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ENVIRONMENTAL SUSTAINABILITY IN MOBILE NETWORKS: Analysis of regulations and standards

Report 2 of 3

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Table of Contents

Abbreviations

2G	Second-generation mobile communication technology
3G	Third-generation mobile communication technology
3GPP	3rd Generation Partnership Project
4G	Fourth-generation mobile communication technology
5G	Fifth-generation mobile communication technology
6G	Sixth-generation mobile communication technology
AESA	Absolute Environmental Sustainability Assessment
AI	Artificial Intelligence
BEREC	Body of European Regulators for Electronic Communications
CE	Circular Economy
CGE	Computable General Equilibrium
CO_2	Carbon dioxide
CO_2e/CO_2eq	Carbon dioxide equivalent
CRMA	Critical Raw Materials Act
CSDDD/CS3D	Corporate Sustainability Due Diligence Directive
CSR	Corporate Social Responsibility
CSRD	Corporate Sustainability Reporting Directive
CUE	Carbon Usage Effectiveness
dB(A)	A-weighted decibel
DC	Direct Current
DNA	Digital Networks Act
DNSH	Do No Significant Harm
DPP	Digital Product Passport
DTX	Discontinuous Transmission
EC	European Commission
ECHA	European Chemicals Agency
ECN/ECNs	Electronic Communications Network / Electronic Communications Networks
ECS/ECSs	Electronic Communications Service / Electronic Communications Services
EE	Environmental Engineering
EECC	European Electronic Communications Code
EEE	Electrical and Electronic Equipment
EFRAG	European Financial Reporting Advisory Group
EPR	Extended Producer Responsibility
ERF	Energy Reuse Factor
ES	ETSI Standard
ESEF	European Single Electronic Format
ESG	Environmental, Social and Governance

ESPR	Ecodesign for Sustainable Products Regulation
ESRS E1	European Sustainability Reporting Standard E1: Climate Change
ESRS E2	European Sustainability Reporting Standard E2: Pollution
ESRS E3	European Sustainability Reporting Standard E3: Water and Marine Resources
ESRS E4	European Sustainability Reporting Standard E4: Biodiversity and Ecosystems
ESRS E5	European Sustainability Reporting Standard E5: Resource Use and Circular Economy
ESRS	European Sustainability Reporting Standards
ETSI	European Telecommunications Standards Institute
EU ETS	European Union Emissions Trading System
EU	European Union
EUR	Euro
GHG	Greenhouse Gas
GRI	Global Reporting Initiative
ICT	Information and Communication Technology
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radiocommunication Sector
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
JRC	Joint Research Centre
kg CO_2e	Kilograms of carbon dioxide equivalent
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
M2M	Machine-to-Machine
MNO	Mobile Network Operators
MSA	Mean Species Abundance
mtCO_2e	Metric tonnes of carbon dioxide equivalent
MWh	Megawatt-hour
NFRD	Non-Financial Reporting Directive
NFV	Network Function Virtualisation
NGOs	Non-Governmental Organisations
NRAs	National Regulatory Authorities
OAM	Operations, Administration and Maintenance
ODN	Office for Digital Networks
PPA	Power Purchase Agreement
PUE	Power Usage Effectiveness
PV	Photovoltaic
QR	Quick Response

RAN	Radio Access Network
RAT	Radio Access Technology
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
REF	Renewable Energy Factor
RoHS	Restriction of Hazardous Substances
RRU	Repairability, Reusability and Upgradeability
RSPB	Radio Spectrum Policy Body
RSPG	Radio Spectrum Policy Group
SDGs	Sustainable Development Goals
SFDR	Sustainable Finance Disclosure Regulation
SG5	Study Group 5
SMEs	Small and Medium-sized Enterprises
SSC	Smart Sustainable City
TC	Technical Committee
TEP	Telecommunication Equipment Provider
TRAFICOM	Finnish Transport and Communications Agency
TS	Technical Specification
UER10	Ratio of use-phase emissions during 10 years over embodied emissions
UN SDGs	United Nations Sustainable Development Goals
UN	United Nations
VDC	Volts Direct Current
VSME	Voluntary Sustainability Reporting Standard for non-listed Small and Medium-sized Enterprises
WEEE	Waste Electrical and Electronic Equipment
WUE	Water Usage Effectiveness
XBRL	eXtensible Business Reporting Language

Abstract

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ENVIRONMENTAL SUSTAINABILITY IN MOBILE NETWORKS: Analysis of regulations and standards

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This report describes how the environmental sustainability in mobile communications sector is addressed by the regulations and standards. This is the second report in a series of three reports prepared by University of Oulu in Green ICT VISIIRI project. A structured, multi-phased methodology was adopted to review and analyse regulatory and standardization documents relevant to environmental sustainability in mobile communications in Europe, including sustainability reporting. First, relevant documents were identified from regulatory and standardization organisations and supporting institutional sources. Then, the selected documents were reviewed and analysed to extract key information on environmental sustainability themes and related requirements, indicators, methodologies, and best practices to help companies in the information and communication technology (ICT) sector towards energy efficient operations. The study identified how environmental sustainability is addressed across regulations, reporting requirements, and standards, with particular attention to their relevance for ICT companies and mobile communication stakeholders to reduce negative impacts (footprint) and improve positive impacts (handprint). Findings provide guidance for companies and organizations with interest, showcasing how the stakeholders can improve their own operations and contribute to enhancing environmental sustainability.

Keywords – directives, energy consumption, energy efficiency, environmental sustainability, greenhouse gas emissions, mobile communications, regulations, standards, sustainability reporting

1

Introduction

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1 Introduction

Sustainable development can be generally defined as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" based on the seminal work in (G. Brundtland, 1987). Sustainability on the other hand can be seen as the "principle of ensuring that our actions today do not limit the range of economic, social, and environmental options open to future generations" (Elkington, 1997).

Within the information and communication technology (ICT) sector, sustainable development and sustainability are nowadays generally addressed through the three interrelated pillars of economic, social, and environmental sustainability (Hexa-X-II, 2023). These sustainability pillars present distinct but closely interconnected views. As the demand for digital solutions and services expands to cloud computing and Artificial Intelligence (AI) and mobile connectivity requirements continue to grow, so does the ICT sector's environmental impact (World Bank Group, 2024), (IEA, 2025). Growth in data traffic and numbers of devices, and the use of AI increase the energy consumption, and the use of resources and materials, contributing to increased greenhouse gas (GHG) emissions. The ITU and the World Bank assessed 200 leading digital companies and reported that these companies consumed an estimated 581 TWH of electricity, which is equivalent to 2.1% of global electricity consumption. The combined operational emissions from 166 of the 200 companies were 297 million tCO_2e which is approximately 0.8% of global emissions related to energy. This represents a 1.4% increase in emissions from the previous year (ITU and WBA, 2025).

The sustainability related regulatory frameworks and standards impacting the ICT sector include the Paris Agreement (UNFCCC, 2019), the United Nations Sustainability Development Goals (UN SDGs) (UN, 2015) and the European Green Deal (EC, 2019a), among others. They define the high-level targets for the ICT sector to manage its environmental sustainability impact. The Paris Agreement (UNFCCC, 2019) is an international treaty on climate change that was adopted by 195 countries in Paris France in 2015 to ensure that global average temperatures remain well below 2°C above pre-industrial levels and to limit temperature increase to 1.5°C above pre-industrial levels. The UN SDGs (UN, 2015) are the internationally agreed agenda with 17 goals that call for action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030, among others. The European Green Deal (EC, 2019a) is a legally binding strategy that aims to cut greenhouse gas emissions by at least 50% by 2030 and achieve climate neutrality by 2050 by transforming Europe's economy, energy systems, transport, and industries.

Energy efficiency is a central environmental sustainability issue in mobile communications because mobile networks require continuous electricity for radio access networks, base stations, backhaul, core network equipment, power systems, cooling systems, and supporting infrastructure. As mobile data traffic increases and networks evolve towards 5G and future 6G systems, reducing energy consumption per unit of service becomes increasingly important.

Mobile communication network infrastructure within the ICT sector is the backbone for modern societies. Mobile communication networks have a dual role in environmental sustainability discussions. On one hand, they create environmental sustainability burden by producing greenhouse gas emissions through energy consumption, manufacturing, logistics and operations, among others, resulting in so-called environmental footprints. On the other hand, they function as enablers for environmental sustainability improvements including decarbonization across different sectors by providing digital solutions that optimize use of resources, reduce travel, and improve operational efficiency among others, resulting in so-called environmental handprint. For example, the use of mobile communication solutions can enable intelligent transport solutions, remote working, and precision agriculture and contribute to enabling emissions reductions in other sectors. This dual role presents both a challenge and an opportunity for the mobile communication sector to contribute to sustainable development (GSMA, 2023), (NGA, 2023).

This study is conducted in the VIISIRI project, a national Green ICT initiative in Finland that aims to accelerate the green transition of the ICT sector by fostering environmentally sustainable practices, reducing environmental impact, and promoting energy-efficient solutions for future ICT solutions including mobile communication networks. This report is the second in a series of three reports on Environmental Sustainability in Mobile Networks. The companion reports in this series are: Environmental Sustainability in Mobile Networks: A study of mobile communication stakeholders' activities and indicators (first report), and Environmental Sustainability in Mobile Networks: Energy efficiency enhancing techniques and design principles (third report). The reports can be read independently of one another. This report examines the relevant environmental sustainability regulations and standards applicable to the mobile communications sector within the wider ICT industry in Europe. The regulations and standards are categorised and presented in a structured format to help companies get familiar with them and distinguish between mandatory legal requirements and voluntary or industry-recognised standards. This approach enables ICT companies of all sizes to more easily identify applicable requirements, support compliance efforts, and incorporate environmental sustainability practices into their operational and strategic decision-making. In addition, the report discusses sustainability reporting as a key mechanism for demonstrating regulatory compliance, enhancing transparency, and communicating environmental sustainability performance to stakeholders.

The remainder of this report is structured as follows. Chapter 2 describes the methodology adopted for this study. Chapter 3 presents the regulatory framework relevant to environmental sustainability in mobile communications, with emphasis on European regulations and selected regulatory bodies. Chapter 4 discusses the sustainability reporting framework in Europe, including key reporting requirements and environmental disclosure topics relevant to ICT companies. Chapter 5 examines the standardization framework, focusing on standardization bodies and selected standards related to environmental sustainability in ICT and mobile communications. Finally, Chapter 6 reviews how energy efficiency is considered in the regulations and standards by identifying the key regulatory, reporting, and standardization aspects relevant to improving energy performance in mobile communication networks.

2

Methodology

2 Methodology

This study adopts a qualitative document-based approach to review and analyse regulatory and standardization activities relevant to environmental sustainability in mobile communications. The analysis is based on publicly available legal documents, regulatory reports, sustainability reporting frameworks, and technical standards. The scope of the study is limited to environmental sustainability in mobile communications in Europe. This study follows a structured and multi-phased methodology including systematic data collection, analysis and reporting as shown in Figure 2.1. The methodology consists of five sequential phases: regulatory and standards bodies identification, data source selection, data extraction and coding, analysis and categorization, and integrated synthesis and reporting, which are detailed in the following.

The first phase, regulatory and standards bodies identification focuses on determining the relevant regulatory and standardization bodies that impacts and drive environmental sustainability in mobile communication.

In the second phase, data sources selection, relevant documents were identified through a structured mapping of regulatory, reporting, and standardization sources to the scope of the study. Regulatory documents were selected mainly from European Union legal and policy sources. Standardization documents were selected from international and European standardization bodies relevant to ICT and telecommunications, especially International Telecommunication Union – Telecommunication Standardization Sector (ITU-T) and European Telecommunications Standards Institute (ETSI). Additional materials from Radio Spectrum Policy Group (RSPG) that assists the European Commission in the development of radio spectrum policy, Body of European Regulators for Electronic Communications (BEREC), which supports corporation among national regulatory authorities in the EU and the Joint Research Centre (JRC), which is the European Commission's in-house science and knowledge service, were included where they provided indicators, policy guidance, or sector-specific discussion on environmental sustainability in telecommunications networks.

In the third phase, data extraction and coding, the analysis was organised into three separate but related dimensions since different types of documents were used in each dimension: regulatory frameworks, sustainability reporting frameworks, and standardization frameworks. Regulatory frameworks were analysed to identify legal and policy instruments relevant to environmental sustainability in mobile communication. Sustainability reporting frameworks were analysed to identify environmental disclosure topics, indicators, and calculation requirements. Standardization frameworks were analysed to identify technical methodologies, metrics, requirements, and best practices that support environmental assessment and improvement in ICT and telecommunications.

In the fourth phase, a thematic analysis was carried out to group the content according to their main environmental sustainability focus. Regulatory documents were categorised under themes including basic legislation, climate action, energy, waste management, circularity and material usage, and infrastructure. Standardization documents were categorised according to their function, including guidelines and best practices, standards directly related to regulations, impact assessments- indicator, and requirements – related to indicators.

Finally, the fifth and last phase, integrated synthesis and reporting, delivers the results in a structured manner, which is this report.

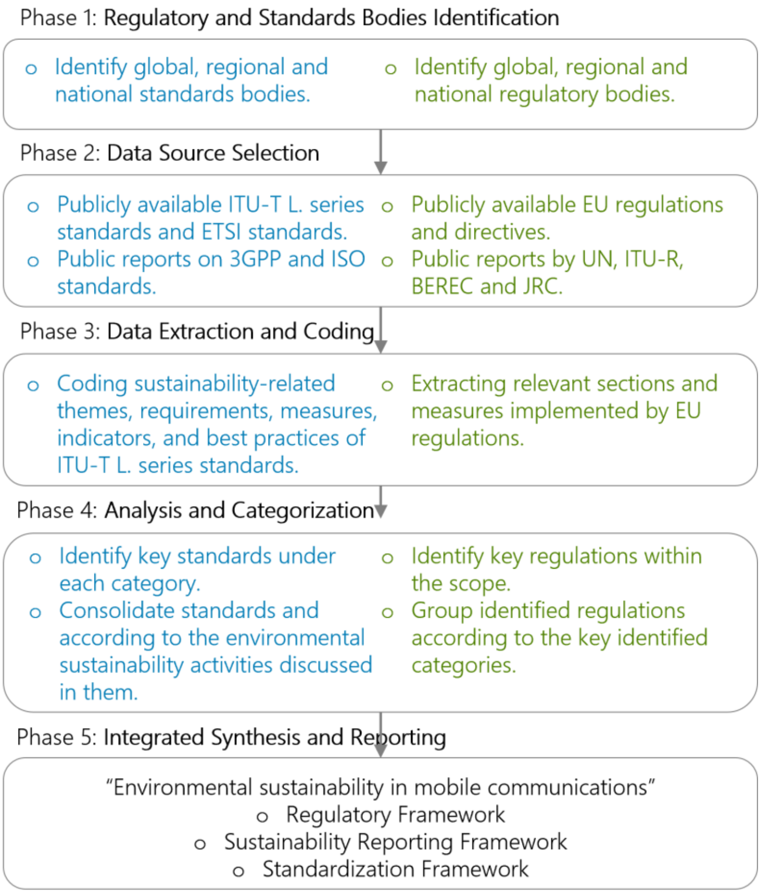

Figure 2.1: Methodology for analysing regulations and standards (regulations and standards are represented in green (right-hand side) and blue (left-hand side), respectively)

3

Regulatory framework

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3 Regulatory framework

This chapter provides a comprehensive yet non-exhaustive account of the regulatory bodies and regulations relevant to environmental sustainability in mobile communications. It first begins with the broader international regulatory context, including the United Nations (UN) level activities in the UN Sustainable Development Goals (UN SDGs) and relevant activities of the UN specialised agency for the ICTs - International Telecommunication Union (ITU) in its Radiocommunication Sector (ITU-R). The chapter then focuses on Europe including the European Union regulations and identifies and categorises regulatory instruments related to climate action, energy efficiency, renewable energy, sustainable product design, circularity, waste management, and communications infrastructure relevant to mobile communications. It also considers the role of supporting institutions, including the Radio Spectrum Policy Group (RSPG) , Body of European Regulators for Electronic Communications (BEREC) and Joint Research Centre (JRC), and in providing guidance, indicators, and technical evidence for assessing and improving the environmental performance of mobile communications networks and services.

3.1 Identified regulatory bodies

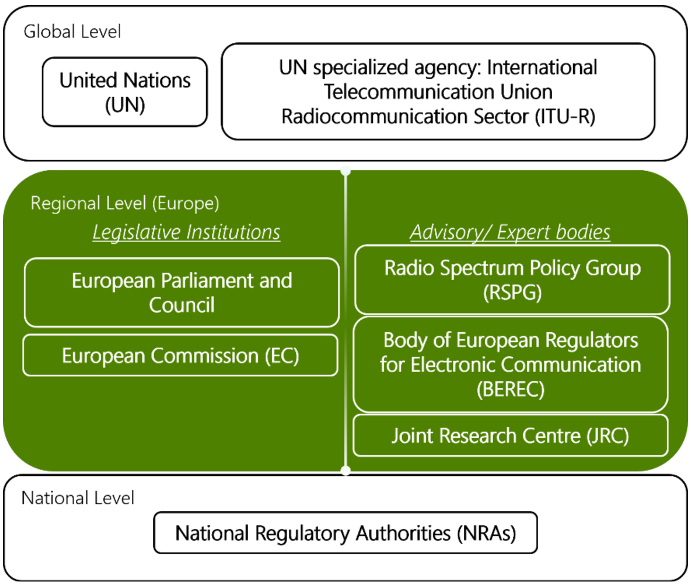

Figure 3.1: Classification of regulatory bodies

Regulatory bodies in general are public authorities or agencies that contribute to the implementation, monitoring, and enforcement of rules within a specific sector or policy area (European

Commission, 2002). They can be categorised into global, regional, and national bodies, reflecting their different levels of jurisdiction, legal authority, and enforcement capacity as shown in Figure 3.1. This study focuses primarily on the regional regulatory framework of Europe considering the European Union, making use of publicly available regulations, directives, recommendations, reports, and guidance documents issued by the European Commission, and supporting institutions including RSPG, BEREC and JRC.

At the global level, sustainability is considered thoroughly in the UN SDG framework, which comprises of 17 goals, which are further characterised with 169 targets whose progress is measured with 234 unique indicators (UN, 2015) providing the main global framework for sustainable development. The original version was adopted by United Nations Member States in 2015 (UN, 2015), and it provides a blueprint peace and prosperity for people and planet. Out of the 234 unique indicators 5 are directly related to ICT, as shown in Figure 3.2.

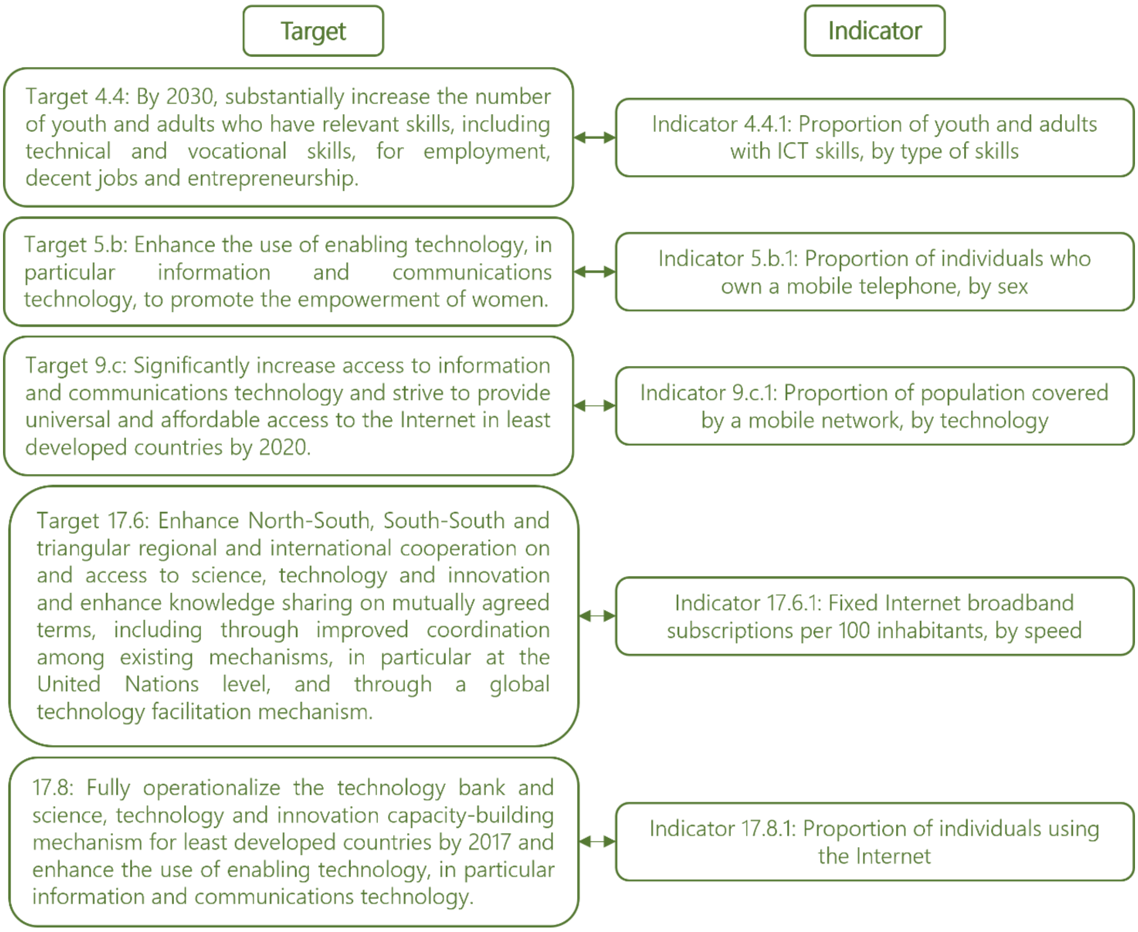

Figure 3.2: UN SDG targets and indicators directly related to ICT (ITU n.d.-b)

Mobile communications are governed at the global level in the UN based specialised agency for ICTs, i.e. the ITU. Within the ITU, the Radiocommunication Sector (ITU-R) is the global regulatory body for the telecommunications and plays a central role in the international coordination of radio-frequency spectrum, which are essential for mobile communication systems. ITU also addresses the environmental implications of digitalisation to some degree. One of ITU's areas of action is "Environment and Climate Change", which focuses on greening the digital transition and supporting the use of ICTs for environmentally sustainable development (ITU, n.d.-a)

At the European level, environmental sustainability in mobile communications, which falls under electronic communications, is supported by a combination of legislation, regulatory coordination, technical research, and policy guidance. The European Commission plays a central role by proposing legislation, developing EU policy strategies, and preparing delegated and implementing acts where authorised by EU law (EC, n.d.-a), (EC, n.d.-b). Its policy initiatives include the European Green Deal, which sets the wider framework for climate action, resource efficiency, energy transition, circular economy, sustainable products, and the green and digital transformation (EC, 2019a). The European Parliament and the Council of the European Union act as co-legislators under the ordinary legislative procedure by examining, amending, negotiating, and adopting EU regulations and directives proposed by the Commission (European Parliament, n.d.; Council of the European Union, n.d.). Through this process, sustainability-related requirements affecting mobile communication stakeholders are established across areas such as climate action, energy performance, waste management, sustainable product design, corporate sustainability reporting, and communications infrastructure.

Bodies such as Radio Spectrum Policy Group (RSPG), Body of European Regulators for Electronic Communications (BEREC), and Joint Research Centre (JRC) play important complementary roles in this framework. Although they do not replace binding EU legislation, their reports, consultations, indicators, and technical guidance help regulators, policymakers, and industry stakeholders interpret sustainability challenges in the telecommunications sector and develop more harmonized approaches across Member States.

RSPG is a high-level advisory group and assists the European Commission in the development of radio spectrum policy supporting the idea of sustainable spectrum use (RSPG, 2023b). Its spectrum policy affects mobile network deployment, spectrum efficiency, technology migration, energy consumption, and 6G planning. BEREC contributes mainly through regulatory analysis and coordination among National Regulatory Authorities (NRAs). It has conducted environmental sustainability work on the environmental footprint of electronic communications networks and services, including energy consumption, carbon emissions, e-waste, infrastructure sharing, environmental transparency, and sustainability indicators (RSPG, 2025). BEREC has emphasized the need for reliable and comparable data, harmonized indicators, and clearer methodologies to assess the environmental impact of electronic communications networks and services.

The JRC provides technical and scientific evidence base for EU policy making. JRC has worked on identifying common indicators for measuring the environmental footprint of electronic communications networks used to provide electronic communications services (JRC, 2024). The recent EU code of conduct by JRC (JRC, 2026), for the sustainability of telecommunications network provides evidence on the importance of harmonizing regulations and technical standards and help the industry follow and establish sustainability best practices and improve overall sustainability.

At the national level, EU legislation is operationalised through domestic legal frameworks, competent authorities, and sector-specific regulatory bodies. In the Finnish context, Ministry of Transport and Communications and Finnish Transport and Communications Agency (TRAFICOM) are particularly relevant due to their responsibilities in communications regulation. The ministry published climate and environmental strategy for the ICT sector in Finland in 2021 (Ministry of Transport and Communications, 2021).

3.2 Identified European regulations

European regulations in the mobile communication sector aims to harmonize the market across Europe, ensuring that both businesses and citizens of member countries benefit from high-quality, affordable, and secure mobile services. For the purposes of this report, the reviewed EU regulations and directives are analytically grouped into six proposed thematic categories, as shown in Figure 3.3, according to their primary relevance to environmental sustainability in mobile communications. These six thematic categories include basic legislation, climate action, energy, waste management, circularity and material usage, and infrastructure. This classification was developed for this report, based on the main environmental sustainability themes addressed by the selected instruments and their relevance to ICT and mobile communication stakeholders. The grouping is not intended to represent an official EU legal classification, but rather to provide a structured way to analyse a broad and cross-cutting regulatory framework.

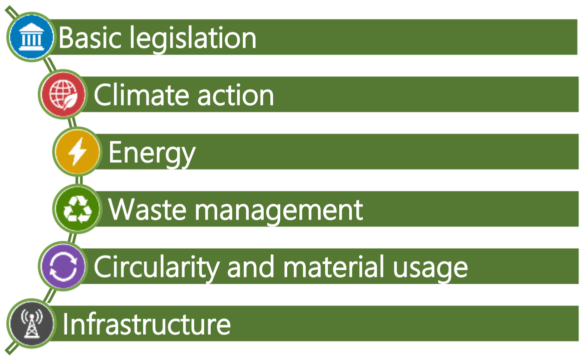

Figure 3.3: Proposed thematic categories of European regulations related to environmental sustainability in mobile communications.

The European regulatory framework relevant to environmental sustainability in mobile communications was further analysed with respect to these six thematic categories to identify the key regulations. These include basic legislation (EU, 2020), (EU, 2024a), (EU, 2024b), (EU, 2019a), (EC, 2022), climate action (EU, 2021), (EU, 2024c), (EU, 2024d), energy (EC, 2023a), (EU, 2017), (EU, 2018a), (EU, 2023a), (EU, 2023b), waste management (EU, 2012), (EU, 2023c), (EU, 2024e) ,circularity and material usage (EC, 2019b), (EC, 2023b), (EU, 2003), (EU, 2006), (EU, 2009), (EU, 2011), (EU, 2019b), (EU, 2024b), (EU, 2024f) , and infrastructure (EU, 2018b), (EC, 2026). In Figure 3.4 the selected regulations and directives for this study are grouped into the thematic categories and subsequently discussed.

Basic Legislation

- EU Taxonomy Framework
- Corporate Sustainability Due Diligence Directive
- EU's Consumer Protection Framework
- Sustainable Finance Disclosure Regulation
- Do no Significant harm (DNSH) principle

Climate Action

- EU Climate Law
- Critical Raw Materials Act
- Net-Zero Industry Act

Energy

- Energy Efficiency Directive (recast)
- Renewable Energy Directive (revised)
- EU's common framework for promoting energy from renewable sources
- A harmonised EU framework for the energy labelling of energy-related products
- Mandatory energy labelling requirements for smartphones and slate tablets

Waste Management

- Waste Electrical and Electronic Equipment (WEEE) Directive
- The Batteries and Waste Battery Act
- Common EU rules to strengthen the repair of consumer goods

Circularity and Material Use

- European Union Emissions Trading System
- EU Ecodesign Framework
- The Ecodesign for Sustainable Products Regulation
- Eco-design requirements for smartphones, other mobile phones, cordless phones and slate tablets
- Regulation on market surveillance and compliance of products
- Eco-design requirements for servers and online data-storage products

Infrastructure

- European Electronic Communications Code (EECC)
- The proposed Digital Networks Act

Figure 3.4: Selected regulations and their mapping to proposed six thematic categories.

3.2.1 Basic legislation

Next, basic legislation components from the European regulatory framework relevant to mobile communications are introduced.

EU Taxonomy framework

The EU Taxonomy framework (regulation (EU) 2020/852) defines clear and harmonised criteria for determining whether an economic activity can be considered environmentally sustainable, with the aim of guiding sustainable investment and improving transparency in financial markets (EU, 2020). It is relevant to environmental sustainability in mobile communications due to its influence on how investments in mobile networks, data centres, and ICT infrastructure are evaluated, encouraging capital flows towards low-carbon, energy-efficient, and circular mobile communication systems that contribute to climate change mitigation and adaptation. Key points of the regulation include its six environmental objectives, the “do no significant harm” principle, mandatory technical screening criteria, application to large companies and financial market participants, and its role in aligning financing of mobile communication infrastructure with long-term EU sustainability and climate goals.

Corporate Sustainability Due Diligence Directive

The Corporate Sustainability Due Diligence Directive (CSDDD/CS3D) (directive (EU) 2024/1760), establishes binding obligations for large EU and non-EU companies to identify, prevent, mitigate, and remediate actual and potential adverse human rights and environmental impacts across their own operations, subsidiaries, and value chains, while also requiring the adoption of a climate transition plan aligned with limiting global warming to 1.5 °C under the Paris Agreement (EU, 2024a). It is highly relevant to environmental sustainability in mobile communications because major mobile network operators, equipment manufacturers, and other ICT companies typically fall within its scope and must therefore address environmental risks such as emissions, resource use, and electronic waste throughout complex global supply chains. Key points include mandatory risk-based environmental due diligence, corporate liability for non-compliance, integration of sustainability into business strategy, supply-chain accountability, and the requirement for climate mitigation transition plans, all of which reinforce more transparent, responsible, and sustainable practices in the mobile communications ecosystem.

EU's consumer protection framework

The EU's consumer protection framework supports the green transition by strengthening rules against greenwashing and ensuring that consumers receive reliable information on the environmental performance (directive (EU) 2024/825), durability and reparability of products at the point of sale. This directive is relevant to environmental sustainability in mobile communications because it affects how sustainability claims can be made for mobile communication equipment and services, ensuring that users receive transparent information on product longevity, software update periods and repair options; factors that can reduce electronic waste and extend device lifetimes (EU, 2024b). Key points include stricter controls on environmental claims and sustainability labels, mandatory disclosure on durability and repairability, harmonised notices on legal guarantees, transparency on commercial guarantees of durability, and clearer information on software update support for goods with digital elements such as smartphones, routers and other user equipment.

Sustainable Finance Disclosure Regulation

The Sustainable Finance Disclosure Regulation (SFDR) (regulation (EU) 2019/2088) sets harmonised EU-wide transparency rules requiring financial market participants and financial advisers to disclose how they integrate sustainability risks, consider adverse environmental and social impacts, and assess sustainability characteristics of financial products (EU, 2019a). While the regulation targets the financial sector rather than the ICT industry directly, it is relevant to environmental sustainability in mobile communications because investors financing mobile network operators, device manufacturers network infrastructure providers, and other ICT companies must disclose sustainability risks and impacts, thereby incentivising low-carbon investments, greener technologies and stronger environmental, social and governance (ESG) performance across the mobile communications value chain. Key points include mandatory disclosure of sustainability risks, reporting on adverse impacts on ESG factors, clearer distinctions between sustainability-risk exposure and sustainability impacts, and enhanced transparency designed to reduce greenwashing and steer capital toward genuinely sustainable activities. By shaping investment flows, the SFDR indirectly supports the transition to more energy-efficient, climate-aligned and resource-responsible mobile communication systems.

Do no Significant harm (DNSH) principle

Do no Significant harm (DNSH) principle supplements the SFDR (commission delegated regulation (EU) 2022/1288) by specifying detailed regulatory technical standards for how financial market participants and advisers must present sustainability-related information, including adherence to the "do no significant harm" principle, disclosure of adverse sustainability impacts and sustainability indicators, and the presentation of environmental or social characteristics and sustainable investment objectives (EC, 2022). Although it applies to the financial sector, it is relevant to environmental sustainability in mobile communications because investors and financing institutions evaluating mobile network operators, device manufacturers, network infrastructure companies and other ICT companies must report sustainability risks and impacts using these harmonised standards, thereby strengthening incentives for the mobile communications sector to reduce emissions, improve supply-chain responsibility and enhance electronic-waste and resource-efficiency performance. Key points include mandatory clear, accessible and non-misleading sustainability disclosures; standardised templates for pre-contractual documents, websites and periodic reports; the requirement to provide information in searchable electronic formats; rules for maintaining up-to-date disclosures; and inclusion of identifiers to ensure transparency and traceability across sustainable-finance reporting.

3.3.2 Climate action

Next, climate action related components from the European regulatory framework relevant to mobile communications are introduced.

EU Climate Law

The EU Climate Law (regulation (EU) 2021/1119) establishes a legally binding framework for the progressive and irreversible reduction of greenhouse gas emissions, setting the objective of climate neutrality in the European Union by 2050 and a net emission reduction of at least 55% by 2030 compared to 1990 levels (EU, 2021). It is directly relevant to environmental sustainability in mobile communications because it provides the overarching legal basis that drives sector-wide decarbonisation measures, influencing mobile network operators to reduce energy consumption, increase renewable energy use, and align network expansion with long-term climate targets. Key points of the regulation include its binding nature, requirement for continuous progress toward climate mitigation and adaptation, integration of scientific guidance through an independent European Scientific Advisory Board on Climate Change, and its role in steering policies and investments that shape the transition to sustainable, low-carbon mobile communication systems.

Critical Raw Materials Act

The Critical Raw Materials Act (CRMA) (regulation (EU) 2024/1252) establishes an EU framework to secure a stable, resilient and sustainable supply of critical and strategic raw materials that are essential for green and digital technologies, while promoting efficiency and circularity across the value chain (EU, 2024c). This regulation is highly relevant to environmental sustainability in mobile communications because mobile devices, network equipment, hardware and batteries rely heavily on strategic and critical materials, such as; rare earth elements, cobalt, lithium and gallium, making supply stability and responsible sourcing essential for developing low-carbon, resource-efficient communication networks. Key points include EU-level benchmarks for 2030 (10% domestic extraction, 40% processing, and 25% recycling capacity), requirements to diversify imports so no single non-EU country supplies more than 65% of a given material, identification of 17 strategic and 34 critical raw materials, and support for strategic projects that enhance circularity, resource efficiency and environmental protection. Through these measures, the regulation strengthens the sustainability and resilience of supply chains underpinning mobile communication technologies.

Net-Zero Industry Act

The Net-Zero Industry Act (regulation (EU) 2024/1735) establishes the EU framework to scale up the manufacturing capacity and deployment of net-zero technologies to secure a resilient supply of climate-critical industrial capabilities and support the Union’s climate-neutrality objective under the EU Climate Law (EU, 2024d). This regulation is relevant to environmental sustainability in mobile communications because mobile networks increasingly rely on net-zero-related technologies, such as; renewable-powered base stations, advanced batteries, efficient power systems, and carbon-capture-enabled industrial inputs, to decarbonise network operations and reduce lifecycle emissions. Key points include EU measures to reduce supply-chain risks by expanding domestic manufacturing of 19 priority net-zero technologies, creating an internal market for CO_2 storage services, supporting public procurement that favours sustainable technologies, developing skills through dedicated training academies, and setting manufacturing targets of meeting at least 40% of EU deployment needs by 2030 and 15% of global production by 2040. Through these mechanisms, the act strengthens the technological and industrial foundations needed to accelerate the decarbonisation of digital and mobile communication infrastructure.

3.2.3 Energy

Next, energy related components from the European regulatory framework relevant to mobile communications are introduced.

The recast Energy Efficiency Directive

The recast Energy Efficiency Directive (directive (EU) 2023/1791), establishes a common EU framework to promote energy efficiency across all sectors, embedding the "energy efficiency first" principle and supporting the EU Climate Law's objectives of climate neutrality by 2050 and at least a 55% reduction in greenhouse gas emissions by 2030 (EU, 2023a). It is directly relevant to environmental sustainability in mobile communications because mobile networks, data centres, and ICT infrastructure are energy-intensive, and the directive incentivises operators to optimise network energy use, deploy energy-efficient equipment, and integrate efficiency considerations into planning, operation, and investment decisions. Key points include binding EU-level energy efficiency targets for 2030, indicative national contributions, prioritisation of efficiency across the entire energy chain, alignment with the European Green Deal and REPowerEU objectives, and its role in reducing energy consumption and emissions associated with mobile communication systems.

Revised Renewable Energy Directive

The revised Renewable Energy Directive (directive (EU) 2023/2413) establishes the EU framework for increasing the share of renewable energy across all sectors, supporting the Union's climate-neutrality objectives by accelerating deployment of renewables in electricity, heating, cooling, transport and industry (EU, 2023b). This directive is directly relevant to environmental sustainability in mobile communications because mobile networks and data centres are major electricity consumers, and increasing the renewable share in the energy mix significantly reduces the carbon footprint of network operations, data transmission and mobile device use. Key points include binding EU-wide renewable energy targets for 2030, streamlined permitting for renewable projects, measures to expand renewable energy in industry and buildings, sector-specific sub-targets, and strengthened guarantees of origin, all of which support the transition toward low-carbon mobile communication infrastructures powered increasingly by renewable electricity.

EU's common framework for promoting energy from renewable sources

The EU's common framework for promoting energy from renewable sources (directive (EU) 2018/2001) sets a binding 2030 target for the share of renewables in the Union's gross final energy consumption and introduces harmonised rules for renewable electricity, heating and cooling, transport fuels, self-consumption, guarantees of origin, sustainability criteria and administrative procedures (EU, 2018a). This directive is directly relevant to environmental sustainability in mobile communications because mobile networks, data centres and other ICT infrastructure are large electricity consumers, and increasing the share of renewable energy in the grid significantly reduces the carbon footprint associated with powering mobile communication services. Key points include binding EU-wide renewable-energy targets, rules that support renewable self-consumption, sustainability and greenhouse-gas saving criteria for bioenergy, strengthened cooperation mechanisms between Member States, and a comprehensive governance framework under the Clean Energy for All Europeans package, all contributing to greener, lower-carbon energy supply for digital and mobile communication systems.

A harmonised EU framework for the energy labelling of energy-related products

A harmonised EU framework for the energy labelling of energy-related products (regulation (EU) 2017/1369) requires clear and standardised information on energy efficiency and resource consumption to support informed purchasing decisions and reduce overall energy use (EU, 2017). It relates to environmental sustainability in mobile communications primarily through user equipment and related ICT products, as energy labelling encourages the market uptake of more energy-efficient devices, thereby lowering electricity consumption and associated greenhouse gas emissions over their use phase. Key points include the mandatory A-to-G energy-efficiency scale, product information sheets, rescaling of legacy labels to reflect technological progress, exclusion of second-hand products and transport, and its role in complementing eco-design measures to reduce the environmental footprint of mobile communication devices.

Mandatory energy-labelling requirements for smartphones and slate tablets placed on the EU market

Mandatory energy-labelling requirements for smartphones and slate tablets placed on the EU market (commission delegated regulation (EU) 2023/1669) ensure that consumers receive standardised, comparable information on the energy efficiency and environmental performance of these devices (EC, 2023a). The regulation supports environmental sustainability in mobile communications by encouraging the uptake of more energy-efficient devices, thereby reducing electricity consumption over the use phase and supporting the broader shift toward lower-impact digital technologies. Key points include the introduction of a mandatory energy label with graded efficiency classes, requirements for supplementary product information, exclusions for flexible-display devices and high-security smartphones, and alignment with the eco-design rules to ensure consistent sustainability standards across mobile devices. By increasing transparency and driving competition on energy performance, the regulation contributes to reducing the environmental footprint of widely used mobile communication devices.

3.2.4 Waste management

Next, waste management related components from the European regulatory framework relevant to mobile communications are introduced.

The Waste Electrical and Electronic Equipment (WEEE) Directive

The Waste Electrical and Electronic Equipment (WEEE) Directive (directive 2012/19/EU) establishes measures to protect environmental and human health by reducing the adverse impacts of electrical and electronic waste through prevention, reuse, recycling, and efficient resource recovery (EU, 2012). The directive is directly relevant to environmental sustainability in mobile communications because the ICT and mobile sectors generate significant amounts of electrical and electronic waste from devices, network equipment, and supporting infrastructure, making proper end-of-life management essential to reduce resource depletion and environmental harm. Key points include its broad "open scope" covering almost all electrical and electronic equipment since 2018, mandatory extended producer responsibility, clear categorisation of WEEE (including IT and telecommunications equipment), and its role in promoting circular-economy practices within mobile communication systems.

The Batteries and Waste Battery Act

Batteries and Waste Battery Act (regulation (EU) 2023/1542) establishes comprehensive EU rules for the sustainability, safety, labelling, due diligence, collection and recycling of all battery types aiming to reduce their carbon footprint, limit harmful substances, improve supply-chain responsibility and advance circular-economy practices across the Union (EU, 2023c). This regulation is highly relevant to environmental sustainability in mobile communications because batteries are essential components of mobile phones, IoT devices, network equipment, energy-backup systems and base-station power solutions, making responsible sourcing, longer battery lifetimes and high recycling rates crucial for reducing environmental impacts associated with mobile communication infrastructure. Key points include strict sustainability and performance requirements, mandatory due-diligence obligations for raw-material sourcing (covering lithium, cobalt, nickel and graphite), restrictions on hazardous substances, carbon-footprint labelling, extended-producer-responsibility obligations, high collection and recycling targets, and the introduction of a digital "battery passport" and QR code for providing transparent information on components, recycled content and environmental performance. By promoting durable, traceable and recyclable batteries, the regulation strengthens the environmental sustainability of battery-dependent mobile communication technologies.

Common EU rules to strengthen the repair of consumer goods

Common EU rules to strengthen the repair of consumer goods (directive (EU) 2024/1799) aim to improve the functioning of the internal market while ensuring high levels of consumer and environmental protection by encouraging repair over replacement (EU, 2024e). This directive is relevant to environmental sustainability in mobile communications because mobile phones, routers, modems, and other ICT devices are frequently replaced prematurely, and enhanced repair rights can extend device lifetimes, reduce electronic waste, and lower the environmental footprint associated with mobile communication equipment. Key points include harmonised rules applying to the repair of goods when defects occur outside the seller's liability period, obligations linked to products covered by EU repairability requirements, and provisions that complement existing consumer protection laws without reducing higher national standards. By promoting a culture of repair and longer-lasting devices, the directive supports circular economy objectives within the mobile communications sector.

3.2.5 Circularity and material usage

Next, circularity and material usage related components from the European regulatory framework relevant to mobile communications are introduced.

European Union Emissions Trading System

The European Union Emissions Trading System (EU ETS) (directive 2003/87/EC) is a cap-and-trade framework aimed at reducing greenhouse gas emissions in a cost-effective and economically efficient manner while supporting the EU's climate-neutrality objectives and commitments under the Paris Agreement (EU, 2003). Although mobile communications and the wider ICT sector are not directly covered, the directive is relevant to environmental sustainability in mobile networks through indirect effects such as carbon pricing on electricity generation and upstream industries, which incentivise mobile network operators to improve energy efficiency and increase the use of renewable energy in network operations. Key points of the directive include its economy-wide emissions cap, tradable emission allowances, progressive tightening under the Fit for 55-package, and its role in creating systemic decarbonisation signals that influence sustainable practices across sectors connected to mobile communications.

EU Ecodesign Framework

The EU Ecodesign Framework (directive 2009/125/EC) sets harmonised minimum environmental and energy-efficiency requirements for energy-related products placed on the EU market, with the aim of supporting sustainable development, protecting the environment, and ensuring the free movement of goods within the internal market (EU, 2009). The directive is highly relevant to environmental sustainability in mobile communications because it directly applies to key ICT products such as computers, servers, data storage equipment, external power supplies, and power transformers, which are core components of mobile network infrastructure and data centres. Key points include its life-cycle-based approach to product sustainability, increasing focus on energy efficiency, durability, reparability, and recyclability, mandatory CE marking for compliant products, and its role in reducing the environmental footprint of mobile communication systems through more efficient and resource-efficient ICT hardware.

The Ecodesign for Sustainable Products Regulation

The Ecodesign for Sustainable Products Regulation (ESPR) (Regulation (EU) 2024/1781) establishes a strengthened EU-wide framework for setting eco-design requirements for virtually all physical products placed on the market, with the aim of making sustainable products the default and reducing their environmental and carbon footprints throughout the life cycle (EU, 2024f). The regulation is highly relevant to environmental sustainability in mobile communications because it applies to ICT hardware—such as mobile devices, network equipment, components, and data-centre infrastructure—thereby incentivising improved energy efficiency, durability, reparability, recycled content, and end-of-life circularity in products critical to mobile networks. A core feature of the regulation is the introduction of the Digital Product Passport (DPP), which provides traceable, electronic sustainability information on materials, repairs, recycling, and environmental impacts, enhancing transparency across supply chains and enabling better resource management in ICT systems. Key points include its expanded scope replacing the previous Ecodesign Directive, requirements that may be set through delegated acts for specific or cross-product groups, measures to prevent the destruction of unsold goods, support for mandatory green public procurement, and its alignment with the EU Circular Economy Action Plan and the European Green Deal.

Eco-design requirements for smartphones, other mobile phones, cordless phones and slate tablets placed on the EU market

Regulation (regulation (EU) 2023/1670) establishes binding eco-design requirements for smartphones, other mobile phones, cordless phones and slate tablets placed on the EU market, with the goal of reducing their environmental impact by improving durability, reparability, resource efficiency and overall sustainability (EC, 2023b). This regulation is directly relevant to environmental sustainability in mobile communications because mobile devices constitute a major share of the sector's environmental footprint, and improving device lifetimes, repairability and material efficiency helps reduce electronic waste and lower the carbon and resource burden associated with device production and disposal. Key points include minimum eco-design standards covering durability, protection against accidental damage, battery longevity, availability of spare parts, repairability requirements, software support expectations, and restrictions on premature obsolescence. As part of the European Green Deal, this regulation complements the parallel energy-labelling rules to help consumers choose more sustainable devices and encourages manufacturers to adopt circular-economy design practices across the mobile device value chain.

Regulation on market surveillance and compliance of products

Regulation on market surveillance and compliance of products (regulation (EU) 2019/1020) strengthens EU market surveillance by ensuring that only products complying with Union harmonisation legislation, covering health, safety, consumer protection and environmental standards, are made available on the internal market (EU, 2019b). This regulation is relevant to environmental sustainability in mobile communications because mobile devices, network equipment and related ICT products must meet EU compliance requirements, preventing non-compliant or environmentally harmful products from entering the market and supporting higher standards for product safety, energy performance and material sustainability. Key points include clearer responsibilities for economic operators, requirements for traceability and availability of technical documentation, stronger enforcement mechanisms, and systematic controls on imported products, ensuring that ICT equipment, including mobile phones, tablets, servers, and network hardware, meets EU environmental and safety regulations throughout the supply chain.

Eco-design requirements for servers and online data-storage products placed on the EU market

Eco-design requirements for servers and online data-storage products placed on the EU market (commission regulation (EU) 2019/424), with the aim of reducing their environmental impact by improving energy efficiency and promoting more sustainable product design (EC, 2019b). This regulation is highly relevant to environmental sustainability in mobile communications because servers and data-storage systems are core components of mobile network infrastructure and cloud-based services, and improvements in their efficiency directly reduce the energy consumption and carbon footprint of mobile communications. Key points include binding efficiency requirements for power supply units, idle-state power limits, resource-efficiency measures such as ease of disassembly and availability of firmware updates, detailed verification and conformity procedures, and benchmarks for best-performing products. By ensuring that network-critical equipment becomes more energy- and resource-efficient, the regulation supports the broader decarbonisation of digital and mobile communication ecosystems.

Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment

Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (directive 2011/65/EU) commonly known as the RoHS Directive, sets EU-wide rules restricting the use of certain hazardous substances, such as; lead, mercury, cadmium, hexavalent chromium and specific flame retardants, in electrical and electronic equipment (EEE) to protect human health and the environment and support the environmentally sound recovery and disposal of electronic waste (EU, 2011). This directive is directly relevant to environmental sustainability in mobile communications because mobile phones, network equipment, routers, base-station electronics and other ICT devices fall under EEE, and limiting hazardous substances reduces toxic pollution, improves recyclability and enables safer material recovery across the mobile communications supply chain. Key points include its broad applicability to most categories of EEE, updated and strengthened restrictions compared with the earlier Directive 2002/95/EC, exemptions for specific categories such as military, space and large-scale industrial tools, and alignment with wider EU chemicals and waste legislation to ensure safe manufacturing, use and end-of-life treatment of electronic products.

REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals)

REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) (Regulation (EC) No 1907/2006), establishes a comprehensive EU framework requiring manufacturers, importers and downstream users to ensure that chemicals used, produced or placed on the market do not adversely affect human health or the environment, while promoting innovation and safer alternatives (EU,2006). This regulation is relevant to environmental sustainability in mobile communications because electronic devices, network components, batteries and materials used in mobile infrastructure contain numerous chemical substances whose safety, restriction and substitution directly affect environmental performance, recyclability and the reduction of hazardous waste across the ICT value chain. Key points include mandatory registration of chemicals above one tonne per year, industry responsibility for risk assessment, restrictions and authorisation for high-concern substances, promotion of non-animal testing methods, creation of the European Chemicals Agency (ECHA), and obligations to replace hazardous substances with safer alternatives whenever feasible. Through these mechanisms, REACH ensures safer material use throughout the lifecycle of mobile devices and communication networks, supporting cleaner production and more sustainable end-of-life processes.

3.2.6 Infrastructure

European Electronic Communications Code (EECC)

The European Electronic Communications Code (EECC) (Directive (EU) 2018/1972), establishes a harmonised regulatory framework for electronic communications networks, services, associated facilities and terminal equipment across the EU, aiming to stimulate competition, investment and the deployment of very high-capacity networks such as 5G (EU, 2018b). While its primary focus is market regulation and connectivity, the directive is relevant to environmental sustainability in mobile communications because it drives the roll-out of more energy-efficient, high-capacity networks, promotes infrastructure sharing and efficient spectrum use, and encourages technological innovation that can reduce overall network energy consumption per unit of data. Key points include rules supporting very high-capacity network deployment, updated consumer protections, harmonised regulatory procedures for national authorities, obligations to ensure accessibility and service quality, integration of 5G and next-generation network objectives, and alignment within a broader package of telecom legislation including BEREC. By enabling modern, efficient and interoperable communications infrastructure, the directive indirectly supports greener and more sustainable mobile network evolution.

The proposed Digital Networks Act

The proposed Digital Networks Act (DNA) establishes a unified EU regulatory framework governing the provision of electronic communications networks and services, associated facilities, spectrum planning and management, and certain aspects of terminal equipment, while creating a new governance structure involving national regulatory authorities, BEREC, a new Radio Spectrum Policy Body (RSPB) and the Office for Digital Networks (ODN) (EC, 2026). The DNA proposal aims to replace the EECC. Although the act primarily focuses on improving connectivity, spectrum coordination and regulatory coherence, it is relevant to environmental sustainability in mobile communications because it supports efficient network deployment, efficient spectrum management, and shared infrastructure models—all of which can reduce energy consumption, limit redundant equipment, and enable greener next-generation networks such as 5G and future 6G systems. Key points include the harmonisation of rules across the EU, streamlined governance for electronic communications, enhanced cooperation between regulators, and strengthened strategic spectrum planning that promotes efficient, less resource-intensive network operations. By improving regulatory efficiency and promoting coordinated infrastructure development, the DNA indirectly supports the transition toward more sustainable and energy-efficient mobile communication networks.

3.3 Regional supporting institutions' activities

Next, we review the activities of selected regional supporting institutions in Europe on environmental sustainability in mobile communications.

3.3.1 The Radio Spectrum Policy Group (RSPG)

The Radio Spectrum Policy Group (RSPG) supports the European Commission by providing strategic advice on radio spectrum policy. RSPG highlights the need for common methodologies to assess the climate impact of wireless technologies and for accurate information on energy consumption and energy efficiency related to spectrum use. It also notes that modern radio equipment and migration from older technologies such as 2G and 3G to newer technologies such as 4G, 5G, and future 6G can improve spectrum and energy efficiency. However, this transition must consider legacy services such as e-Call, emergency calls, smart meters, and M2M/IoT applications (RSPG, 2023a; RSPG, 2023b). In its 6G strategic vision, RSPG identifies sustainability, spectrum sharing, non-terrestrial networks, and coordinated spectrum planning as important elements for future mobile networks. RSPG contributes to environmental sustainability by supporting efficient and future-ready spectrum policies for mobile communications (RSPG, 2025). RSPG's 6G strategic vision (RSPG, 2026) encourages academia and industry to develop sustainable 6G technologies that address next-generation mobile network environmental requirements and to integrate these outcomes into the standardisation process.

3.3.2 The Body of European Regulators for Electronic Communications (BEREC)

BEREC's first sustainability report frames digital networks as part of the green transition, noting that "digital solutions" are "critical enablers of achieving climate neutrality" (BEREC, 2022). At the same time, the report identifies a key measurement gap: "the lack of available standardized data" and heterogeneous methodologies for assessing the digital sector's environmental footprint (BEREC, 2022). BEREC's sustainability-indicator work develops this concern further. The 2023 indicator report states that "one of the toughest challenges" is "the lack of available data" and the need for "a harmonized approach" to methodologies and standards (BEREC, 2023c). It identifies indicators such as energy and electricity consumption, carbon footprint, water consumption, energy efficiency, renewable energy use, e-waste, and reused or recycled products. The related public consultation report confirms the importance of stakeholder input. It states that the report aims to identify sustainability indicators for "measuring and communicating the environmental footprint" of the electronic communications sector (BEREC, 2023b). It also highlights the role of NRAs in harmonizing indicators and methodologies for ECN/ECS environmental assessment. BEREC also considers the regulatory implications of emerging technologies. Its AI report states that "AI may bring significant benefits for the sector" and can support network optimization, service improvement, and energy efficiency (BEREC, 2023a). However, it also notes risks related to reliable data, explainability, privacy, cybersecurity, and regulatory oversight.

Environmental transparency for end-users is another important part of BEREC's sustainability work. The 2024 public consultation report states that awareness of environmental issues is "critical for end-users' empowerment" and ICT sustainability (BEREC, 2024a). This links sustainability regulation with consumer information, digital product transparency, and greenwashing prevention. The final end-user report further argues that "reliable, comparable and clear environmental data" enables users to integrate environmental aspects into purchasing decisions (BEREC, 2024b). This is relevant to mobile communications because smartphones, tablets, routers, and digital services form part of the wider lifecycle footprint of ICT. BEREC's 2024 workshop report emphasizes implementation. It states that BEREC continues to support the collection of "relevant and harmonized environmental indicators" in the telecom sector (BEREC, 2024c). This work also supports the European Commission's efforts on environmental transparency and the Code of Conduct for sustainable telecommunications networks and services.

Infrastructure sharing is especially relevant to mobile networks. BEREC states that infrastructure sharing can reduce environmental impact through "decreased infrastructure duplication, energy conservation, and reduced material consumption" (BEREC, 2024d). However, these benefits must be balanced against competition, investment, quality-of-service, and regulatory-mandate considerations. Finally, BEREC's work on Digital Decade connectivity indicators highlight the importance of practical and comparable data collection. The report notes that "adding complexity to the indicators doesn't necessarily result in more comparability" (BEREC, 2024e). This is relevant to sustainable mobile network governance because reliable connectivity indicators support evidence-based infrastructure planning.

Overall, BEREC contributes to the environmental sustainability of mobile communications by translating broad EU green and digital objectives into regulatory questions relevant to NRAs and market actors. Its work supports the development of common indicators, environmental transparency, data-driven regulation, infrastructure-sharing assessment, and more consistent monitoring of electronic communications networks and services.

3.3.3 The Joint Research Centre (JRC)

The Joint Research Centre (JRC) provides scientific and technical support for EU policymaking. In the context of mobile communications, its role is particularly important because environmental sustainability requires measurable indicators, common assessment methods, and practical guidance for implementation. JRC's 2024 report on electronic communications networks focuses on "common indicators for measuring the environmental footprint" of ECNs used to provide ECSs (JRC, 2024). The report analyses sustainability in terms of climate, energy, and environmental impacts, and prepares the basis for a future Code of Conduct for sustainable telecommunications networks. The report identifies 19 sustainability indicators and classifies them by priority. The indicators include energy consumption, energy efficiency, renewable energy use, Scope 1, Scope 2 and Scope 3 greenhouse gas emissions, e-waste production, and the distribution or use of recycled, refurbished, or reused products (JRC, 2024).

The EU Code of Conduct for the sustainability of telecommunications networks further develops this approach. It sets out a measurement framework, expected practices, optional practices, and relevant standards for environmentally sustainable telecommunications networks (JRC, 2026). This is important for mobile communications because it translates high-level sustainability objectives into concrete practices for network operators, reporting organizations, auditors, and equipment-related stakeholders. JRC also contributes methodological guidance beyond the telecommunications sector. Its 2025 guidance on Absolute Environmental Sustainability Assessment defines AESA as an approach based on "comparing the environmental burdens" of activities with planetary boundaries and environmental carrying capacities (JRC, 2025).

Overall, JRC supports the environmental sustainability of mobile communications by providing the technical basis for common indicators, lifecycle-oriented assessment, and implementation guidance. While BEREC mainly supports the regulatory coordination role, JRC provides the scientific and methodological foundation needed to measure, compare, and improve the environmental performance of telecommunications networks.

4

Sustainability reporting framework

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4 Sustainability reporting framework

This chapter presents in more detail the development of sustainability reporting in Europe, with particular attention to its transition from voluntary corporate disclosure to mandatory regulatory reporting. It discusses the evolution of corporate sustainability reporting, the European sustainability reporting framework under the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS), and the environmental disclosure topics most relevant to mobile communications. Consequently, this chapter presents both regulation and standardisation activities related to corporate sustainability reporting with the European Union.

4.1 Evolution of sustainability reporting

The European Commission defined Corporate Social Responsibility (CSR) as "a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis" (EC, 2011). With a close alignment to the CSR, sustainability reporting by companies became commonly known as ESG reporting, where the companies disclose about their environmental issues, social responsibilities and governance structures. Earlier, ESG and sustainability reporting were largely voluntary. The Global Reporting initiative, founded in 1997 became the most influential voluntary reporting framework worldwide. Increasing global challenges such as climate change, social inequality and rapid resources depletion has made ESG reporting a key tool to ensure companies are in line with the sustainable development (Fagbemi et al., 2025).

The move from voluntary and philanthropic reporting or disclosures to mandatory uniform disclosures is a result of stakeholder pressure and regulatory reforms (Zervoudi et al., 2025). Among other reasons are weak comparability, fragmented measurements and greenwashing attempts by the corporate. The adoption of Corporate Sustainable Reporting Directive (CSRD) in 2022 still has these issues to a certain extent and are in the process of addressing those issues and making positive amendments. Figure 4.1 shows how to evolution occurred which started as an environmental awareness to mandatory audited unform reporting requirement. Major stakeholders in sustainability reporting are investors and financial markets, corporations, governmental and regulatory bodies, public and community, NGOs and activists, customers.

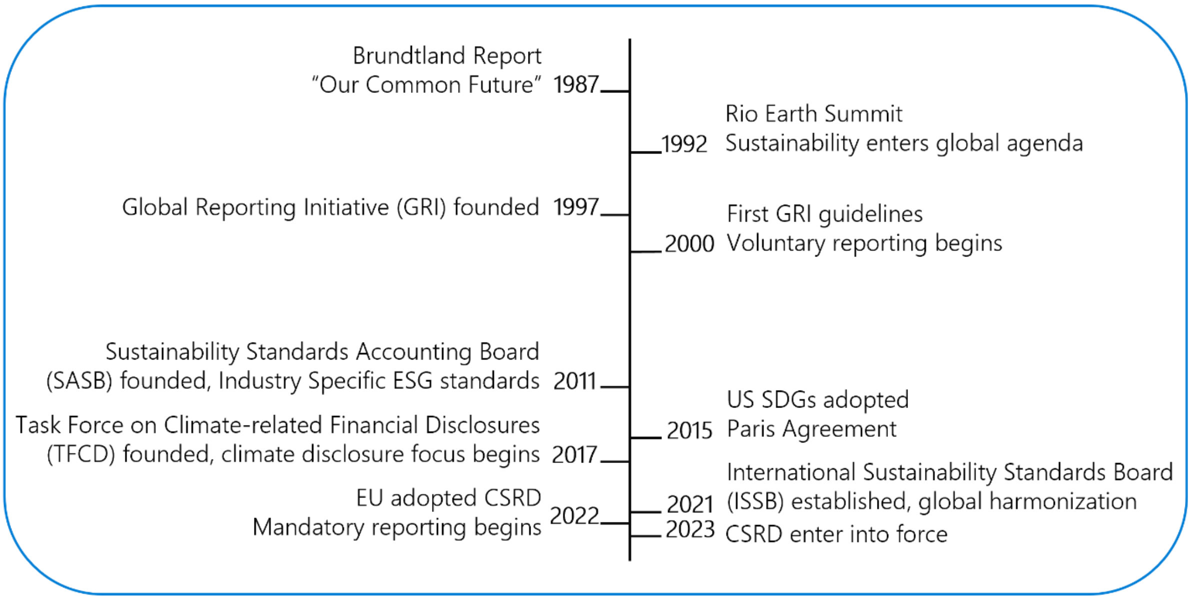

Figure 4.1: Evolution of sustainability reporting

4.2 European sustainability reporting

The Corporate Sustainability Reporting Directive, (CSRD) (Directive (EU) 2022/2464) (EU,2022), is an EU directive that strengthens and modernises sustainability reporting requirements for companies operating in the EU. CSRD replaces the Non-Financial Reporting Directive (Directive 2014/95/EU) (EU,2014). It strengthened and modernised corporate sustainability reporting requirements through modifications to the Accounting Directive, the Transparency Directive, the Audit Directive and the Audit Regulation. Key changes in CSRD from NFRD include:

- Extended reporting requirements, includes more companies.
- Standardization in reporting, ensuring comparability of information.
- Third-party assurance, mandatory assurance for credibility.
- Digital reporting, XBRL Taxonomy (by the European Financial Reporting Advisory Group.)

ESRS is the Commission Delegated Regulation 2023/2772 (European Commission, 2023c), which gives the technical specifications that companies must follow to comply with the legal requirements outlined in the CSRD. While the CSRD mandates that companies report on their sustainability performance, the ESRS provides the detailed framework for how this reporting should be done. BRL taxonomy in ESRS refers to the use of the eXtensible Business Reporting Language to digitally tag sustainability disclosures made under the ESRS, based on Article 29d of the CSRD and Commission

Delegated Regulation (EU) 2019/815 (EC, 2019c) on the European Single Electronic Format (ESEF). The novel use of digital tagging of sustainability reports ensures Machine readability, Interoperability, Transparency and Comparability of the reports.

A central feature of ESRS reporting is double materiality. Companies assess sustainability matters from two perspectives: impact materiality, which considers how the company affects people and the environment, and financial materiality, which considers how sustainability matters affect the company's financial position, performance, or development. For mobile communication companies, this means that topics such as network energy use, greenhouse gas emissions, e-waste, device circularity, supply-chain emissions, and infrastructure deployment may become reportable when they are material.

The recent omnibus proposal by the European Commission focuses on the Corporate Sustainability Reporting Directive (CSRD), sustainability reporting standards, and Corporate Sustainability Due Diligence Directive (CSDDD) to reduce the burden and compliance cost while facilitating competitiveness and resilience (EC, 2025). This was reflected in the report 'The Future of European Competitiveness', by Mario Draghi.

To reduce the burden and simplify the framework following ways were proposed (EC, 2025):

- Reduce the number of companies mandatorily required to comply with by approximately 80%. Large companies with up to 1,000 employees and listed Small and Medium-sized Enterprises (SMEs) would fall outside the scope of the requirements. As a result, the reporting obligations would apply only to large companies with more than 1,000 employees and either an annual turnover exceeding EUR 50 million or a balance sheet total above EUR 25 million. This revised threshold would bring the CSRD into closer alignment with the CSDDD.

- For companies that fall out mandatory compliance, the Commission proposes a proportionate voluntary reporting standard based on European Financial Reporting Advisory Group's (EFRAG's) Voluntary Sustainability Reporting Standard for non-listed Small and Medium-sized Enterprises (VSME standard), adopted through a delegated Act. Until then the Commission plans to issue a Recommendation that follows the VSME standard.

- The value-chain cap would be expanded and strengthened. It would apply directly to the reporting undertaking, rather than merely limiting what the ESRS may require, and it would protect all undertakings with up to 1,000 employees instead of only SMEs. (The value-chain cap is basically a legal ceiling on how much sustainability information a CSRD-reporting company can demand from smaller companies in its value chain, such as suppliers.)

- The proposal also removes the introduction of sector-specific reporting standards, thereby avoiding an increase in the number of mandatory data points that undertakings would be required to disclose.

- The option of moving from limited assurance to reasonable assurance would be removed, in anticipation to provide greater certainty that companies within scope will not face higher assurance costs in the future.

Apart from these, there would be changes to ESRS standards to simplify and streamline. Finally a proposal to postpone by two years the entry into application of the reporting requirements for the second wave (large undertakings that are not public interest entities and that have more than 500 employees, as well as large undertakings with up to 500 employees) and the third wave (listed SMEs, small and non-complex credit institutions, and captive insurance and reinsurance undertakings).

The proposals for better sustainability reporting highlights that the European level sustainability reporting is of high importance and especially environmental sustainability among ESG reporting would require companies to adopt their practises so that the data points required can be collected and assessed with ease, adding value to the company among stakeholders.

4.3 Environmental disclosure overview

Figure 4.2 illustrates the environmental topical standards under the European Sustainability Reporting Standards (ESRS). Within the ESRS framework, environmental sustainability is structured into five main disclosure areas: ESRS E1 Climate Change, ESRS E2 Pollution, ESRS E3 Water and Marine Resources, ESRS E4 Biodiversity and Ecosystems, and ESRS E5 Resource Use and Circular Economy. These standards provide the basis for companies to report environmental impacts, risks, opportunities, policies, actions, targets, and performance metrics where the topics are material. The figure shows the main types of information that may need to be disclosed under each topic, depending on the company's materiality assessment.

The figure highlights that environmental reporting under ESRS is broader than greenhouse gas emissions alone. ESRS E1 focuses on climate-related disclosures such as emissions, energy consumption, renewable energy, and decarbonization actions. ESRS E2–E4 extend the reporting scope to pollution, water use, land use, biodiversity, and ecosystem impacts. ESRS E5 addresses resource use, circularity, waste, material sourcing, durability, and repairability. Together, these standards require companies to consider both operational impacts and value-chain impacts.

E1 Climate Change	E2 Pollution	E3 Water and Marine Resources	E4 Biodiversity and Eco systems	E5 Resource Use and Circular Economy
o Scope 1 2 and 3 GHG emissions o Decarbonization levers o Climate change mitigation actions o GHG removals o Avoided emissions o Energy consumption o Energy mix o Renewable energy o Carbon pricing	o Substances of concern o Substances of very high concern o Air pollutants o Emissions to water o Pollution to soil o Microplastics generated	o Water consumption o Total water recycled o Water intensity information o Water treatment o Anticipated financial effects	o Sustainable land use o Deforestation o Invasive alien species o Ecological thresholds o Fresh water use-change o Anticipated financial effects	o Circular material use rate o Sustainable material souring o Hazardous waste o Waste disposal and treatment o Durability and repairability o Anticipated financial effects

Figure 4.2: Summary of environmental sustainability related disclosures in ESRS.

5

Standardization framework

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5 Standardization framework

Next, we proceed to examining the standardization framework relevant to environmental sustainability in mobile communications. The standardization framework relevant to sustainability reporting within European Union was presented in Section 4, while this section focuses on the technical standards for improving environmental sustainability of mobile communications.

5.1 Identified standardization bodies

Environmental sustainability in mobile communications is influenced by both regulatory requirements and technical standards that shape the design, deployment, operation and assessment. This study considers four main standardization bodies shown in fig. 5.1: International Organization for Standardization (ISO), International Telecommunications Union- Telecommunications Standards Sector (ITU-T), European Telecommunications Standards institute (ETSI), and 3rd Generation Partnership Project (3GPP). These organisations differ in scope and function, but together they contribute to the development of environmental sustainability practices in ICT and telecommunications.

Figure 5.1: Identified Standards Bodies

ITU-T - Telecommunication Standardization Sector of the International Telecommunication Union

ITU-T is a specialized agency in United Nations to assist in issues related to information and communications technologies worldwide. They publish standards as "recommendations" and the ITU-T L. series on the topic "Environment and ICTs, climate change, e -waste, energy efficiency; construction, installation and protection of cables and other elements outside plants" contains the relevant standards for environmental sustainability in mobile communications. Therefore, in this report detailed study on those standards and their results are presented in section 5.2. This series were developed by the study group 5 (SG5), at ITU-T and they focus on enabling a safe, resilient, efficient and responsible ICT development through global standardization (ITU, n.d.-a).

ISO – The International Organization for Standards

ISO is the International Organization for Standardization, developing international standards across a different sector as a multi-sectoral non-governmental body (ISO, 2019). Among their sectors "environmental sustainability" is considered as one of the thirteen. Under the sector of environmental sustainability, the key subtopics are environmental management, circular economy, climate change, air quality, smart cities, soil quality, and water quality among other. According to ISO, international standards on environmental sustainability offer a practical and a clear path to achieve operational excellence, meet stakeholder expectations and comply with legal requirements (ISO, n.d.). The table 5.1 contains few of the relevant and important standards for environmental sustainability in mobile communications.

Table 5.1: ISO standards and their relevance to mobile communications

ISO standard / family	Focus	Relevance to environmental sustainability in mobile communications
ISO 14001	Environmental management systems	Supports telecom operators, vendors, data centers, and ICT organizations in managing environmental responsibilities and continual improvement.
ISO 50001	Energy management systems	Relevant to energy management in mobile networks, RAN sites, core networks, data centers, offices, and facilities.
ISO 14040 / ISO 14044	Life-cycle assessment	Supports assessment of environmental impacts across the life cycle of ICT equipment, user devices, network infrastructure, batteries, and data-centre hardware.
ISO 14064-1 / 14064-2 / 14064-3	Greenhouse gas accounting, reporting, and verification	Relevant for organizational GHG inventories, emission-reduction projects, and verification of climate-related claims.
ISO 14067	Product carbon footprint	Useful for assessing the carbon footprint of ICT products such as user equipment, servers, routers, batteries, and telecom network hardware.
ISO 14020 / ISO 14024 / ISO 14025	Environmental labels and declarations	Relevant to environmental product claims, ecolabelling, and Environmental Product Declarations for ICT products and infrastructure components.

ISO 14031	Environmental performance evaluation	Supports the development and use of environmental performance indicators for ICT organizations and mobile network operations.
ISO 59004 / ISO 59010 / ISO 59020 / ISO 59040	Circular economy and circularity measurement	Relevant to reuse, repair, refurbishment, recycling, circular value chains, product circularity data, and circularity performance assessment in ICT.

ETSI- European Telecommunications Standards Institute

ETSI is a European Standards Organization that deals with telecommunications, broadcasting and other electronic communications networks and services in Europe. ETSI operates through technical committees (TCs) and the TC responsible for sustainability is the Environmental Engineering (EE) technical committee. Key areas of work under this committee includes; environmental conditions, thermal management and acoustic noise, power supply and sustainable energy solutions, environmental impact assessment of ICT, environmental and energy efficiency and mechanical structure and physical design (ETSI, n.d.). In section 5.2 the technical equivalent ETSI standards to the selected ITU-T standards are summarized.

3GPP - 3rd Generation Partnership Project

The 3rd Generation Partnership Project is a global collaboration platform that unites telecommunication standardization organizations to help develop specifications for mobile communication systems. 3GPP was created to develop 3G mobile standards access and core networks which later continued to create mobile broadband standards. 3GPP develops technical specifications for cellular telecommunications technologies, including radio access, core network, and service capabilities. According to 3GPP, energy-efficiency work has been present since Release 10 and has expanded from early radio energy-saving recommendations to more systematic 5G energy-efficiency management, measurement and key performance indicator (KPI) frameworks. In this context, 3GPP outputs are especially relevant to RAN energy saving, OAM-based energy management, 5G network performance measurement and Power, Energy and Environmental parameter monitoring (3GPP, 2024). A summary of the 3GPP standards under the scope of this study is in table 5.2.

Table 5.2: 3GPP standards and their relevance to mobile communications

3GPP specification / report	How it relates to mobile communications
3GPP TR 25.927	Covers approaches such as dormant mode, secondary antenna deactivation, common-channel power control and Cell DTX to reduce radio power consumption.

3GPP TR 36.927	Addresses energy saving in dense and overlay cell deployments, including switching off smaller or less-used cells during low-traffic periods.
3GPP TR 32.826	Provides general considerations for energy savings management, including cell on/off scenarios and the relationship between traffic load and power consumption.
3GPP TR 32.834	Studies energy saving across different radio access technologies, where one RAT may reduce capability while another provides backup coverage.
3GPP TS 32.551	Defines energy-saving management concepts and requirements, including centralized and distributed energy-saving approaches.
3GPP TS 32.522	Supports energy-saving operation through self-organizing network and load-balancing functions, especially when cells are switched off or traffic is offloaded.
3GPP TR 23.866	Considers system-level deployment scenarios for energy efficiency, such as pooled control-plane deployment and optimized network entity placement.
3GPP TR 45.926	Studies energy-saving solutions for 2G base stations and legacy radio access networks.
3GPP TR 32.856	Studies OAM support for assessing energy efficiency in mobile access networks and links 3GPP work with energy-efficiency assessment approaches.
3GPP TR 32.972	Studies system and functional aspects of energy efficiency in 5G networks, including how energy consumption and data volume are collected for KPI calculation.
3GPP TS 28.310	Provides an overall framework for energy efficiency and energy-saving scenarios, including 5G Core-related scenarios.
3GPP TS 28.552	Defines 5G performance measurements and includes a section on Power, Energy and Environmental measurements.
3GPP TS 28.554	Defines 5G end-to-end KPIs, including energy-efficiency KPIs such as mobile network data energy efficiency measured in bit/J.
3GPP TS 28.304 / TS 28.305 / TS 28.306	Defines requirements, information service and solution-set definitions for controlling and monitoring Power, Energy and Environmental parameters.

5.2 Analysis of ITU-T Standards

The standardization framework shows that environmental sustainability in mobile communications is supported by a broad set of technical standards covering products, network infrastructure, organizations, and sector-level assessment. ITU-T provides extensive ICT-specific recommendations, especially through the L-series, while ETSI provides European technical standards for telecommunications environmental engineering, energy efficiency, LCA, material efficiency, monitoring interfaces, and power systems. For ICT companies, the most relevant standards are those that support energy-efficiency measurement, mobile network assessment, base-station site performance, circularity, e-waste management, battery management, GHG accounting, LCA, digital product information, and climate adaptation. The full list of analysed standards should remain in the Annex with a brief description of what each contain, while section 5.2 synthesises the main themes and explain their relevance to mobile communications. In the study of ITU-T L series the technical equivalent ETSI standards of the in-scope standards were also included.

ITU-T L series has their own environment sustainability themes. E-waste and circular economy (from L.1000 to L.1199), power feeding and energy storage (from L.1200 to L.1299), Energy efficiency, smart energy and green data centres (from L.1300 to L.1399), Assessment methodologies of ICTs and CO2 trajectories (from L.1400 to L.1499), adaptation to climate change (from L.1500 to L.1599), circular and sustainable cities and communities (from L.1600 to L.1699) and low cost sustainable infrastructure (from L.1700 to L.1799). The study analysed the standards according to their level of applicability; product level, network infrastructure level, organizational level, or wider sector/city/country-level systems. This information and classification can support companies with an overview of each standard before diving into the technical details of it.

The range of standard types are quite different to one another and is not easy to capture from the introduction of the standard itself. In this report, the standards are further classified into four types which acknowledge the main substance of each standard including guidelines and best practices, standards directly related to regulations, impact assessments, and requirements as shown in Figure 5.2. The following Tables 5.3– 5.9 carry a summary of the classifications of standards with the icons used in Figure 5.2. This gives an overview to companies as to in each theme what type of information and what level of application is covered. Note- The name of the standard is simplified in the tables.

Figure 5.2: Proposed classification of standards for analysis in this report.

Theme - e-waste and circular economy

Table 5.3 presents ITU-T L-series recommendations related to e-waste and circular economy. The standards in this theme cover product-level solutions such as universal chargers, lifecycle and circularity assessment methods, sustainable e-waste management, battery management, and circular ICT goods and networks. Their relevance to mobile communications is significant because mobile devices, batteries, base stations, and network equipment contribute to material use and electronic waste generation. The table shows that circular economy issues are addressed across product, network infrastructure, organisational, and national levels, making this theme relevant to both telecom operators and wider policy implementation.

The environmental performance of smartphones can be evaluated by addressing material efficiency and through consideration of the LCA of environmental impacts. The environmental performance of smartphones in terms of material efficiency can be evaluated by analysing three impact groups: durability, repairability, reusability and upgradeability (RRU), and material impacts according to ITU-T L.1017, on environmental performance scoring of smartphones. ITU-T L.1021 Extended Producer Responsibility (EPR) guidelines for sustainable e-waste management is an important concept that is addressed through supply chains in sustainability reporting. EPR systems carry several benefits listed in the standard, among them “the contribution to a circular economy that promotes sustainable production and consumption, thereby directly contributing to the fulfilment of the United Nations sustainable development goals” shows the linkage of standards to global commitments. L.1028 Global warming impact evaluation of extending ICT equipment lifetime, introducers a new indicator UER10, "ratio of use-phase emissions during 10 years over embodied emissions", as defined in this Recommendation, is applicable to all ICT equipment.

Table 5.3: Selected ITU-T standards under the theme "e-waste and circular economy" and their categories.

E-WASTE AND CIRCULAR ECONOMY			
Product level	Network Infrastructure level	Organization level	Sector / City / Country level
L.1000 Universal power adapter and charger solution for mobile terminals and hand-held devices	L.1036 Base station waste and e-waste management plan	L.1020 Circular ICT goods and network - migration guide for operators and suppliers	L.1030 National e-waste management framework
L.1004 Universal fast-charging solution for mobile terminals	L.1041 Resource saving, e-waste reduction and energy saving system methodology using twisted single pair cable	L.1022 Circular economy concepts for material efficiency for ICT	L.1033 Higher education guidance for e-waste/e-equipment lifecycle management
L.1011 Lithium-ion battery durability assessment guidelines	L.1050 Key network equipment identification for impact and e-waste assessment methodology	L.1024 Servitization impact on ICT waste and environment	L.1061 Circular public procurement for ICT
L.1015 Mobile Phone's Environmental Impact Evaluation Criteria		L.1028 Global warming impact evaluation of extending ICT equipment lifetime	
L.1017 Environmental performance scoring of smartphones		L.1060 Green supply chain management principles for ICT manufacturing industry	

L.1018 Mobile telecommunication terminal- durability assessment specification	
L.1021 Extended Producer Responsibility (EPR) guidelines for sustainable e-waste management	
L.1023 Circularity performance scoring assessment method	
L.1025 Secure data deletion functionality of server and data storage products	
L.1027 Server and data storage product disassembly requirements and Instructions	
L.1032 E-waste recyclers' guidelines and certification schemes	
L.1034 Counterfeit ICT products' environmental impact assessment	
L.1035 Sustainable battery management guidelines	
L.1037 WEEE collection, transportation, storage, dismantling, valorisation and final disposal requirements.	
L.1070 Digital Product Passport opportunities for circular economy	

L.1071 Digital Product Passport sustainability data model
L.1080 Server and data storage product availability of firmware and of security updates to firmware

Theme - power feeding and energy storage

Table 5.4 summarises standards related to power feeding and energy storage for telecommunication and ICT sites. These recommendations focus mainly on network infrastructure, including direct current power systems, migration to 400 VDC power distribution, sustainable power-feeding solutions for 5G networks, photovoltaic systems for base-station sites, and stationary energy storage using batteries and supercapacitors. This theme is highly relevant to mobile communications because base stations and telecom sites require continuous and reliable electricity supply. The standards support energy-efficient power architecture, integration of renewable energy, and improved resilience of mobile network infrastructure.

Table 5.4: Selected ITU-T standards under the theme "power feeding and energy storage" and their categories.

POWER FEEDING AND ENERGY STORAGE			
Product level	Network Infrastructure level	Organization level	Sector / City / Country level
	L.1206 ICT equipment design impact of mixed AC, −48 VDC, and 400 VDC Inputs		
	L.1207 Migration roadmap to 400 VDC sources and distribution in telecommunication and ICT sites		
	L.1210 Sustainable power-feeding solutions for 5G networks		
	L.1211 Smart photovoltaic (PV) system control for base station sites		
	L.1220 Overview of energy storage		
	L.1221 Stationary energy storage in batteries		
	L.1222 Stationary energy storage in supercapacitors		

Theme - energy efficiency, smart energy and green data centres

Table 5.5 contains one of the most directly relevant groups of standards for mobile network sustainability. The standards cover energy efficiency metrics for telecommunication equipment, mobile networks, base-station sites, power and cooling equipment, network function virtualisation, 5G radio access network equipment, smart energy solutions, and green data centres (data centres are out of scope for this study and the standards were selected accordingly). This theme is central to the report because energy consumption is one of the main environmental impacts of mobile communications. The table 5.5 shows that energy efficiency is addressed at multiple levels, from individual equipment and base-station sites to full network systems and organisational energy frameworks.

L.1330 defines energy-efficiency measurements and metrics for telecommunication networks, especially the radio access parts of mobile networks. The methodology covers energy consumption metrics, performance metrics, mobile network energy-efficiency metrics, and additional parameters needed for network energy-efficiency evaluation. L.1333 introduces network carbon intensity as a performance-monitoring indicator. The methodology relates greenhouse gas emissions from electricity consumption across network sites to the total data traffic handled by the network during the same period. Among others, L.1390 standard provides energy-saving technologies and best practices for 5G radio access network equipment. Its methodology covers dynamic scaling, shutdown capabilities, performance-energy trade-offs, time-domain, spatial-domain, frequency-domain and power-domain energy saving, and AI-based optimisation using traffic forecasting and scene identification.

Table 5.5: Selected ITU-T standards under the theme "energy efficiency, smart energy and green data centres" and their categories.

ENERGY EFFICIENCY, SMART ENERGY AND GREEN DATA CENTRES			
Product level	Network Infrastructure level	Organization level	Sector / City / Country level
L.1310 Telecommunication equipment energy efficiency metrics and measurement methodology	L.1320 Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres	L.1315 Energy efficiency standardization terms and trends	

L.1311 Heterogeneous server energy efficiency metrics and measurement methodology	L.1325 Green ICT solutions for telecom network facilities	L.1316 Energy efficiency framework
L.1318 Q-factor metric for IC energy efficiency	L.1326 Liquid cooling and high-efficiency solutions for 5G baseband units in C-RAN mode.	
L.1340 Telecom equipment energy efficiency informative values	L.1328 Telecommunication rooms and data centre specification for waste heat reuse.	
L.1341 Energy efficiency functional requirements for IoT platforms	L.1330 Telecommunication network energy efficiency measurements and metrics	
	L.1331 Mobile network energy efficiency assessment	
	L.1332 Total network infrastructure energy efficiency metrics	
	L.1333 Carbon data intensity for network energy performance monitoring	
	L.1350 Base station site energy efficiency metrics	
	L.1351 Base station site energy efficiency measurement method	
	L.1361 Network function virtualization (NFV) energy efficiency measurement method	
	L.1362 Enhanced interface for power management in network function virtualization environments	
	L.1380 Smart energy solution for telecom sites	

L.1382 Smart energy solution for telecommunication rooms
L.1384 Virtual micro power station implementation at base station sites
L.1390 5G RAN energy saving technologies and best practices
L.1391 IMT-2020 network sharing and co-construction for climate change mitigation
L.1395 Generic monitoring and control interface for power, cooling, and environment systems in telecommunication networks
L.1396 ICT equipment power, energy and environmental parameters monitoring information model
L.1397 Battery system with integrated control and monitoring information model

Theme - assessment methodologies of ICTs and CO2 trajectories

These recommendations in table 5.6 include lifecycle assessment of ICT goods, networks, and services; organisational energy and GHG impact assessment; project-level environmental assessment; city-level and sector-level methodologies; ICT sector emissions trajectories aligned with the Paris Agreement; and guidance for net-zero target setting. For mobile communication stakeholders, these standards support structured measurement of both direct footprint and ICT-enabled emission reductions in other sectors.

In L.1420, the methodology is in two parts. Evaluation of energy consumption and GHG impact of ICT activities in non-ICT organizations. Evaluation of energy consumption and GHG impact of ICT organizations. This methodology assesses both the energy consumption and the GHG emissions over a period for, direct GHG emissions, energy indirect GHG emissions and, other indirect GHG emissions.

The same methodology in ITU-T L. 1410 is to be used here and aggregated to an organizational level according to the principles (relevance, completeness, consistency, accuracy, transparency). "It should be noted that the assessment of the second order effects needs to be documented and reported separately from the first order GHG emission impact."

In L.1440, analysis is done in two tier levels. Tier one is the 'An assessment of the impact of ICT where only the energy consumption and GHG emissions of the use phase of ICT are assessed.' and Tier two is the ' An assessment of the impact of ICT where the impacts of the energy consumption and GHG emissions for the whole life cycle of ICT are assessed, including those occurring outside city boundaries.' Same measurement units, kg CO2eq and percentage allocations per year. Estimated and direct measured data is used. System and service boundaries are kept with sensitivity analysis done for the results at the end. In L.1451, Computable General Equilibrium (CGE) is a top-down economic approach using economic input-output tables. As a principle, the CGE model calculates the pricing effects of using ICT services and derives the positive effects of this ICT usage. If the effect is not measurable as a cost, then it is not evaluated in this version.

Table 5.6: Selected ITU-T standards under the theme "assessment methodologies of ICTs and CO2 trajectories" and their categories.

ASSESSMENT METHODOLOGIES OF ICTS AND CO2 TRAJECTORIES			
Product level	Network Infrastructure level	Organization level	Sector / City / Country level
		L.1400 Overview and general principles of methodologies for assessing the environmental impact of ICTs	L.1440 City-level environmental impact assessment of ICTs
		L.1410 ICT goods, network and services life cycle assessment methodology	L.1490 Digital GHG emissions management system framework for public sector
		L.1420 Energy consumption and GHG impact assessment methodology for ICTs in organizations	L.1491 Industrial Park decarbonization measurement and best practices
		L.1430 Environmental impact assessment methodology for ICT GHG and energy projects	

L.1450 ICT sector environmental impact assessment methodologies
L.1451 Methodology to assess ICT sector's aggregated positive impacts in other sectors
L.1460 Connect 2020 GHG emissions guidelines
L.1470 UNFCCC Paris agreement aligned ICT sector emissions trajectories
L.1471 Net zero target-setting guidance and criteria for ICT organizations
L.1480 Assessment of ICT-enabled emissions reductions in other sectors
L.1481 Guidance for meeting connect 2030 net GHG abatement targets

Theme - adaptation to climate change

Table 5.7 shows that the adaptation to climate change is mostly analysed in the network infrastructure level. These standards address how ICTs can support adaptation to climate change, how telecom infrastructure can be made more resilient, and how ICT sites can support environmental sensing. In L.1500 we identify two types of climate change adaptation; emergent or spontaneous and planned policy driven adaptation processes. In L.1510 Environmental KPIs for climate resilient digital infrastructure summarises main KPIs as;

- The key metrics of energy consumption; Total energy consumption (kWh), PUE Power Usage Effectiveness, Total renewable energy consumption (kWh), REF Renewable Energy Factor, ERF Energy Reuse factor
- The key metrics of GHG emissions; Scope 1 – direct GHG emissions (mtCO2e), Scope 2 – indirect GHG emissions (mtCO2e), Scope 3 – indirect GHG emissions (mtCO2e), CUE (kg CO2e/ kWh), Total carbon offsets (mtCO2e), Hourly renewable supply and consumption matching (%)
- The key metrics of water usage; Total site water usage (m3), Total source energy water usage (m3), WUE (m3/MWh), Water replenishment (m3), Total water use in supply chain (m3)

- The key metrics of waste generation; Waste generated – total waste, e–waste, and end- of-life battery (metric ton), Waste diversion rate – total waste, e-waste and end-of-life battery
- The key metrics of local ecosystem impacts; Land – total land use (m2), Land-use power intensity (kW/m2), Outdoor noise – dB(A), Mean species abundance (MSA) density (MSA/km2)
- The key metrics of enablement; Total enabling GHG emission reduction (mtCO2e), Enablement factor (ratio)

Table 5.7: Selected ITU-T standards under the theme "adaptation to climate change" and their categories.

ADAPTATION TO CLIMATE CHANGE			
Product level	Network Infrastructure level	Organization level	Sector / City / Country level
	L.1501 Country level best practices for ICT-enabled climate adaptation	L.1500 Framework ICTs and climate change adaptation	
	L.1502 Climate-resilient ICT infrastructure guidance		
	L.1506 Climate risk assessment framework for telecom and electrical facilities		
	L.1507 ICT sites to support environmental sensing		
	L.1510 Environmental KPIs for climate-resilient digital infrastructure		

Theme - circular and sustainable cities and communities

In L.1600, L.1601 and L. 1602 a general guidance to cities is given and provide the definitions of key performance indicators (KPIs) related to the sustainability impact of information and communication technology (ICT) in the context of smart sustainable cities (SSCs). Key performance indicators of Smart Sustainable cities capture, productivity, equity and social inclusion, quality of life, physical infrastructure, ICT and environmental sustainability. These standards given requirements related to indicators and guidelines or best practices as shown in table 5.8.

Table 5.8: Selected ITU-T standards under the theme "circular and sustainable cities and communities" and their categories.

CIRCULAR AND SUSTAINABLE CITIES AND COMMUNITIES

Product level	Network Infrastructure level	Organization level	Sector / City / Country level
			L.1600 Smart sustainable city – overview of KPIs
			L.1601 ICT use' KPIs for smart sustainable cities
			L.1602 ICT sustainability impact KPIs for smart sustainable cities

Theme - low-cost sustainable infrastructure

In L.1700 there are seven distinct requirements for low-cost sustainable telecommunications infrastructure for rural communications in developing countries and since it is about network infrastructure the level of application is "Network Infrastructure Level" in table 5.9. Among general performance requirements there are sustainability related requirements included; energy-efficient power feed architecture and solutions and environmentally friendly life cycle.

Table 5.9: Selected ITU-T standards under the theme "low-cost sustainable infrastructure" and their categories.

LOW-COST SUSTAINABLE INFRASTRUCTURE			
Product level	Network Infrastructure level	Organization level	Sector / City / Country level
	L.1700 Low-cost sustainable rural telecom infrastructure framework in developing countries		

In table 5.10 the listed ITU-T L. Series standards in scope for the study explicitly contained best practises. The summary is intended to help interested parties to get an overview of the standards related to environmental sustainability in mobile communication with clear best practises.

Table 5.10: Selected ITU-T standards with best practises.

Standard	Best Practises
Rec. ITU-T L.1450 - Methodology to identify key equipment for environmental impact and e-waste generation	The key equipment required to estimate the environmental impact of network architectures needs to be identified. Therefore, this recommendation has tables of equipment in every segment of telecom network and groping to identify which are to be considered when calculating environmental impact and whether they are included or not in the calculations.

assessment of network architectures	
Rec. ITU-T L.1491 - Measurement methodology and best practices for decarbonization of industrial parks in support of net zero.	"Describes the best practices for achieving net zero goal in industrial parks through ICT, mainly consisting of four clauses covering intelligent infrastructure, integrated management systems for industrial parks, digital energy management platforms and intelligent buildings." o Microgrid and clean energy utilization o Upgrading, renovating and phasing out high carbon emission equipment
Rec. ITU-T L.1035 - Sustainable management of batteries	Best practices for battery recycling and final disposal. o Lithium-ion batteries- discharging: The batteries are firstly discharged. The main purpose of discharging the batteries is to reduce the reactivity of the batteries so that it is close to being inert. Afterwards, the discharged batteries are directly landfilled, then transported to hazardous waste landfill. o Alkaline batteries are commonly removed and disposed of as transported to hazardous waste landfill, they are then solidified in concrete moulds in a solidification unit due to the presence of manganese dioxide, zinc and an alkaline potassium hydroxide electrolyte. The product is then disposed of in special cells at landfill. o Silver oxide batteries are commonly removed and disposed of first by being transported to hazardous waste landfill, then solidified in concrete moulds in a solidification unit.
Rec. ITU-T L.1390 - Energy saving technologies and best practices for 5G radio access network (RAN) equipment	Four main practices to save energy is presented along with energy saving design principles in 5G network. o Energy saving practice based on AI – Service awareness energy saving for 4G/5G coordination. o Using high gain antenna-lens antenna. o Ultra-large-scale antenna array with beam pattern optimization. o Beam optimization assisted energy saving.
Rec. ITU-T L.1391 - Specification of IMT-2020 network sharing and co-construction adapting to climate change mitigation	The best practices identified in the China Telecom and China Unicom IMT-2020 network sharing and co-construction case can be listed as follows: o Nationwide shared access network with independent core networks

	o Full lifecycle cooperation model o Resource efficiency through shared spectrum, equipment, and infrastructure

Finally, in the detailed study of the ITU-T Series standards for this report, among the selected standards, the technical equivalent ETSI standards were identified as in scope and relevant and are listed in table 5.11.

Table 5.11: Technical Equivalent ETSI standards in the study scope

ETSI Standard	Technical Equivalent ITU-T standard
ETSI EN 303 800-2 - Assessment of material efficiency of ICT network infrastructure goods (circular economy); Part 2: Server and data storage product secure data deletion functionality	Rec. ITU-T L.1025 - Assessment of material efficiency of information and communication technology network infrastructure goods – Server and data storage product secure data deletion functionality
ETSI EN 303 800-5 - Assessment of material efficiency of ICT network infrastructure goods (circular economy); Part 5: Server and data storage product disassembly and disassembly instruction	Rec. ITU-T L.1027 - Assessment of material efficiency of ICT network infrastructure goods (circular economy) – Server and data storage product disassembly and disassembly instruction
ETSI TS 103 881 - Global digital sustainable product passport opportunities to achieve a circular economy	Rec. ITU-T L.1070 - Global digital sustainable product passport opportunities to achieve a circular economy
ETSI ES 204 082 - An information model for digital product information on sustainability and circularity	Rec. ITU-T L.1071 - A model for digital product passport information on sustainability and circularity
ETSI TS 103 531 - Impact on ICT equipment architecture of multiple AC, −48 VDC or up to 400 VDC power inputs	Rec. ITU-T L.1206 - Impact on information and communication technology equipment architecture of multiple AC, −48 VDC or up to 400 VDC power inputs
ETSI EN 303 800 - Assessment of material efficiency of ICT network infrastructure goods (circular economy)	Rec. ITU-T L.1080 - Assessment of material efficiency of information and communication technology network infrastructure goods – Server and data storage product availability of firmware and of security updates to firmware
ETSI TS 103 553-1 - Innovative energy storage technology for stationary use; Part 1: Overview	Rec. ITU-T L.1220 - Innovative energy storage technology for stationary use – Part 1: Overview of energy storage

ETSI TS 103 553-2 - Innovative energy storage technology for stationary use; Part 2: Battery	Rec. ITU-T L.1221 - Innovative energy storage technology for stationary use – Part 2: Battery
ETSI TS 103 533-3 - Innovative energy storage technology for stationary use; Part 3: Supercapacitor technology	Rec. ITU-T L.1222 - Innovative energy storage technology for stationary use – Part 3: Supercapacitor technology
ETSI ES 204 083 (V1.1.1) - Energy efficiency measurement methodology and metrics for heterogeneous servers	Rec. ITU-T L.1311 - Energy efficiency measurement methodology and metrics for heterogeneous servers
ETSI ES 203 475 - Standardization terms and trends in energy efficiency	Rec. ITU-T L.1315 - Standardization terms and trends in energy efficiency
ETSI ES 203 997 - Requirements and use cases of liquid cooling and high energy efficiency solutions for 5G BBU in C-RAN mode	Rec. ITU-T L.1326 - Requirements and use cases of liquid cooling solutions and high energy efficiency solutions for 5G baseband units in centralized-RAN mode
ETSI ES 203 228 first version - Assessment of mobile network energy efficiency	Rec. ITU-T L.1330 - Energy efficiency measurement and metrics for telecommunication networks
ETSI ES 203 228 second version - Assessment of mobile network energy efficiency	Rec. ITU-T L.1331 - Assessment of mobile network energy efficiency
ETSI ES 203 539 - Measurement method for energy efficiency of Network Functions Virtualisation (NFV) in laboratory environment	Rec. ITU-T L.1361 - Measurement method for energy efficiency of network functions virtualization
ETSI ES 203 682 - Green Abstraction Layer (GAL); Power management capabilities of future energy telecommunication fixed network nodes; Enhanced interface for power management in Network Functions Virtualisation environments	Rec. ITU-T L.1362 - Power management capabilities of the future energy telecommunication network nodes – Enhanced interface for power management in network function virtualization environments
ETSI ES 202 336-1 - Monitoring and Control Interface for Infrastructure Equipment; Part 1: Generic Interface	Rec. ITU-T L.1395 - Monitoring and control interface for power, cooling and building environment systems in telecommunication networks – Generic interface
ETSI ES 202 336-11 - Monitoring and control interface for infrastructure equipment; Part 11: Battery system with integrated control and monitoring information model	Rec. ITU-T L.1397 - Monitoring and control interface for power, cooling and building environment systems in telecommunication networks – Battery system with integrated control and monitoring information model
ETSI ES 203 199 - Methodology for environmental Life Cycle Assessment (LCA) of	Rec. ITU-T L.1410 - Methodology for environmental life cycle assessments of

Information and Communication Technology (ICT) goods, networks and services	information and communication technology goods, networks and services

6

Energy efficiency considerations

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6 Energy efficiency considerations

Regulations set the policy direction for energy savings, renewable energy use, product energy performance, and sustainable infrastructure. Sustainability reporting frameworks require companies to disclose energy consumption, energy mix, climate targets, and greenhouse gas emissions where material. Standards provide technical methods, indicators, and best practices for measuring and improving energy performance at equipment, site, network, and organizational levels.

Energy efficiency is addressed in EU regulation both directly and indirectly. The most directly relevant instrument is the recast Energy Efficiency Directive, Directive (EU) 2023/1791, which promotes energy efficiency across sectors and introduces the "energy efficiency first" principle. This is relevant to mobile communications because network operation depends on continuous electricity consumption, especially in radio access networks, base stations, cooling systems, and supporting ICT infrastructure. Renewable-energy legislation is also relevant. Directive (EU) 2018/2001 and Directive (EU) 2023/2413 support the increased use of renewable energy across the EU. For mobile network operators, renewable electricity procurement, power purchase agreements, guarantees of origin, and on-site renewable generation can help reduce the operational carbon footprint of network services. Product-related regulations also support energy efficiency. The Ecodesign Framework Directive, the Ecodesign for Sustainable Products Regulation, and specific eco-design and energy-labelling rules for smartphones, tablets, servers, data-storage products, and external power supplies influence the energy performance, durability, repairability, and lifecycle impact of ICT products used in mobile communications.

Energy efficiency is mainly addressed in sustainability reporting through ESRS E1 Climate Change. For mobile communication companies, ESRS E1 is relevant because it covers climate-related policies, actions, targets, energy consumption, energy mix, and greenhouse gas emissions. The most relevant disclosure is E1-5 Energy consumption and mix, which requires companies to report energy use and the breakdown of energy sources. For mobile network operators, this may require data from base-station sites, telecom rooms, core network facilities, offices, network energy-management systems, and electricity procurement records. Energy efficiency is also linked to E1-6 Gross Scope 1, Scope 2, Scope 3 and total GHG emissions. Scope 1 emissions may arise from diesel generators, company vehicles, or other direct fuel use. Scope 2 emissions arise from purchased electricity used to operate networks and facilities. Scope 3 emissions may include purchased network equipment, devices, batteries, logistics, outsourced services, product use, and end-of-life treatment.

Table 6.1: ESRS E1 disclosures relevant to energy efficiency

ESRS E1 disclosure area	Relevance to mobile communication stakeholders
E1-1 Transition plan for climate change mitigation	Can include plans to reduce network energy use, increase renewable energy, and decarbonize operations
E1-2 Policies related to climate change mitigation and adaptation	Can include policies on energy efficiency, renewable energy, and network energy optimization
E1-3 Actions and resources	Can include equipment upgrades, RAN energy-saving actions, cooling improvements, site modernization, and renewable-energy procurement
E1-4 Targets	Can include energy-efficiency targets, renewable-energy targets, and GHG emission reduction targets
E1-5 Energy consumption and mix	Requires data on total energy consumption and energy source breakdown
E1-6 Gross Scope 1, Scope 2, Scope 3 and total GHG emissions	Links energy use with direct fuel emissions, purchase-electricity emissions, and value-chain emissions

Standards provide the technical basis for measuring and improving energy efficiency. In mobile communications, the most relevant standards are found in the ITU-T L-series and ETSI Environmental Engineering standards. These standards support consistent measurement, comparison, procurement, monitoring, and reporting of energy performance. Energy-efficiency indicators should be selected according to the level of analysis. High-level indicators are useful for reporting and benchmarking, while technical indicators are needed for operational optimization. At the network level, ITU-T L.1330, ITU-T L.1331, ITU-T L.1332, and ETSI ES 203 228 are particularly relevant because they address energy-efficiency metrics and assessment methods for telecommunication and mobile networks. ITU-T L.1333 adds carbon data intensity as an indicator for network energy performance monitoring. At the equipment and site level, ITU-T L.1310 provides energy-efficiency metrics for telecommunication equipment. ITU-T L.1350 and ITU-T L.1351 focus on energy-efficiency metrics and measurement methods for base-station sites. For 5G, ITU-T L.1390 is important because it addresses energy-saving technologies and best practices for 5G radio access network equipment. ETSI standards such as ETSI ES 202 706-1, ETSI TS 102 706-2, and ETSI TS 103 786 are also relevant for wireless access and 5G base-station energy-efficiency measurement. Energy efficiency also depends on power feeding, renewable energy, storage, and cooling. ITU-T L.1210 and ETSI ES 203 700 address sustainable power feeding for 5G networks. ITU-T L.1211 addresses photovoltaic systems at base-station sites. ITU-T L.1220, L.1221, and L.1222 cover stationary energy storage, batteries, and supercapacitors. Cooling and smart-energy standards such as ITU-T L.1326, L.1328, L.1380, L.1382, and L.1384 are relevant for telecom rooms, centralized-RAN facilities, and base-station sites.

7

Conclusions

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7 Conclusions

This report has examined how environmental sustainability in mobile communications is addressed through regulations, sustainability reporting requirements, and standards. The analysis showed that mobile communication networks have a dual role in the green transition. They contribute to environmental impacts through energy consumption, equipment manufacturing, infrastructure deployment, resource use, and end-of-life waste. At the same time, they enable sustainability improvements in other sectors through digital services, connectivity, automation, and more efficient use of resources.

The findings of the study indicate that the European sustainability framework for mobile communications is becoming more comprehensive, but also more complex. Regulations, reporting requirements, and standards are developing in parallel, creating opportunities for stronger environmental governance but also challenges for implementation. For companies, this creates a need to understand which requirements are legally binding, which standards are voluntary but industry-relevant, and which indicators are useful for monitoring environmental performance.

This study concludes that environmental sustainability in mobile communications requires an integrated approach combining regulation, reporting and standardisation. Future work should focus on improving common indicators, strengthening links between regulatory requirements and technical standards, supporting harmonised data collection, and identifying practical methods for reducing the footprint of mobile networks while enhancing their handprint across society. In this way, mobile communication stakeholders can better support the European green and digital transition while ensuring that future mobile communications development remains energy-efficient, resource-conscious, and environmentally sustainable.

Disclaimer - The regulatory analysis focuses primarily on the European Union and does not provide a complete global legal comparison. The report is not intended as legal advice. The standardization analysis prioritises selected ITU-T L. series standards that are most relevant to environmental sustainability in mobile communications, rather than covering every standard issued by standardization bodies. Since, sustainability regulation and reporting requirements are evolving, some documents may require future updating. In conclusion, this report remains an information package around the topic "environmental sustainability in mobile communications".

Annex - analysed ITU-T standards

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Annex – analysed ITU-T standards

List of ITU-T standards analysed in this report and their brief description with the public link for ease of access.

Document	Description
Rec. ITU-T L.1000 (07/2019) Universal power adapter and charger solution for mobile terminals and other hand-held ICT devices	Contains general requirements for a universal power adapter and charger solution for mobile terminals and other hand-held ICT devices. The basic configurations and general requirements for the power adapter and charger interface, energy efficiency, safety, electromagnetic compatibility, resistibility, and eco-environmental specifications.
Rec. ITU-T L.1004 (07/2025) Universal fast-charging solution for mobile terminals	Defines the overall framework of the solution and the role of each part and specifies requirements for various aspects such as system, safety, electromagnetic compatibility (EMC), material, co-environment and energy efficiency and specifies requirements for various aspects such as system, safety, electromagnetic compatibility (EMC), material, co-environment and energy efficiency.
Rec. ITU-T L.1011 (09/2025) Guidelines for the durability assessment of lithium-ion batteries	Provides guidelines for the durability assessment of Lithium-ion batteries, on different stages of the product life cycle. Contains durability evaluation methods and suggestions for improving durability in different evaluation dimensions with proposals for evaluation indicators.
Rec. ITU-T L.1015 (05/2019) Criteria for evaluation of the environmental impact of mobile phones	Proposes and establishes a criterion to be used when evaluating the environmental impact of mobile phones. It provides a reference for manufacturers to enhance environmental performance at a global level. It does not include eco-rating, scoring, eco-labelling or a life cycle assessment (LCA) methodology.
Rec. ITU-T L.1017 (08/2024) Environmental performance scoring of smartphones	Presents a standardised method to assess the environmental performance of smartphones considering the material efficiency and life cycle assessment aspects this method gives an aggregated score to reflect the overall environmental performance.

Rec. ITU-T L.1018 (07/2025) Specification for the durability assessment of mobile telecommunication terminals	Provides a durability assessment standard for the mobile telecommunication terminals. The assessment indicators for mobile telecommunication terminals include environmental applicability, maintenance and repair of the entire device and its accessories, recycling and reuse, system management, data security and manufacturer operation.
Rec. ITU-T L.1020 (01/2018) Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks	Suggests approaches of circular economy for the information and communication technology goods. Particularly guidance on the topic for the operator's supply chain through a 'manifesto' intended to improve the circularity of products through supply chain actions.
Rec. ITU-T L.1021 (04/2018) Extended producer responsibility – Guidelines for sustainable e-waste management	Provides guidelines and recommendations for the development of extended producer responsibility (EPR) policies for sustainable e-waste management.
Rec. ITU-T L.1022 (10/2019) Circular economy: Definitions and concepts for material efficiency for information and communication technology	Explains key Circular Economy concepts and metrics and gives parameters, metrics, indicators in Circular Economy for ICT sector.
Rec. ITU-T L.1023 (08/2023) Assessment method for circularity performance scoring	Gives an assessment method for circularity scoring of information and communication technology (ICT) goods. The score is based on three circularity aspects. First durability of ICT goods. Second, the ICT good's ability to be recycled, repaired, reused and upgraded. Third, manufacturer's ability to recycle, repair, reuse and upgrade the ICT good put into market.
Rec. ITU-T L.1024 (01/2021) The potential impact of selling services instead of equipment on waste creation and the environment – Effects on global information and communication technology	Contains analysis and predictions of the real or potential environmental consequences of selling services instead of equipment for the global ICT industry.
Rec. ITU-T L.1025 (07/2025) Assessment of material efficiency of information and communication technology network infrastructure	Specifies a method for the verification of compliance with the requirements on the secure data deletion functionality for servers and data storage equipment.

goods - Server and data storage product secure data deletion functionality	
Rec. ITU-T L.1027 (08/2023) Assessment of material efficiency of ICT network infrastructure goods (circular economy) – Server and data storage product disassembly and disassembly instruction	Contains methods to measure the ability to be disassembled in servers and data storage equipment.
Rec. ITU-T L.1028 (11/2024) Evaluating the global-warming-potential impact of extending the operating lifetime of information and communication technology equipment	Provides indicator UER10, "Ratio of use-phase emissions during 10 years over embodied emissions" which gives the ratio of use-stage GHG emissions versus embodied emissions as an indication of lifetime extension potential. LCA data can be used as an input for this indicator calculation.
Rec. ITU-T L.1030 (06/2018) E-waste management framework for countries	Provides guidelines on policy/legal frameworks, resource mobilisation, collection and financial mechanisms and stakeholder engagement in designing and adjusting e-waste management systems in national level.
Rec. ITU-T L.1032 (08/2019) Guidelines and certification schemes for e-waste recyclers	Considers requirements for recyclers of waste information and communication technology (ICT), with particular attention to the informal sector involved in WEEE collection and dismantling. It provides guidelines and certification criteria to help formalize informal practices, improve environmental performance, protect workers, and identify the steps, resources, and methods needed to transition the sector into a formalized, regulated industry.
Rec. ITU-T L.1033 (10/2021) Guidance for institutions of higher learning to contribute in the effective life cycle management of e-equipment and e-waste	Provides guidance for institutions of higher learning to contribute through effective collaborative involvement in managing e-resources and e-waste.
Rec. ITU-T L.1034 (08/2022) Adequate assessment and sensitization on counterfeit information and communication technology products and their environmental impact	Provides guidance for consumers and retailers on counterfeit information and communication technology (ICT) products, focusing on environmental and health (EH) risks.
Rec. ITU-T L.1035 (02/2022) Sustainable management of batteries	Focuses on managing used and waste batteries in ICT with methods to recycle batteries effectively with ensured worker safety in the management of waste batteries. Also

	includes proposals for policies, legislation and management plans for batteries.
Rec. ITU-T L.1036 (02/2022) Scheduled waste management for a base station (inclusive of e-waste)	Describes requirements to minimise the pollution of waste management at a base station and enhance sustainability of the telecommunications industry.
Rec. ITU-T L.1037 (09/2025) Requirements for the collection, transportation, storage, dismantling, valorization and final disposal of waste electrical and electronic equipment	Presents a framework for the collection, transportation, storage, dismantling, valorization and final disposal of WEEE in a safe and environmentally sound manner (ESM), and to improve valorization and the recycling rate of WEEE in developing countries.
Rec. ITU-T L.1041 (12/2025) Resource saving, e-waste reduction and energy saving system methodology using twisted single pair cable	Proposes a resource-saving methodology for a new cable system that provides power supply and communication functions using only one twisted pair cable.
Rec. ITU-T L.1050 (01/2022) Methodology to identify key equipment for environmental impact and e-waste generation assessment of network architectures	Presents the necessary requirements for identifying equipment types used in network life cycle assessments (LCAs).
Rec. ITU-T L.1060 (07/2021) General principles for the green supply chain management of information and communication technology manufacturing industry	Provides the general principles for the green supply chain (GSC) management of information and communication technology (ICT) manufacturing industry and the requirements for planning, implementation and control, performance evaluation, management review and continuous improvement of the product life cycle.
Rec. ITU-T L.1061 (03/2023) Circular public procurement of information and communication technologies	Provides a set of principles that provides a basis for circular public procurement of ICT equipment to maximize usable life, maximize the use of energy-efficient equipment, minimize any resulting amount of e-waste produced, and the adverse effects of e-waste, and increase recyclability, thereby contributing to circular economy realization.
Rec. ITU-T L.1070 (11/2023) Global digital sustainable product passport opportunities to achieve a circular economy	Provides an overview of sustainability opportunities, environmental related, about product-related digital information common to all ICT products, with global scope for harmonization- Digital Product Passport
Rec. ITU-T L.1071 (11/2024)	Provides a structure for collecting information items organized to represent circularity and environmental sustainability information about information and

A model for digital product passport information on sustainability and circularity	communication technology (ICT) products and product-related standards.
Rec. ITU-T L.1080 (07/2025) Assessment of material efficiency of information and communication technology network infrastructure goods – Server and data storage product availability of firmware and of security updates to firmware	Specifies how manufacturers of server products and online data storage products make available the latest available firmware version and the security updates to the firmware, to whom these updates are made available and the skill levels required to install these updates.
Rec. ITU-T L.1206 (07/2025) Impact on information and communication technology equipment architecture of multiple AC, −48 VDC or up to 400 VDC power inputs	Defines the requirements for the power inputs combination of the three power interfaces: A1 alternating current (AC), A (−48 Volt DC (VDC)), P or A3 (up to 400 VDC)) that could potentially be used single or in combination for each input.
Rec. ITU-T L.1207 (05/2018) Progressive migration of a telecommunication/ information and communication technology site to 400 VDC sources and distribution	Defines solutions for progressive migration of information and communication technology (ICT) sites (telecommunication and data centres) to up to 400 V direct current (400 VDC) distribution and direct use of up to 400 VDC powering ICT equipment from 400 VDC sources.
Rec. ITU-T L.1210 (12/2025) Sustainable power-feeding solutions for 5G networks	Defines power-feeding solutions for 5G, converged wireless and wireline access equipment and networks, while taking into consideration their enhanced requirements on service availability and reliability, new deployment scenarios, together with the environmental impact of the proposed solutions.
Rec. ITU-T L.1211 (12/2025) Smart controlling methods for photovoltaic system installed in base station site	Defines smart controlling methods for photovoltaic system installed in base station site and also considers typical practice.
Rec. ITU-T L.1220 (08/2017) Innovative energy storage technology for stationary use – Part 1: Overview of energy storage	Identifies the main needs and applications of stationary electrical energy storage for information and communication technology (ICT) sites such as back-up on different grid quality and cyclic use of renewable energy systems.
Rec. ITU-T L.1221 (11/2018) Innovative energy storage technology for stationary use – Part 2: Battery	Contains the main requirements for evaluating appropriate innovative batteries for stationary use for powering ICT equipment in telecom sites, active network

	units and data centres or customer premises with standardized power interfaces in –48V, up to 400 VDC or 12V.
Rec. ITU-T L.1222 (05/2018) Innovative energy storage technology for stationary use – Part 3: Supercapacitor technology	Provides an overview of available supercapacitor (SC) technology, with details of SC characteristics (electrical, mechanical, thermal) and applicability in the telecommunication/information and communication technology (TLC/ICT) domain.
Rec. ITU-T L.1310 (09/2024) Energy efficiency metrics and measurement methods for telecommunication equipment	Presents the principles and concepts of energy efficiency metrics and measurement methods for telecommunication network equipment.
Rec. ITU-T L.1311 (07/2025) Energy efficiency measurement methodology and metrics for heterogeneous servers	Provides test conditions, metrics requirements for the measurement process for energy efficiency of general and heterogeneous servers.
Rec. ITU-T L.1315 (05/2017) Standardization terms and trends in energy efficiency	Contains terminology, principles and concepts for energy efficiency and energy management.
Rec. ITU-T L.1316 (11/2019) Energy efficiency framework	Presents a framework of existing standards, from ITU-T, ETSI and ATIS, covering various aspects of energy efficiency (EE) and energy management.
Rec. ITU-T L.1318 (08/2022) Q factor: A fundamental metric expressing integrated circuit energy efficiency	Defines the integrated circuit metric for energy efficiency as the Q factor (also known as "quality factor" or "Q"). Q factor provides a key means to accurately express energy efficiency at the integrated circuit (IC) level.
Rec. ITU-T L.1320 (03/2014) Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres	Provides principles and concepts of energy efficiency metrics and measurement methods for power feeding equipment and cooling equipment in telecommunications rooms and data centres.
Rec. ITU-T L.1325 (12/2016) Green ICT solutions for telecom network facilities	Describes Green ICT solutions for telecom network facilities and aims to increase the energy efficiency of the whole telecom network and to reduce carbon emissions.
Rec. ITU-T L.1326 (08/2023) Requirements and use cases of liquid cooling solutions and high energy efficiency solutions for 5G baseband units in centralized-RAN mode	Requirements for liquid cooling and high energy efficiency solutions for 5G Baseband Unit (BBU) in centralized-RAN mode.

Rec. ITU-T L.1328 (09/2025) Specification for waste heat reuse in telecommunication rooms and data centres	Presents the technologies for the reuse of waste heat in telecommunications rooms and data centres.
Rec. ITU-T L.1330 (03/2015) Energy efficiency measurement and metrics for telecommunication networks	Defines the topology and level of analysis necessary to assess the energy efficiency (EE) of mobile networks.
Rec. ITU-T L.1331 (01/2022) Assessment of mobile network energy efficiency	Provides an understanding of the energy efficiency of mobile networks considering the networks' evolution in different periods of time.
Rec. ITU-T L.1332 (01/2018) Total network infrastructure energy efficiency metrics	Contains the basic definition of energy efficiency metrics and measurement methods required to evaluate the energy efficiency of a total network.
Rec. ITU-T L.1333 (09/2022) Carbon data intensity for network energy performance monitoring	Defines a KPI for the carbon emission intensity of a network focused on network energy consumption in relation to data traffic. It includes the KPI definition and describes the KPI calculation and methods of measurement of the quantities necessary to calculate the KPI.
Rec. ITU-T L.1340 (02/2014) Informative values on the energy efficiency of telecommunication equipment	Defines a set of informative values for telecommunication network equipment and small networking equipment used in the home and small enterprise locations.
Rec. ITU-T L.1341 (12/2025) Functional Requirements for Energy Efficiency in Intelligent Internet of Things Platforms	Presents challenges related to energy efficiency in intelligent IoT platforms and provides functional requirements to improve it.
Rec. ITU-T L.1350 (10/2016) Energy efficiency metrics of a base station site	Gives principles and concepts of energy efficiency metrics used to evaluate the energy efficiency of a base station site.
Rec. ITU-T L.1351 (08/2018) Energy efficiency measurement methodology for base station sites	Provides base station site energy efficiency parameter measurement- SEE Site Energy Efficiency.
Rec. ITU-T L.1361 (11/2018) Measurement method for energy efficiency of network functions virtualization	Defines the metrics and measurement methods for the evaluation of the energy efficiency of functional components of a network functions virtualization (NFV) environment.
Rec. ITU-T L.1362 (01/2024)	Provides an evolved version of the green abstraction layer (GAL) capable of operating within ETSI NFV environments.

Power management capabilities of the future energy telecommunication network nodes – Enhanced interface for power management in network function virtualization environments	
Rec. ITU-T L.1380 (11/2019) Smart energy solution for telecom sites	Provides details of photovoltaic (PV) systems are powered by solar energy.
Rec. ITU-T L.1382 (06/2020) Smart energy solution for telecommunication rooms	Contains a smart energy solution for telecommunication rooms, provides design requirement for power supply and backup systems for telecommunication rooms.
Rec. ITU-T L.1384 (08/2024) Implementation of a virtual micro power station at base station sites	Provides technical requirements for a virtual micro power station integrated system design based on energy storage system base stations present in sites.
Rec. ITU-T L.1390 (08/2022) Energy saving technologies and best practices for 5G radio access network (RAN) equipment	Gives best practises on how to use the technologies around energy saving potential and energy saving principles in 5G RAN, to reduce 5G RAN energy consumption.
Rec. ITU-T L.1391 (01/2024) Specification of IMT-2020 network sharing and co-construction adapting to climate change mitigation	Describes IMT 2020 (5th generation 5G) network sharing and co-construction (NSCC) concept and its contribution to climate change mitigation. A cost benefit analysis and for IMT 2020 NSCC are included.
Rec. ITU-T L.1395 (07/2025) Monitoring and control interface for power, cooling and building environment systems in telecommunication networks – Generic interface	Describes monitoring and control of infrastructure environments such as power, cooling, and building environments systems for telecommunication centres and access network locations; also, the monitoring of energy and environmental parameters: power energy environmental (PEE) parameters for ICT equipment in telecommunications sites or datacentre or customer premises are considered.
Rec. ITU-T L.1396 (10/2025) Monitoring and control interface for power, cooling and building environment systems in telecommunication networks - Information and communication technology equipment power, energy and environmental parameters monitoring information model	Defines measurement and monitoring of power, energy and environmental parameters for information and communication technology (ICT) equipment in telecommunications or data centre or customer premises.

Rec. ITU-T L.1397 (10/2025) Monitoring and control interface for power, cooling and building environment systems in telecommunication networks – Battery system with integrated control and monitoring information model	Provides a monitoring and controlling in a battery system with a dedicated monitoring and control system (CU) is defined.
Rec. ITU-T L.1400 (03/2023) Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies	Provides overview and general principles of methodologies for assessing the environmental impact of ICTs
Rec. ITU-T L.1410 (11/2024) Methodology for environmental life cycle assessments of information and communication technology goods, networks and services	Provides methodology for ICT goods, Network and services. Also, the LCA is used as a comparative analysis with the reference product system and/or another ICT good, network, service.
Rec. ITU-T L.1420 (02/2012) Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations	Provides methodology for energy consumption and GHG impact assessment of information and communication technologies in organizations can be used in two ways. It can be used to assess the life cycle GHG emissions (first and second order effects) emerging from the use of ICT in non-ICT organizations. Secondly as a supplement to GHG protocol for ICT organizations who wants to assess their own organizational energy consumption GHG related impact.
Rec. ITU-T L.1430 (12/2013) Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects	Provides a project-level methodology (not an LCA of a product) to quantify, monitor, and report the environmental impacts of ICT GHG projects and ICT energy projects; GHG emission reductions / removal enhancements and energy consumption reductions plus enhancements of energy generation and storage.
Rec. ITU-T L.1440 (10/2015) Methodology for environmental impact assessment of information and communication technologies at city level	Provides guidance on assessing ICT related GHG emissions and energy consumption at city level. Part I relates to the first order effects from the use of ICT goods and networks in a city's organizations and households. Part II relates to the first and second order effects from ICT projects and services applied in the city.

Rec. ITU-T L.1450 (12/2025) Methodologies for the assessment of the environmental impact of the information and communication technology sector	Provides methodologies to assess the environmental impact of ICT at a sector level including its future development. Two main methodologies are; methodology for calculating the information and communication technology (ICT) sector footprint with respect to life cycle environmental impact including greenhouse gas (GHG) emissions; and methodology for defining GHG emissions budget for the ICT sector considering a 2^{0}C or lower trajectory.
Rec. ITU-T L.1451 (11/2019) Methodology for assessing the aggregated positive sector-level impacts of ICT in other sectors	Assess the environmental and economic impacts of information and communication technologies (ICTs) at the sectoral level, here we use a Computable General Equilibrium (CGE) model as a possible methodology.
Rec. ITU-T L.1460 (08/2018) Connect 2020 greenhouse gases emissions – Guidelines	Provides guidelines to address the Connect 2020 greenhouse gas (GHG) emissions target.
Rec. ITU-T L.1470 (01/2020) Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement	Provides detailed trajectories of greenhouse gas (GHG) emissions for the global information and communication technology (ICT) sector and sub-sectors.
Rec. ITU-T L.1471 (08/2023) Guidance and criteria for information and communication technology organizations on setting Net Zero targets and strategies	Provides guidance and criteria to ICT organizations on setting Net Zero targets and strategies based on approaches put forward by major Net Zero initiatives.
Rec. ITU-T L.1480 (07/2025) Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impacts greenhouse gas emissions of other sectors	Provides methodology for assessing how the use of ICT solution impacts GHG emissions of other sectors. This methodology provides guidance on the assessment of the use of ICT solutions covering the net second order effect.
Rec. ITU-T L.1481 (12/2022) Guidance on how to address the Connect 2030 targets on net greenhouse gas abatement	Guides on how to address the Connect 2030 sustainability target 3.4, which states: "By 2023, net telecommunication/ICT-enabled greenhouse gas abatement should have increased by 30% compared to the 2015 baseline".
Rec. ITU-T L.1490 (08/2024)	Describes the design principles, framework and functional requirements of the greenhouse gas emissions

Framework and functional requirements of a greenhouse gas emissions management system using digital technology for the public sector	management system (GHGEMS), which applies to the design of a greenhouse gas emissions management system for the public sector.
Rec. ITU-T L.1491 (09/2025) Measurement methodology and best practices for decarbonization of industrial parks in support of net zero	Explains how to use advanced information and communication technology (ICT) to help industrial parks carry out net zero assessment and achieve the net zero goal.
Rec. ITU-T L.1500 (06/2014) Framework for information and communication technologies and adaptation to the effects of climate change	Describes the framework for using ICTs in adaptation to the effects of climate change.
Rec. ITU-T L.1501 (12/2014) Best practices on how countries can utilize ICTs to adapt to the effects of climate change	Provides best practices and a framework around them for countries to integrate their ICTs into their national strategies for adaptation to climate change.
Rec. ITU-T L.1502 (11/2015) Adapting information and communication technology infrastructure to the effects of climate change	Provides a set of requirements useful for planning or upgrading ICT infrastructure to adapt to the effects of climate change.
Rec. ITU-T L.1506 (01/2018) Framework of climate change risk assessment for telecommunication and electrical facilities	Describes a framework for assessing climate change risks to telecommunication and electrical facilities.
Rec. ITU-T L.1507 (07/2019) Use of ICT sites to support environmental sensing	Focuses on collecting the environmental data utilizing ICT sites and infrastructure. Describes present challenges in fine grain sensing for data collection, architecture of the sensing system, and requirements for installing them in ICT sites.
Rec. ITU-T L.1510 (10/2025) Environmental key performance indicators for digital infrastructure adapting to climate change	Defines key performance indicators (KPIs) for assessing the environmental impact of digital infrastructures and six categories of digital infrastructure metrics for KPI calculation and reporting, enabling harmonized, transparent and comparable sustainability assessment across the industry.
Rec. ITU-T Y.4900/L.1600 (06/2016)	Provides the overview for KPIs related to ICT adoption and use in the context of smart sustainable cities (SSCs).

Overview of key performance indicators in smart sustainable cities	
Rec. ITU-T Y.4901/L.1601 (06/2016) Key performance indicators related to the use of information and communication technology in smart sustainable cities	Provides the KPIs related to ICT adoption and use in the context of smart sustainable cities (SSCs).
Rec. ITU-T Y.4902/L.1602 (06/2016) Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities	Gives a general guidance to cities and provide the definitions of key performance indicators (KPIs) related to the sustainability impact of information and communication technology (ICT) in the context of smart sustainable cities (SSCs).
Rec. ITU-T L.1700 (06/2016) Requirements and framework for low-cost sustainable telecommunications infrastructure for rural communications in developing countries	Identifies technology-independent general requirements for ultimately affordable urban-to-rural broadband backhaul infrastructure, for connecting rural, remote and sparsely populated areas in developing countries, considering affordability, reliability, flexibility and scalability of the solutions.

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VISIIRI – National ecosystem for Green ICT transition

The Green ICT project VISIIRI creates an overview of the impact of the Finnish ICT sector on climate and the environment. The project supports the green transition of the ICT sector by connecting the sector's actors in a national ecosystem. The ecosystem will enable the sharing of best practices and bring together Finnish industry and academia.

The project will develop methods to measure the environmental impact of the ICT sector and produce environmental awareness training materials for companies. Raising environmental awareness will reduce the carbon footprint of the ICT sector, while increasing the handprint at the same time. Green business will enable Finland's pioneer position, opening up opportunities in international markets.

Funding

The project is co-financed by European Union through the Economic Development Centre of Northern Finland.

Project duration

01.04.2024–31.05.2026

More information

tieke.fi/green-ict-visiiri (in Finnish)