regulations but that technology-driven shifts could also interact with and inform sustainability efforts. EP points out that deployments of 5G, due to its increased energy efficiency, will contribute to improvements in environmental performance. However, the impact of new technologies like AI on environmental performance is not yet clear. EP indicates that AI can play a role in assisting the development of improved, energy-efficient products for future network equipment. However, the rapid advancements in the field make it unclear what AI or similar technologies will be used in the next years five or ten years, highlighting the need to continuously reassess the relationship between AI, ICT, and sustainability strategies in the telecommunications industry.

5 Discussion

By using a mixed-methods approach, this study seeks to elicit the direct environmental impacts from telecom operators headquartered in the EU, as well as the trends and challenges the industry faces with regards to their environmental performance and reporting. The direct environmental impacts, or life cycle impacts (Hilty & Aebischer, 2015), involve all activities related to the provision of the telecommunications services. By using the sustainability reports from telecom operators, that simultaneously offer a mix of fixed and mobile telecommunications, cover a wide geographical scope, over a four-year period; the first part identified and analyzed different environmental material topics and how these have evolved in the proposed timeframe. Based on the initial findings, six interviews were conducted to different stakeholders about the trends and challenges faced by the sector when it comes to the environmental performance and reporting.

The discussion is presented considering the research questions.

RQ1. What are the reported and under-reported direct environmental effects from EU-based TOs considering their sustainability reports and relevant reporting frameworks and standards?

The findings from analyzing the sustainability reports of the selected companies indicate that companies align with the general trends seen in academic literature, where GHG emissions and energy considerations are considered the most important environmental aspects. Despite the differing approaches for identifying material topics across selected companies, the reports analyzed indicate that that apart from GHG emissions and energy, circular economy (encompassing material efficiency, waste and wastewater management, and end-of-life processes) has become of growing importance for telecom operators. These material topics, depending on the companies' size, reach, and strategy have remained the same, evolved, or emerged over the past four years. Moreover, the material topics are expected to change considering new regulations on sustainability reporting, like the ESRS and CSRD.

Climate change and carbon footprint are the most covered aspects by the reviewed companies. Their assessments consider Scope 1, 2, and 3 emissions and follow the guidelines provided by the GHG Protocol and the GRI standards. Like the selection of material topics, the reporting companies tend to justify the selection or omission of specific aspects to be reported in their climate disclosures; in the case of GHG emissions, this is palpable as all reporting aspects (Scope 1, 2, and 3 emissions) present significant differences across companies.

By examining Scope 1 emissions, these direct emissions constitute the smallest share of emissions from the selected companies and present a downward trend. However, the variance in the level of detail offered by Deutsche Telekom and Orange in disaggregating these emissions in contrast to more aggregated reporting by the other companies indicates discrepancies in reporting depth. Scope 2 emissions represent the second largest share of emissions within the companies and display remarkable progress on the commitment of telecom operators to energy efficiency and adoption of renewable energy; sharp declines in these emissions are presented by Deutsche Telekom and Telefonica. The most complex issue for telecom operators in terms of climate change is Scope 3 emissions. For the analyzed companies, these emissions account for between 84% and 99% of the overall emissions. Despite the magnitude different levels of granularity are presented across companies; more complete assessments are presented by companies that report on 10 (A1 Telekom) and 11 (Deutsche Telekom) of the 15 categories detailed by the GHG Protocol. More nuanced approaches to Scope 3 emissions reporting are found in the rest of the companies, where aggregated figures hinder comparisons across Scope 3 categories; according to Radonjič & Tompa (2018) the selection of Scope 3 categories is a result of the interplay of factors such as the size of the firm, service portfolio and the time and period of carbon policy implementation. Overall, the GHG emissions show a downward trend in all Scopes, and Scope

3 emissions are the area where improvements are less pronounced. These downward trends reflect the progress from the companies towards improving their environmental performance and aiming at staying within their established Science-Based Targets. Accordingly, and considering data from the SBTi (SBTi, 2023) it is possible to see that major progress has been achieved in terms of Scope 1 and 2 emissions, with some of the companies exceeding their targets for emissions reductions. However, Scope 3 emissions remain the most difficult area, especially considering that targets set for reductions have been made for the near term, between 2025 and 2030. This trend is also present for other EU-headquartered telecom operators, where, in some cases, negative or no progress has been reported (SBTi, 2023). Also, the extensive deployment of 5G networks, which requires the manufacture and installation of new base stations is set to increase the overall climate impact from telecom operators (Freitag et al., 2021; Golard et al., 2023).

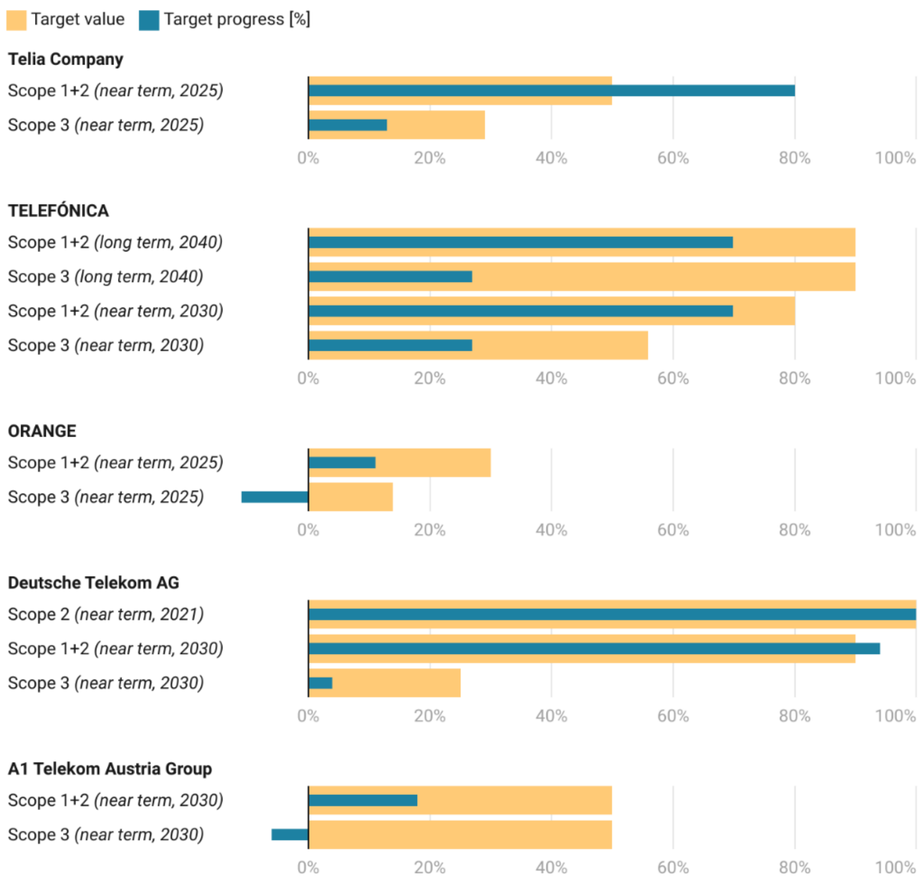

Figure 8 Science-based targets established and progress by the analyzed companies
Source: SBTi (2023)

The voluntary adoption of such disclosure standards gives operators the flexibility to adhere to them partially or fully, resulting in varied approaches and granularity. Specifically for measuring Scope 3 emissions, despite literature mentioning that supplier or product-specific data (i.e. life cycle assessments) aids in providing a more accurate representation of the climate impact (Barrow et al., 2013; GSMA et al., 2023), their use (to a limited extent) is only mentioned by the analyzed companies, with only Telefonica providing an LCA study of their connectivity solutions in their 2022 (Telefonica, 2022).

In the case of energy consumption, the increased use of energy-efficient equipment and networks (i.e. 5G), and the substantial adoption of renewable energy has allowed to improve the companies' performance in key metrics such as their energy intensity (kWh/TB), meaning less energy is required to transmit data over fixed or mobile networks. However, energy consumption overall has increased, due to expansions of network coverage and increasing data traffic (Freitag et al., 2021). Moreover, according to Golard et al. (2023), the current scenario where 4G and 5G networks operate concurrently uses more energy than using only one generation, which calls for sufficiency within the sector.

There has been a growing focus on circularity in the industry. However, each company has its own approach to dealing with these aspects of their operations. A common approach to circularity involves end-of-life management of both network infrastructure and end-user devices. The reporting, mainly guided by the GRI standards for waste illustrates different approaches from the companies towards the topic. The reported companies lack a clear categorization of the waste they generate, with different categories being used that hinder comparisons among them. Nevertheless, the main aspects covered in this aspect are related to recycling, mainly end-user devices, but reuse, refurbishing, and product-as-a-service approaches have emerged as part of the operators' circularity strategies.

Also, circularity is an aspect that has seen increasing collaboration. Despite not being reported as part of their impact, Deutsche Telekom, Orange, Telefonica, and Telia constitute four out of the five proponents of the Eco Rating, a rating system that aims at assisting customers in making more informed decisions about the environmental performance of mobile phones. This rating system evaluates the devices' durability, reparability, recyclability, climate efficiency, and resource efficiency using LCA-based criteria. As of 2024, a total of 143 models of mobile phones from 18 manufacturers have been rated.(Eco Rating, 2024).

It can be argued that the direct environmental impacts are significant for telecom operators and that climate change, energy, and circularity considerations have been, and will remain, at the top of the environmental agenda within the selected companies and the sector overall. Visible progress is seen over climate and energy aspects, and more nuanced approaches are conducted on circularity, which is slowly transitioning towards more comprehensive actions beyond end-of-life management. Despite the claimed alignment with relevant frameworks and standards, such as the GHG Protocol and GRI standards, the voluntary adoption of these allows companies to be flexible on how they conduct their assessments and reporting. As a result, significant differences are found in the reported data, as seen in the analyzed reports, where the granularity of the disclosures varies across companies.

The establishment of science-based targets or commitments by multiple companies, including those under analysis, to adhere to the Paris Agreement's goal of limiting global warming to well below 2°C above pre-industrial levels, contributes to enhanced transparency in disclosures. This is particularly beneficial as it facilitates the development of strategic roadmaps aimed at addressing climate-related concerns. In the telecom industry, this is relevant to the decarbonization of the supply chain, given these emissions account for 85 and 99% of the total emissions in the companies being analyzed. Yet disclosures or commitments do not translate automatically in progress on the established targets (See Figure 8).

The different approaches to reporting the direct environmental impacts from telecom operators indicate that the sector lacks harmonization. Given this, industry-wide efforts have been conducted to equip companies with guidance and metrics to tackle these issues. Among such efforts are the GSMA Metrics for Mobile (GSMA, 2022), the EU Commission's Common Indicators for measuring environmental footprint from ICT metrics (Baldini et al., 2024), and the ITU-T L Series recommendations (ITU, 2024). The latter provides detailed guidance on concepts and methodologies that can further enhance the reporting. It is noteworthy that efforts towards harmonization have been made in close collaboration with telecom operators, including some of the analyzed in this study, yet their adoption, as per their sustainability reports, has not been reported.

RQ2. What are the trends and challenges towards the improvement of the environmental performance and its reporting of EU-based telecommunications operators?

Telecom operators are dealing with ongoing trends and challenges regarding their environmental impact. The conducted interviews confirmed that internal and external stakeholders will continue to closely scrutinize GHG emissions, energy usage, and circularity, which will be subject to stricter action and reporting. Moreover, the indirect impacts, i.e., enablement impact, have also started to gain relevance in the reporting landscape, although claims about this are made on a more cautious way considering the lack of standardized methodologies for conducting such assessments.

For telecom operators in Europe and globally, it is expected that their GHG emissions will increase considering two aspects mentioned before increased data traffic (that can offset energy efficiency gains) and the need for extensive deployment of networks. The latter is particularly important for companies that operate in different geographical regions such as Africa, Asia, and the Americas, where levels of deployment are currently low. Network infrastructure is not immune to climate change effects, such as high temperatures or flooding, so both network equipment replacement and maintenance are aspects to consider since they can add to the emissions and overall impact from the sector.

The most challenging aspect of the environmental performance in the sector is its supply chain (upstream and downstream), which has repercussions on all aspects related to the environmental performance, but mainly on the climate impact (Scope 3 emissions) and the circularity of the sector. Despite the challenges this represents, telecom operators have the capacity to tackle these issues through discussions and agreements with suppliers, consumer education, and their purchasing decisions (Radonjič & Tompa, 2018).

Trends and challenges on environmental reporting

The reporting landscape for telecom operators has evolved, becoming stricter on the type of disclosures required, and currently guided by regulations like the EU CSRD to which telecom operators with headquarters in the EU or with significant activities in the region must adhere. Additional factors influencing environmental reporting include national regulations (e.g., the Chaize Act in France), the development of industry-specific standards and recommendations (ITU L recommendations), and stakeholder expectations, which mainly influence the report to different ESG ratings.

The transition towards more uniform and thorough disclosures is key to understanding telecom operators' environmental impact since the information provided by these companies can be crucial for analyzing the sector's performance and for different research processes. Yet, different constraints need to be addressed to avoid current misalignments with established frameworks and inconsistent reporting among members of the same industry.

At a general level, enforced and emerging regulations need to consider compatibility parameters with already established and widely recognized standards and frameworks to facilitate their adoption; an example of this is the GRI-ESRS interoperability index provided by GRI and the European Financial Reporting Advisory Group (EFRAG) in which highlights the level of alignment of the two sets of standards. Similarly, considering that telecom operators report to different voluntary ESG ratings, interoperability among those is also required to ensure environmental and sustainability disclosures are consistent, transparent meaningful (Mora, 2016). Ensuring interoperability among reporting standards and disclosures would allow for improved allocation of resources for conducting such tasks, reducing the burden of reporting on sustainability analysts and professionals. Although the lack of interoperability might not pose a significant challenge for large firms with specialized reporting teams, it could become a burden for medium-sized and smaller firms with limited resources that need to balance reporting with substantive sustainability actions, as TO mentioned.

Moreover, relying on third-party data for sustainability reporting compromises the ability to provide accurate representations of telecom operators' overall impacts (Roussilhe et al., 2023), thus it is necessary for telecom operators to gradually shift towards the use of supplier or product-level information for assessing their impact and reporting accordingly, avoiding incomplete and inconsistent disclosures(Klaaßen & Stoll, 2021; Rouphael et al., 2023). This process of improved reporting and disclosure requires that telecom operators engage with suppliers and provide consistent guidance (GSMA, 2022; GSMA et al., 2023).

Given the relevance of environmental sustainability on telecom operators, several industry-specific recommendations and disclosing frameworks have been established with close collaboration from these companies, yet the reasons for their limited or null adoption remain unclear. In summary, the reporting on environmental performance is tied to existing regulations and established frameworks, and to ensure transparent reporting, several challenges need to be addressed, including resource allocation, supplier engagement, data quality, and adherence to industry-specific recommendations toward the improvement of both environmental performance and reporting.

This study highlighted the relevance of the enablement impact telecom operators can have and the current limitations for their estimating. While a complex issue, it is necessary that claims around this enablement, estimated at 10 times the ICT sector's GHG emissions (GSMA, 2019b), are validated to making informed decisions for tackling climate change (Rasoldier et al., 2022). Though methodologies (Bergmark et al., 2020; ITU, 2022) have been developed, their testing has been limited.

Practical implications

This research provides updated insights that contribute to the discussion of environmental sustainability and ICT in corporate, consumer, policy, and decision-making. By identifying telecom operators' reported and underreported direct environmental impacts, as well as the trends and challenges surrounding their reporting, this study assists in pinpointing the particular areas where actions are needed and cooperation can be promoted among telecom operators and their supply chain. Considering the relevant factors identified and the obstacles associated with them, this research has the potential to inform plans or strategies for companies that are starting their environmental assessments and reporting.

Limitations

The selected research design allowed to capture an integrative perspective to fulfill the research aim. However, some constraints must be acknowledged within the limitations of this research. The scope of analysis was restricted to only five telecom operators, dictated by the available time constraints. While these operators were chosen based on levels of operation, geographic coverage, and reporting practices, including more companies could potentially enhance the generalizability of the findings across the telecommunications industry, particularly within the European Union. Additionally, the interviewee selection provided information that complemented and helped further understand the findings of the quantitative inquiry. It is worth noting, however, that the interviews did not fully cover specific aspects since they acknowledged that specific aspects fell beyond their expertise; highlighting the need for expanding the pool of respondents to integrate more specific insights in aspects that were not fully covered, such as circularity in telecom operators. A core aspect to consider in this regard is the limited availability of such potential interviewees.

Future work

Considering the findings of this research, potential avenues for research are evident. First, considering the relevance of supply chains for telecom operators, research can be directed towards understanding the mechanisms for engaging suppliers towards improving environmental performance and circularity practices in the telecommunications industry. Another path for research is related to the reporting aspects; first, research can be directed toward assessing the influence of current standards and regulations, such as the ESRS and CSRD, in the reporting quality, consistency, and overall transparency of environmental disclosures in telecom operators. Another research topic aligned with the harmonization of disclosures in the telecommunications industry that could be addressed is understanding the factors that limit the adoption of industry-level standards and recommendations towards their implementation in the reporting practices.

Finally, although not related to direct environmental impacts, research can address the impact of enablement. For years, telecom operators and the entire ICT sector have asserted enablements. However, with the introduction of the new Green Claims Directive mandating supporting information for any environmental claim, this assertion must be maintained and justified. This is particularly relevant given that methodologies for calculating enablements have faced continuous methodological scrutiny, especially around claims made by industry associations like GSMA and GeSI.

6 Conclusions

By examining sustainability reports from selected, EU-headquartered telecom operators and conducting interviews with relevant stakeholders following a mixed methods research design this research sought to elicit the direct environmental effects of telecom operators considering their sustainability reports and applicable reporting frameworks.

The main aspects covered and reported upon by telecom operators are climate change, energy, and circularity. Climate change is the most pressing issue for telecom operators' sustainability considerations. Despite alignment to the same frameworks, inconsistent reporting is presented, especially for scope 3 emissions, which constitute around 90% of the GHG emissions from the selected telecom operators. Despite inconsistencies in the reporting, an overall downward trend is observed for climate-related disclosures, with scope 2 emissions experiencing the biggest improvements. Despite the overall reductions, Scope 3 emissions remain the biggest challenge for telecom operators since progress around these has been limited considering the established near and long-term science-based targets by the analyzed telecom operators.

On the energy aspects, relative indicators such as energy intensity present improvements, but in absolute terms, the overall energy consumption from the selected telecom operators has increased due to increased data traffic and ongoing network deployments. Moreover, circularity has emerged as a core aspect of telecom operators' sustainability, with companies and the sector in general gradually shifting their focus from end-of-life management of network and end-user equipment towards a more comprehensive approach, considering early stages such as design and waste prevention.

The relevance of environmental considerations, coupled with scrutiny from different actors, makes it necessary that sectors use harmonized metrics for disclosing and reporting their environmental performance so they can capture the most crucial elements that can be used for proper decision-making and policymaking, as well as for transparency towards stakeholders like investors, consumers and academia.

The reporting landscape in the EU is shaped by the EU CSRD and ESRS, with interviewed stakeholders mentioning that this regulation can enhance the quality and granularity of the reporting. Apart from these regional regulations, environmental reporting is influenced by national regulations, established frameworks and standards (GHG Protocol, GRI standards), and stakeholder expectations (for disclosures towards, for example, ESG ratings). The main challenges around reporting include supplier engagement, data quality considerations, and alignment to industry-level standards, which have been adopted to a limited extent despite being developed with the aid of telecom operators.

An additional topic that cannot be ignored is the enablement impact, with several industry-wide reports and individual sustainability reports mentioning high potential and actual GHG emissions savings; however, these numbers are highly contested, especially by academics, who highlight that the methods used for such estimations focus mainly on potential/actual positive effects, but fail in incorporating negative aspects that could be driven by digitalization, and could even surpass the positive impacts.

Bibliography

A1 Group. (2022a). *Combined annual report 2020*. https://a.pagestrip.com/1194/assets/6c/0f/b7fe15c246fc8a912f4c4298484e.pdf

A1 Group. (2022b). *Combined Annual report 2021*. https://a1.group/wp-content/uploads/sites/6/2023/07/A1_TAG_Combined-Annual-Report_2021-eng.pdf

A1 Group. (2023). *A1 Group and Markets—A1 Group*. https://a1.group/a1-group-and-markets/

A1 Group. (2023c). *Consolidated Non'financial report 2022*. https://a1.group/wp-content/uploads/sites/6/2023/07/Konsolidierter-nicht-finanzieller-Bericht-2022_EN_230331.pdf

Andrae, A. S. G. (2023). From an Environmental Viewpoint Large ICT Networks Infrastructure Equipment must not be Reused. *WSEAS TRANSACTIONS ON ENVIRONMENT AND DEVELOPMENT*, *19*, 375–382. https://doi.org/10.37394/232015.2023.19.34

Andrae, A. S. G., & Edler, T. (2015). On Global Electricity Usage of Communication Technology: Trends to 2030. *Challenges*, *6*(1), Article 1. https://doi.org/10.3390/challe6010117

ARCEP. (2022). *Décision n°2022-2149*. https://www.arcep.fr/uploads/tx_gsavis/22-2149.pdf

Baldini, G., Cerutti, I., & Chountala, C. (2024, March 11). *Identifying common indicators for measuring the environmental footprint of electronic communications networks (ECNs) for the provision of electronic communications services (ECSs)*. JRC Publications Repository. https://doi.org/10.2760/093662

Barrow, M., Buckley, B., Caldicott, T., Cumberlege, T., Hsu, J., Kaufman, S., Ramm, K., Rich, D., Temple-Smith, W., Cummis, C., Draucker, L., Khan, S., Ranganathan, J., & Sotos, M. (2013). *Technical Guidance for Calculating Scope 3 emissions*. GHG Protocol.

BCG. (2023, February 20). *How Tech and Telecom Can Create a Triple Win in Green*. BCG Global. https://www.bcg.com/publications/2023/role-of-ict-in-sustainable-development-triple-green-win

Belkhir, L., & Elmeligi, A. (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *Journal of Cleaner Production*, *177*, 448–463. https://doi.org/10.1016/j.jclepro.2017.12.239

Bergmark, P., Coroamă, V. C., Höjer, M., & Donovan, C. (2020). A Methodology for Assessing the Environmental Effects Induced by ICT Services: Part II: Multiple Services and Companies. *Proceedings of the 7th International Conference on ICT for Sustainability*, 46–55. https://doi.org/10.1145/3401335.3401711

Bieser, J. C. T., Hintemann, R., Hilty, L. M., & Beucker, S. (2023). A review of assessments of the greenhouse gas footprint and abatement potential of information and communication technology. *Environmental Impact Assessment Review*, *99*, 107033. https://doi.org/10.1016/j.eiar.2022.107033

Çanakoğlu, E., & Bilgiç, T. (2007). Analysis of a two-stage telecommunication supply chain with technology dependent demand. *European Journal of Operational Research*, *177*(2), 995–1012. https://doi.org/10.1016/j.ejor.2006.01.006

Carbon Trust & GeSI. (2017). *ICT sector Guidance buil of the GHG protocol Product Life Cycle Accounting and Reporting Standard*. https://ghgprotocol.org/sites/default/files/ghgp/GHGP-ICTSG%20-%20ALL%20Chapters.pdf#page=11.75

Coroama, V., & Mattern, F. (2019). Digital Rebound – Why Digitalization Will Not Redeem Us Our Environmental Sins. In *ICT for Sustainability*. https://ceur-ws.org/Vol-2382/ICT4S2019_paper_31.pdf

Creswell, J. W., & Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*.

Deutsche Telekom. (2020). *Corporate Responsibility Report 2019*. https://www.cr-report.telekom.com/site20/index.html#1

Deutsche Telekom. (2021). *Corporate Responsibility Report 2020*. https://www.cr-report.telekom.com/2020/#1

Deutsche Telekom. (2023). *Corporate Responsibility Report 2022*. https://www.cr-report.telekom.com/2022/

Dincer, B., Keskin, A. İ., & Dincer, C. (2023). Nexus between Sustainability Reporting and Firm Performance: Considering Industry Groups, Accounting, and Market Measures. *Sustainability*, *15*(7), 5849. https://doi.org/10.3390/su15075849

Eco Rating. (2024). *Find and compare mobile device Eco Ratings*. Eco Rating. https://www.ecoratingdevices.com/ratings/

Ellen Macarthur Foundation. (2017). *Circular economy*. https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Famularo, J. (2023). Corporate social responsibility communication in the ICT sector: Digital issues, greenwashing, and materiality. *International Journal of Corporate Social Responsibility*, *8*(1), 8. https://doi.org/10.1186/s40991-023-00082-8

Freitag, C., Berners-Lee, M., Widdicks, K., Knowles, B., Blair, G. S., & Friday, A. (2021). The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. *Patterns*, *2*(9). https://doi.org/10.1016/j.patter.2021.100340

Golard, L., Louveaux, J., & Bol, D. (2023). Evaluation and projection of 4G and 5G RAN energy footprints: The case of Belgium for 2020–2025. *Annals of Telecommunications*, *78*(5), 313–327. https://doi.org/10.1007/s12243-022-00932-9

Greenhouse Gas Protocol. (2011). *Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf*. https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf#page=25.00

GSMA. (2019a). Energy Efficiency: An Overview. *Future Networks*. https://www.gsma.com/futurenetworks/wiki/energy-efficiency-2/

GSMA. (2019b). *The enablement effect*. https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf

GSMA. (2022). *ESG Metrics for Mobile*. https://www.gsma.com/betterfuture/esg-metrics-for-mobile

GSMA, GeSI, & ITU. (2023). *Scope 3 Guidance for Telecommunication Operators*. https://www.gsma.com/betterfuture/wp-content/uploads/2023/07/Scope-3-Guidance-2023.pdf

GSMA, Tele2, & Ethos. (2022). *Strategy Paper for Circular Economy: Mobile Devices*. https://www.gsma.com/betterfuture/wp-content/uploads/2023/02/Strategy-Paper-Circular-Economy-Mobile-Devices.pdf

Hankel, A., Heimeriks, G., & Lago, P. (2018). A Systematic Literature Review of the Factors of Influence on the Environmental Impact of ICT. *Technologies*, *6*(3), 85. https://doi.org/10.3390/technologies6030085

Hilty, L. M., & Aebischer, B. (2015). ICT for Sustainability: An Emerging Research Field. In L. M. Hilty & B. Aebischer (Eds.), *ICT Innovations for Sustainability* (pp. 3–36). Springer International Publishing. https://doi.org/10.1007/978-3-319-09228-7_1

IFRS Foundation. (2023). *Telecomunication Services: Sustainability accounting standard.* SASB. https://d3flraxduht3gu.cloudfront.net/latest_standards/telecommunication-services-standard_en-gb.pdf

Itten, R., Hischier, R., Andrae, A. S. G., Bieser, J. C. T., Cabernard, L., Falke, A., Ferreboeuf, H., Hilty, L. M., Keller, R. L., Lees-Perasso, E., Preist, C., & Stucki, M. (2020). Digital transformation—Life cycle assessment of digital services, multifunctional devices and cloud computing. *The International Journal of Life Cycle Assessment*, *25*(10), 2093–2098. https://doi.org/10.1007/s11367-020-01801-0

ITU. (2020). *Handbook for the collection of administrative data on telecommunications/ICT 2020 edition*. https://www.itu.int/en/ITU-D/Statistics/Documents/publications/handbook/2020/ITUHandbookTelecomAdminData2020_E.pdf

ITU. (2022). *ITU-T L.1480 (12/2022) Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impact greenhouse gas emissions of other sectors*. https://www.bing.com/ck/a?!&&p=5a828061a727acf6JmltdHM9MTcxNTkwNDAwMCZpZ3VpZD0wMGZhMDgzMC0zMTU4LTYyNzUtMDc2YS0xYjJhMzAzMzYzYjYmaW5zaWQ9NTE4OA&ptn=3&ver=2&hsh=3&fclid=00fa0830-3158-6275-076a-1b2a303363b6&psq=itu+1480&u=a1aHR0cHM6Ly93d3cuaXR1LmludC9yZWMvVC1SRUMtTC4xNDgwLTIwMjIxMi1J&ntb=1

ITU. (2023). *Measuring digital development: Facts and Figures 2023*. https://www.itu.int/hub/publication/d-ind-ict_mdd-2023-1/

ITU. (2024). *ITU-T Recommendations*. ITU. https://www.itu.int/itu-t/recommendations/index.aspx?ser=L

ITU & World Bank. (2024). *Measuring the Emissions & Energy Footprint of the ICT Sector: Implications for climate action*. https://www.itu.int/hub/publication/d-ind-clim-2023-01/

Kang, Y., Ryu, M.-H., & Kim, S. (2010). Exploring sustainability management for telecommunications services: A case study of two Korean companies. *Journal of World Business*, *45*(4), 415–421. https://doi.org/10.1016/j.jwb.2009.08.003

Klaaßen, L., & Stoll, C. (2021). Harmonizing corporate carbon footprints. *Nature Communications*, *12*(1), 6149. https://doi.org/10.1038/s41467-021-26349-x

Köhler, A., & Erdmann, L. (2004). Expected Environmental Impacts of Pervasive Computing. *Human and Ecological Risk Assessment: An International Journal*, *10*(5), 831–852. https://doi.org/10.1080/10807030490513856

León, R., & Salesa, A. (2023). Is sustainability reporting disclosing what is relevant? Assessing materiality accuracy in the Spanish telecommunication industry. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-03537-x

Malmodin, J., & Bergmark, P. (2015). *Exploring the effect of ICT solutions on GHG emissions in 2030*. 37–46. https://doi.org/10.2991/ict4s-env-15.2015.5

Malmodin, J., & Lundén, D. (2018). *The electricity consumption and operational carbon emissions of ICT network operators 2010-2015*. https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-221740

Malmodin, J., Lundén, D., Moberg, Å., Andersson, G., & Nilsson, M. (2014). Life Cycle Assessment of ICT: Carbon Footprint and Operational Electricity Use from the Operator, National, and Subscriber Perspective in Sweden. *Journal of Industrial Ecology*, *18*(6), 829–845. https://doi.org/10.1111/jiec.12145

Mickoleit, A. (2010). *Greener and Smarter: ICTs, the Environment and Climate Change*. OECD. https://doi.org/10.1787/5k9h3635kdbt-en

Mora, M. (2016). *The role of interoperability in sustainability decisions: The case of CDP*. https://doi.org/10.2991/ict4s-16.2016.26

NGMN. (2021a). *Green Future Networks: Network Equipment: Eco-Design and End to End Service Footprint* (1). https://www.ngmn.org/wp-content/uploads/210719-NGMN_Green-future-Networks_Eco-design-v1.0.pdf

NGMN. (2021b). *Green Future Networks: Sustainability Challenges and Initiatives in Mobile Networks*.

Orange. (2022). *2022 Universal Registration Document*. Orange. https://gallery.orange.com/gallery.orange.com/720167/2022%20Universal%20Registration%20Document.pdf

Patchell, J. (2018). Can the implications of the GHG Protocol's scope 3 standard be realized? *Journal of Cleaner Production*, *185*, 941–958. https://doi.org/10.1016/j.jclepro.2018.03.003

Patil, C., & Karnam, S. (2022). *Sustainable IT Procurement A case of Network and Telecommunications (N&T) Services Sourcing*. Chalmers University of Technology.

Plepys, A. (2002). The grey side of ICT. *Environmental Impact Assessment Review*, *22*(5), 509–523. https://doi.org/10.1016/S0195-9255(02)00025-2

Radonjič, G., & Tompa, S. (2018). Carbon footprint calculation in telecommunications companies – The importance and relevance of scope 3 greenhouse gases emissions. *Renewable and Sustainable Energy Reviews*, *98*, 361–375. https://doi.org/10.1016/j.rser.2018.09.018

Rasoldier, A., Combaz, J., Girault, A., Marquet, K., & Quinton, S. (2022, June 21). *How realistic are claims about the benefits of using digital technologies for GHG emissions mitigation?* LIMITS 2022 - Eighth Workshop on Computing within Limits. https://inria.hal.science/hal-03949261

Rouphael, R. B., Selva, E., Huang, Y., Mouawad, N., Boudry, G., Parmantier, X., & Gati, A. (2023). The Impact of Networks in the Greenhouse Gas Emissions of a Major European CSP. *2023 International Conference on Electrical, Computer and Energy Technologies (ICECET)*, 1–6. https://doi.org/10.1109/ICECET58911.2023.10389498

Roussilhe, G., Ligozat, A.-L., & Quinton, S. (2023). A long road ahead: A review of the state of knowledge of the environmental effects of digitization. *Current Opinion in Environmental Sustainability*, *62*, 101296. https://doi.org/10.1016/j.cosust.2023.101296

Samuel, G., Lucivero, F., Knowles, B., & Wright, K. (2024). Carbon Accounting in the Digital Industry: The Need to Move towards Decision Making in Uncertainty. *Sustainability*, *16*(5), Article 5. https://doi.org/10.3390/su16052017

Santarius, T., Bieser, J. C. T., Frick, V., Höjer, M., Gossen, M., Hilty, L. M., Kern, E., Pohl, J., Rohde, F., & Lange, S. (2023). Digital sufficiency: Conceptual considerations for ICTs on a finite planet. *Annals of Telecommunications*, *78*(5), 277–295. https://doi.org/10.1007/s12243-022-00914-x

SBTi. (2023). *Science-based targets progress review 2022* [Dataset]. https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fsciencebasedtargets.org%2Fresources%2Ffiles%2FSBTiMonitoringReport2022TargetProgressData.xlsx&wdOrigin=BROWSELINK

Scheck, H.-O., & Kallio, S. (2013). Methods and standards for environmental impact assessment of mobile radio networks. *ICT 2013*, 1–5. https://doi.org/10.1109/ICTEL.2013.6632082

Telefonica. (2021). *Main Non-Financial Statements*. https://doi.org/2021

Telefonica. (2022). *Connectivity solution's Life Cycle Assessment*. Telefónica. https://www.telefonica.com/es/sala-comunicacion/reportes/analisis-de-ciclo-de-vida-de-las-soluciones-de-conectividad/

Telefonica. (2023, December 12). *Telefonica*. Telefónica. https://www.telefonica.com/en/

Telia Company. (2020). *Telia Company – Annual and Sustainability Report 2019*. https://www.teliacompany.com/assets/u5c1v3pt22v8/7LvKckLp2EcksQN0JloUr4/572964e24326f93acd3821439e51b58c/Telia_Company_____Annual_and_Sustainability_Report_2019.pdf

Telia Company. (2021). *Telia Company – Annual and Sustainability Report 2020*. https://www.teliacompany.com/assets/u5c1v3pt22v8/1pwOYewddQKSzkOFFgMQaH/26dab781856a1c0245ac2823b3262d82/Telia_Company_____Annual_and_Sustainability_Report_2020.pdf

Telia Company. (2023). *Anual and Sustainability Report 2022*. https://www.teliacompany.com/assets/u5c1v3pt22v8/Gp5w6fVQlTao50XukMg3B/706817

669b20ad8ac8809472bbe386cd/telia-company-annual-and-sustainability-report-2022_ENG_FINAL.pdf

Truant, E., Borlatto, E., Crocco, E., & Bhatia, M. (2023). ESG performance and technological change: Current state-of-the-art, development and future directions. *Journal of Cleaner Production*, *429*, 139493. https://doi.org/10.1016/j.jclepro.2023.139493

Yu, L., Suojapelto, K., Hallikas, J., & Tang, O. (2008). Chinese ICT industry from supply chain perspective—A case study of the major Chinese ICT players. *International Journal of Production Economics*, *115*(2), 374–387. https://doi.org/10.1016/j.ijpe.2008.03.011

7 Appendix

Appendix 1 Interview guide

The following interview guide was used, with variations depending on the interviewee, for conducting the six interviews.

Informed Consent

For your information, I am adhering to the EU GDRP rules and ethical and privacy regulations of Lund University. Your responses are confidential and anonymized in any report or publication resulting from this research. Moreover, your participation is entirely voluntary, and you may choose not to answer specific questions or withdraw from the interview at any time. I would like to highlight that only I will have access to the information obtained through this interview, which will be securely saved on OneDrive, which is secured by Lund University.

I would like to kindly ask you for your permission to record this conversation to facilitate information processing, but this is entirely voluntary for you. In case of recording your personal data will remain anonymous with no name or other identifiers attached to the stored data.

Background Information

Could you please provide a brief summary of your professional or research experience one the telecommunications industry and your experience with environmental management and sustainability reporting?

Trends in environmental performance and reporting

Subtopic 1. Evolution of environmental performance.

How has telecom operators' environmental performance evolved over recent years?

- In what specific domains have notable improvements been observed?

What strategies have telecom operators/equipment providers used to improve their environmental performance and reporting?

- Have there been any noticeable shifts in focus regarding these strategies?

What aspects of environmental performance and reporting do you foresee will receive more attention and scrutiny in the coming years from internal and external stakeholders?

Subtopic 2: Adaptation in reporting practices.

How have Telecom operators adjusted their reporting practices to align with evolving environmental standards and frameworks?

Which regulations, standards, or frameworks have exerted/exert the most influence on reporting practices/ environmental performance?

Challenges and perspectives on environmental performance and reporting of telecommunications/ telecom operators

Subtopic 3: Navigating reporting complexity

Do you encounter/see/identify problems with the different reporting methods and the multiplicity of reporting standards and frameworks applicable to telcom operators?

- Given the multiplicity of standards and frameworks applicable to telecom operators; how does your/ the company/ies navigate the complexities of multi-framework reporting requirements?

- Are there strategies or best practices that have proven effective in managing this situation?

Subtopic 4: circularity in the telecommunications sector

What are the key barriers preventing telecom operators from further embracing circularity principles (slow, narrow, and close material loops) in their operations? And why?

- What are specific areas where circularity efforts are particularly challenging? Consider the company's own operations, as well as upstream and downstream factors.

- What are specific areas where circularity efforts are the easiest for your case/in your context?

Subtopic 5: Impact of global events and trends

- How have current trends (IoT, AI, 5G deployment) impacted the environmental priorities and strategies of telecom operators and/or equipment providers?

- Have there been notable shifts in focus or resource allocation/attention? For example as a result of the pandemic in 2020, global geopolitical tensions, etc.

Subtopic 6: Additional remarks

- Has our conversation sparked any relevant fact you deem relevant for this research or any other aspect you would like to highlight? Or do you want to deepen on specific aspects covered in previous questions?

Appendix 2 Compilation of reporting standards applicable to direct environmental impacts from telecom operators

Topic	Standard	Framework topic	Metric/indicators	Unit (blank if not mentioned)
Biodiversity	GRI Standards	304-1 Operational sites owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas	Operational sites owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas	
	GRI Standards	304-2 Significant impacts of activities, products and services on biodiversity	Significant impacts of activities, products and services on biodiversity	
	GRI Standards	304-3 Habitats protected or restored	Habitats protected or restored	
	GRI Standards	304-4 IUCN Red List species and national conservation list species with habitats in areas affected by operations	IUCN Red List species and national conservation list species with habitats in areas affected by operations	
Circularity, materials, and waste	EU Comission common indicators	Distribution or utilisation of recycled/ refurbished/ reused products	Weight of recycled products	metric tons
	EU Comission common indicators	Distribution or utilisation of recycled/ refurbished/ reused products	Weight of refurbished products	metric tons
	EU Comission common indicators	Distribution or utilisation of recycled/ refurbished/ reused products	Weight of reused components in products	metric tons
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Weight of recycled components in products	metric tons
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Weight of refurbed components in products	metric tons
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Weight of reused components in products	metric tons
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Number of recycled components in products	#
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Number of refurbed components in products	#

Topic	Standard	Framework topic	Metric/indicators	Unit (blank if not mentioned)
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Number of reused components in products	#
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Percentage of recycled components in products	%
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Percentage of refurbed components in products	%
	EU Comission common indicators	Recycled/refurbished/reused components (also the excavated mass) used in products	Percentage of reused components in products	%
	EU Comission common indicators	E-waste production	E-waste generated	metric tons
	EU Comission common indicators	Recyclability	Weight of recycled network elements	metric tons
	EU Comission common indicators	Recyclability	Number of recycled network elements	#
	EU Comission common indicators	Repairability	Percentage of repaired devices	%
	EU Comission common indicators	Repairability	Number of repaired devices	#
	EU Comission common indicators	Expected lifetime	Expected lifetime (years)	#
	EU Comission common indicators	Raw materials depletion		
	GRI Standards	301-1 Materials used by weight or volume	Materials used by weight or volume	
	GRI Standards	301-2 Recycled input materials used	Recycled input materials used	
	GRI Standards	301-3 Reclaimed products and their packaging materials	Reclaimed products and their packaging materials	
	GRI Standards	306-1 Waste generation and significant waste-related impacts	Waste generation and significant waste-related impacts	

Topic	Standard	Framework topic	Metric/indicators	Unit (blank if not mentioned)
	GRI Standards	306-2 Management of significant waste-related impacts	Management of significant waste-related impacts	
	GRI Standards	306-3 Waste generated	Waste generated	
	GRI Standards	306-4 Waste diverted from disposal	Waste diverted from disposal	
	GRI Standards	306-5 Waste directed to disposal	Waste directed to disposal	
	GSMA ESG Metrics for mobile	Materials repaired or reused	i. Percentage of network equipment repaired or reused, by units	%
	GSMA ESG Metrics for mobile	Materials repaired or reused	ii. Percentage of network equipment repaired or reused, by purchase price	%
	GSMA ESG Metrics for mobile	Waste generated	Total waste generated (tonnes) per 1GB of data	t/GB
	GSMA ESG Metrics for mobile	Waste generated	Network waste (tonnes) per 1GB of data	t/GB
	GSMA ESG Metrics for mobile	Waste generated	Handset and other CPE waste (tonnes) per 1GB of data	t/GB
	GSMA ESG Metrics for mobile	Waste generated	All other waste (tonnes) per 1 GB of dat=a	t/GB
	GSMA ESG Metrics for mobile	Materials recycled	Percentage of network waste (from 1.5b) recycled (units)	%
	GSMA ESG Metrics for mobile	Materials recycled	Percentage of purchase price of recycled network waste	%
	GSMA ESG Metrics for mobile	Materials recycled	Percentage of handset and CPE waste (from 1.5c) recycled (units)	%
	GSMA ESG Metrics for mobile	Materials recycled	Percentage of purchase price of recycled handset and CPE waste	%
	GSMA ESG Metrics for mobile	Materials recycled	All other waste recycled	
	GSMA ESG Metrics for mobile	Materials recycled	Percentage of all other waste recycled (units)	%

Topic	Standard	Framework topic	Metric/indicators	Unit (blank if not mentioned)
	GSMA ESG Metrics for mobile	Materials recycled	Percentage of purchase price of all other recycled waste	%
	SASB Standards for Telecommunications	Product end of life management	Materials recovered through take-back programmes	t
	SASB Standards for Telecommunications	Product end of life management	Percentage of recovered materials reused	%
	SASB Standards for Telecommunications	Product end of life management	Percentage of recovered materials recycled	%
	SASB Standards for Telecommunications	Product end of life management	Percentage of recovered materials landfilled	%
Climate and GHG Emissions	EU Comission common indicators	Scope 1 emissions	Absolute Scope 1 emissions	tCO2e
	EU Comission common indicators	Scope 2 emissions	Absolute Scope 2 emissions	tCO2e
	EU Comission common indicators	Scope 3 emissions	Absolute Scope 3 emissions	tCO2e
	EU Comission common indicators	Absolute Scope 1 emissions	Absolute Scope 1 emissions	tCO2e
	EU Comission common indicators	Scope 2 emissions	Absolute Scope 2 emissions	tCO2e
	EU Comission common indicators	Scope 3 emissions	Absolute Scope 3 emissions	tCO2e
	GHG Protocol	Scope 1 emissions (From company facilities and Company vehicles)	Stationary combustion	tCO2e
	GHG Protocol	Scope 1 emissions (From company facilities and Company vehicles)	Fugitive emissions	tCO2e
	GHG Protocol	Scope 1 emissions (From company facilities and Company vehicles)	Mobile combustion	tCO2e
	GHG Protocol	Scope 1 emissions (From company facilities and Company vehicles)	Process emissions	tCO2e
	GHG Protocol	Scope 1 emissions (From company facilities and Company vehicles)	Absolute Scope 1 emissions	tCO2e
	GHG Protocol	Scope 2 emissions	Absolute Scope 2 emissions	tCO2e
	GHG Protocol	Scope 3 emissions	1. Purchased goods and services	tCO2e
	GHG Protocol	Scope 3 emissions	2. Capital goods	tCO2e

Topic	Standard	Framework topic	Metric/indicators	Unit (blank if not mentioned)
	GHG Protocol	Scope 3 emissions	3. Fuel and energy-related activities	tCO2e
	GHG Protocol	Scope 3 emissions	4. Transportation and distribution	tCO2e
	GHG Protocol	Scope 3 emissions	5. Waste generated in operations	tCO2e
	GHG Protocol	Scope 3 emissions	6. Business travel	tCO2e
	GHG Protocol	Scope 3 emissions	7. Employee commuting	tCO2e
	GHG Protocol	Scope 3 emissions	8. Leased assets	tCO2e
	GHG Protocol	Scope 3 emissions	9. Transportation and distribution	tCO2e
	GHG Protocol	Scope 3 emissions	10. Processing of sold products	tCO2e
	GHG Protocol	Scope 3 emissions	11. Use of sold products	tCO2e
	GHG Protocol	Scope 3 emissions	12. End of life treatment of sold products	tCO2e
	GHG Protocol	Scope 3 emissions	13. Leased assets	tCO2e
	GHG Protocol	Scope 3 emissions	14. Franchises	tCO2e
	GHG Protocol	Scope 3 emissions	15. Investments	tCO2e
	GHG Protocol	Scope 3 emissions	Absolute Scope 3 emissions	tCO2e
	GRI Standards	305-1 Direct (Scope 1) GHG emissions	Absolute Scope 1 emissions	
	GRI Standards	305-2 Energy indirect (Scope 2) GHG emissions	Absolute Scope 2 emissions	
	GRI Standards	305-3 Other indirect (Scope 3) GHG emissions	Absolute Scope 3 emissions	
	GRI Standards	305-4 GHG emissions intensity	GHG emissions intensity	
	GRI Standards	305-5 Reduction of GHG emissions	Reduction of GHG emissions	
	GRI Standards	305-6 Emissions of ozone-depleting substances (ODS)	Emissions of ozone-depleting substances (ODS)	
	GRI Standards	305-7 Nitrogen oxides (NOx), sulfur oxides (SOx), and other significant air emissions	Nitrogen oxides (NOx), sulfur oxides (SOx), and other significant air emissions	

Topic	Standard	Framework topic	Metric/indicators	Unit (blank if not mentioned)
	GSMA ESG Metrics for mobile	i. Absolute Scope 1 and 2 emissions (tonnes CO2e)	i. Absolute Scope 1 and 2 emissions (tonnes CO2e)	tCO2e
	GSMA ESG Metrics for mobile	ii. Absolute Scope 1 and 2 emissions (tonnes CO2e) per 1GB data	ii. Absolute Scope 1 and 2 emissions (tonnes CO2e) per 1GB data	tCO2e/GB
	GSMA ESG Metrics for mobile	iii. Percentage change in absolute Scope 1 and 2 emissions since last reporting period	iii. Percentage change in absolute Scope 1 and 2 emissions since last reporting period	%
	GSMA ESG Metrics for mobile	Absolute Scope 3 emissions	Absolute Scope 3 emissions	tCO2e
	GSMA ESG Metrics for mobile	ii. Absolute Scope 3 emissions per 1GB	ii. Absolute Scope 3 emissions per 1GB	tCO2e/GB
	GSMA ESG Metrics for mobile	iii. Percentage change in absolute Scope 3 emissions since laste reporting period	iii. Percentage change in absolute Scope 3 emissions since laste reporting period	%
	GSMA ESG Metrics for mobile	Science-based targets set or committed (Y/N)	Science-based targets set or committed (Y/N)	
Ecotoxicity	EU Comission common indicators	Ecotoxicity	Area of installations in protected areas or of high biodiversity	km2
	EU Comission common indicators	Ecotoxicity	Percentage of sites in protected or of high biodiversity	%
	EU Comission common indicators	Ecotoxicity	Volume of waste water	m3
Energy	EU Comission common indicators	Energy consumption	Total energy consumption	MWh
Energy	EU Comission common indicators	Energy efficiency	Power/Energy saved	MWh
	EU Comission common indicators	Use of renewable energy	Share of renewable energy of total energy consumed	%
	EU Comission common indicators	Use of renewable energy	Renewable energy consumed	MWh
	GRI Standards	302-1 Energy consumption within the organization	Energy consumption within the organization	
	GRI Standards	302-2 Energy consumption outside of the organization	Energy consumption outside of the organization	
	GRI Standards	302-3 Energy intensity	Energy intensity	
	GRI Standards	302-4 Reduction of energy consumption	Reduction of energy consumption	

Topic	Standard	Framework topic	Metric/indicators	Unit (blank if not mentioned)
	GRI Standards	302-5 Reductions in energy requirements of products and services	Reductions in energy requirements of products and services	
	GSMA ESG Metrics for mobile	Energy consumption	i. Total energy consumed	MWh
	GSMA ESG Metrics for mobile	Energy consumption	Total energy consumed per 1GB of data	MWh/GB
	GSMA ESG Metrics for mobile	Energy consumption	i. Total network energy consumed (MWh)	MWh
	GSMA ESG Metrics for mobile	Energy consumption	ii. Total network energy consumed (MWh) per 1GB of data	MWh/GB
	GSMA ESG Metrics for mobile	Energy consumption	i. Percentage grid renewable	%
	GSMA ESG Metrics for mobile	Energy consumption	ii. Percentage grid non-renewable	%
	GSMA ESG Metrics for mobile	Energy consumption	iii. Percentage off-grid renewable	%
	GSMA ESG Metrics for mobile	Energy consumption	iv. Percentage off-grid non-renewable	%
	SASB Standards for Telecommunications	Environmental footprint of operations	Total energy consumed	GJ
	SASB Standards for Telecommunications	Environmental footprint of operations	Percentage grid electricity	%
	SASB Standards for Telecommunications	Environmental footprint of operations	Percentage renewable	
Eutrophication	EU Comission common indicators	Eutrophication	Total nitrogen, total phosphorous, suspended solids	
	EU Comission common indicators	Eutrophication	Weight (kg) of phosphate (PO4) equivalent	
	EU Comission common indicators	Eutrophication	pH, biologicaloxygen demand (BOD), chemical oxygen demand (COD)	
	EU Comission common indicators	Eutrophication	Dissolvved oxygen	
Human toxicity	EU Comission common indicators	Human toxicity	Tons of water pollutant	t
	EU Comission common indicators	Human toxicity	Tons of air pollutant	t
	EU Comission common indicators	Human toxicity	Emitted electromagnetic field	Pending unit
Land use	EU Comission common indicators	Land use	Area of installations	Km2
Waste heat recovery	EU Comission common indicators	Waste heat recovery	Waste heat recovery	
Water and effluents	EU Comission common indicators	Water usage and consumption	Total water consumption	m3

Topic	Standard	Framework topic	Metric/indicators	Unit (blank if not mentioned)
	EU Comission common indicators	Water usage and consumption	Water usage effectiveness	
	GRI Standards	303-1 Interactions with water as a shared resource	Interactions with water as a shared resource	
	GRI Standards	303-2 Management of water discharge-related impacts	Management of water discharge-related impacts	
	GRI Standards	303-3 Water withdrawal	Water withdrawal	
	GRI Standards	303-4 Water discharge	Water discharge	
	GRI Standards	303-5 Water consumption	Water consumption	