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# ENVIRONMENTAL SUSTAINABILITY IN MOBILE NETWORKS: A study of mobile communication sector stakeholders' activities and indicators

Report 1 of 3

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TIEKE TIVIA LUT University UNIVERSITY OF OULU UNIVERSITY OF TURKU UNIVERSITY OF EASTERN FINLAND

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# Abbreviations

| | |
|---|---|
| 5G | 5th Generation |
| 6G | 6th Generation |
| AI/ML | Artificial Intelligence/Machine Learning |
| CDP | Carbon Displacement Project |
| CPEs | Customer Premises Equipment |
| CRM | Critical Raw Material |
| CSRD | Corporate Sustainability Reporting Directive |
| CTUe | Comparative Toxic Units for Ecosystems |
| CTUh | Comparative Toxic Unit for humans |
| CUE | Carbon Usage Effectiveness |
| EAC | Energy Attribute Certificate |
| ESG | Environmental Social and Governance |
| ESRS | European Sustainability Reporting Standards |
| EU | European Union |
| GeSI | Global Enabling Sustainability Initiative |
| GHG | Greenhouse Gas |
| GRI | Global Reporting Initiative |
| GSMA | Groupe Speciale Mobile Association |
| HVAC | High Voltage Air Conditioning |
| ICT | Information and Communication Technology |
| IoT | Internet of Things |
| ITU | International Telecommunications Union |
| ITU-T | International Telecommunication Union – Telecommunication Standardization Sector |
| KPI | Key Performance Indicator |
| LCA | Life Cycle Assessment |
| LED | Light Emitting Diode |
| MNO | Mobile Network Operator |
| MTN | Mobile Telecommunication Networks |
| NGA | Next Generation Alliance |
| NGMN | Next Generation Mobile Networks |
| PPA | Power Purchase Agreement |
| PUE | Power Usage Effectiveness |

| | |
|---|---|
| RAN | Radio Access Network |
| REACH | Registration, evaluation, authorization, and restriction of chemicals. |
| REF | Renewable Energy Factor |
| REPA | Renewable Energy Purchase Agreement |
| SASB | Sustainability Accounting Standards Board |
| SBTi | Science-based Target initiative |
| SCIP | Substances of Concern in Products |
| TCFD | Task Force on Climate-Related Financial Disclosure |
| $tCO_2e$ | Tonnes of carbon dioxide equivalent |
| TEPs | Telecommunication Equipment Provider |
| TNFD | Taskforce on Nature-related Financial Disclosures |
| UN | United Nations |
| UN SDGs | United Nations Sustainability Development Goals |
| UPS | Uninterrupted Power Supply |
| VOC | Volatile Organic Compounds |
| WB | World Bank |
| WUE | Water Use Effectiveness |

# Abstract

**Title of publication**
ENVIRONMENTAL SUSTAINABILITY IN MOBILE NETWORKS: A study of mobile communication sector stakeholders' activities and indicators

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This report describes how the mobile communications sector addresses environmental sustainability, focusing on key stakeholders' activities that reduce negative impacts (footprint) and improve positive impacts (handprint). This is the first report in a series of three reports prepared by University of Oulu in Green ICT VISIIRI project. A structured, multi-phased methodology was adopted, including stakeholder identification, and data collection and analysis, to identify stakeholders' environmental sustainability related activities and indicators. Three stakeholder groups within the mobile communication ecosystem were identified and examined: Mobile Network Operators (MNOs), Telecommunication Equipment Providers (TEPs), and Industry Forums. Stakeholder source material was used to identify key environmental sustainability topics. Then, the stakeholders' environmental sustainability enhancing activities were identified together with relevant indicators highlighting stakeholder specific approaches in the mobile communication sector. Findings provide guidance for different companies and organizations showcasing how the stakeholders can improve their own operations and contribute to enhancing environmental sustainability.

Keywords – energy consumption, energy efficiency, environmental sustainability, greenhouse gas emissions, mobile communications, mobile network operators, networks, stakeholders

# 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 three interrelated pillars: economic, social, and environmental sustainability (Hexa-X-II, 2023). These three 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, use of devices, and virtualization of services increases energy consumption, and the use of resources and materials, contributing to increased greenhouse gas (GHG) emissions. The International Telecommunication Union (ITU) and the World Bank assessed 200 leading digital companies in 2023 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 WB, 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) (United Nations, 2015) and the European Green Deal (European Commission, 2019), 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 (United Nations, 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 (European Commission, 2019) 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, 2023f), (NGA, 2023a).

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 first in a series of three reports on Environmental Sustainability in Mobile Networks. The companion reports in this series are: Environmental Sustainability in Mobile Networks: Analysis of regulations and standards (second 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 consolidates current global environmental sustainability activities from the key stakeholders of the mobile communication sector within the ICT sector including leading mobile network operators (MNOs), telecommunication equipment providers (TEPs), and industry forums. Combining the activities and indicators promoting environmental sustainability by the mobile communication sector's stakeholders in a comprehensive format will help ICT companies to integrate environmental sustainability practices into their operations.

The remainder of this report is structured as follows. Chapter 3 presents the key identified stakeholder groups in this study. Chapter 4 presents the key environmental sustainability topics identified in the study. Chapter 5 analyses the environmental sustainability related activities undertaken by the MNOs and corresponding indicators. Chapter 6 analyses the activities and indicators of the TEPs. Chapter 7 reviews the activities and indicators discussed within the industry forums. Finally, Chapter 8 presents the concluding remarks.

# 2

# Methodology

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# 2 Methodology

This study aims to investigate how the mobile communication sector addresses environmental sustainability. The study aims to identify specific activities and related indicators to promote environmental sustainability within the mobile communication sector through its stakeholders. The study aims to help different companies to reduce their negative environmental sustainability impacts (footprint) and increase their positive environmental sustainability impacts (handprint). 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: stakeholder identification, data source selection, data extraction and coding, analysis and categorization, and synthesis and reporting, which are detailed in the following.

The first phase, stakeholder identification focuses on determining key stakeholder groups within the mobile communication sector. The three main stakeholder groups identified in this study include Mobile Network Operators (MNOs), Telecommunications Equipment Providers (TEPs), and relevant industry forums. The MNOs include companies which build, operate and maintain the mobile communication network infrastructure, which includes radio towers, base stations, fibre networks, and MNOs' own data centres, among others. Data centres that are operated outside the MNO's own domain fall outside the scope of this study and are addressed separately in the VIISIRI project. TEPs include mobile communication network infrastructure vendors and device vendors. Industry forums gather different stakeholders, including operators and vendors, to share best practices and add value to the strategic direction of the industry. Industry forums have played an active role in promoting sustainability within the industry. These three high-level stakeholder groups including MNOs, TEPs and industry forums enable a comprehensive view of environmental sustainability initiatives across different organizational roles within mobile communication sector.

The second phase is the data source selection. The aim is to capture environmental sustainability activities by the mobile communications sector's stakeholders, to share knowledge about what international mobile communication companies are already doing. One key data source for this includes the companies' sustainability reports and annual reports. In addition, industry forum publications and companies' technical documents such as position papers, opinion paper and white papers were studied. To understand the fundamentals in environmental sustainability several reports from other sources such as ITU and EU regulations were also studied. These sources were chosen for their ability to provide detailed insights into up-to-date environmental sustainability practices adopted by the industry.

The third phase is to systematically review the selected data sources to identify and list relevant activities related to environmental sustainability undertaken by the companies. Additionally, this phase

identifies the environmental sustainability indicators related to the companies' activities. The data is mostly qualitative, making use of the organizations' sustainability reports.

In the fourth phase, analysis and categorization, the environmental sustainability activities and indicators identified in the previous phase are grouped into key environmental sustainability topics. The formulation of these key environmental sustainability topics was based on the source material, resulting in one general category "monitoring and reporting" and six specific categories including "greenhouse gas emissions,", "biodiversity, land and water usage", "waste management", "circularity and material usage", and "enablement". The data on stakeholders' activities and indicators was then mapped to these sustainability topics and aggregated by merging similar activities across organizations within the stakeholder group. This approach highlights stakeholder specific activities in environmental sustainability practices.

Finally, the fifth and last phase, synthesis and reporting, includes creating a structured results document, which is this report.

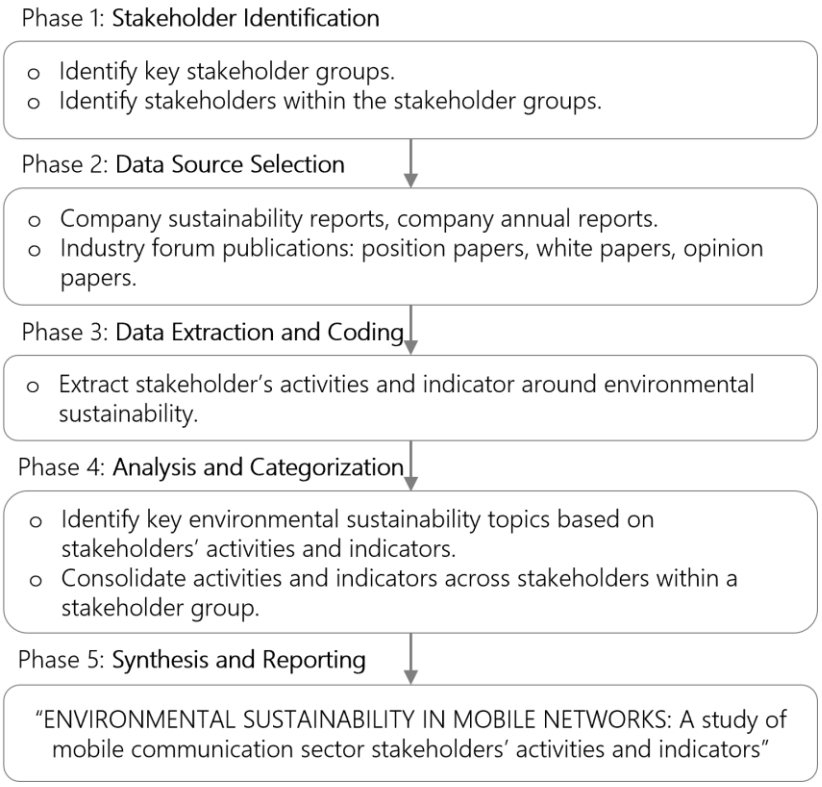

Figure 2.1: Methodology for analysing stakeholders' activities and indicators

# 3

# Key identified stakeholder groups in mobile communications

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# 3 Key identified stakeholder groups in mobile communications

Sustainable and energy efficient mobile communications involve multiple stakeholders across the mobile communication sector, which develops the mobile communication solutions, as well as in other sectors, which use the mobile communication solutions. Environmental sustainability in the mobile communication sector needs coordinated efforts among diverse stakeholders both in the supply and demand sides as companies support and guide their suppliers in the value chain to be more efficient and reduce energy consumption and greenhouse gas emissions among others. These sustainability enhancing efforts include technology development, standardization, operational practices to list a few. Identifying and understanding the key stakeholders and their activities enables and strengthens effective implementation of sustainable development in the mobile communication sector.

This chapter identifies three key stakeholder groups relevant to study the environmental sustainability in mobile communication sector. They are Mobile Network Operators (MNOs), Telecommunication Equipment Providers (TEPs), and Industry Forums. Each group plays a distinct role in shaping the evolution of mobile communication and driving environmental sustainability.

MNOs are the primary mobile communication service providers responsible for deploying and operating mobile communication network infrastructure. They build, operate, and maintain the mobile communication network infrastructure. This includes radio towers, base stations, fibre networks, and data centres, among others. Data centres outside the MNO's domain fall outside the scope of this study. For MNOs, environmental sustainability is of operational, financial, and strategic importance. In this study, seventeen major MNOs were studied through their publicly available sustainability reports and annual reports. The selection of the companies was based on market presence and geographic diversity, ensuring representation from all major global regions, as follows:

- North America: AT&T,[1] Verizon[2], T-Mobile[3]
- Latin America: América Móvil[4], Telefónica[5] (also operates in Europe but maintains a strong presence in Latin America)
- Europe: Orange[6], Vodafone[7], Telia[8], Telefónica[9] (Spain), MTS (Russia)

[1] https://www.att.com/
[2] https://www.verizon.com/
[3] https://www.t-mobile.com/
[4] https://www.americamovil.com/
[5] https://www.telefonica.com/en/
[6] https://www.orange.com/
[7] https://www.vodafone.com/
[8] https://www.telia.fi/
[9] https://www.telefonica.com/en/

- Asia-Pacific: Bharti Airtel[10] (India), China Mobile[11], China Telecom[12], NTT DOCOMO[13] (Japan), Telkomsel[14] (Indonesia), Grameenphone[15] (Bangladesh)
- Middle East & Africa: MTN[16] (South Africa), Ooredoo[17] (Qatar)

TEPs considered in the study include primarily network infrastructure vendors and device vendors. The following six major TEPs were included in this study: Nokia[18], Ericsson[19], Huawei[20], Samsung[21], Cisco[22], and Apple[23], who all have multiple roles in the mobile communication sector. Nokia, Ericsson, Huawei, Samsung and Cisco provide various network infrastructures. Samsung, Huawei and Apple provide end user devices for mobile communications. Additionally, they provide a variety of services, components and other solutions relevant for ICTs and mobile communications.

Industry forums include collaborative organizations that bring together stakeholders across the mobile communication sector. Industry forums gather different stakeholders including MNOs and vendors among others to share best practices, promote common interests, and add value to the strategic direction of the industry. Some of the industry forums have played a particularly active role in promoting sustainability within the industry. Three industry forums were selected for the study considering the membership and contributions including the GSM Association (GSMA)[24], Next Generation Alliance (NGA)[25], and Next Generation Mobile Networks (NGMN)[26]. GSMA is a global industry organization representing mobile network operators and the broader mobile ecosystem. NGA is a North American industry initiative aimed at ensuring North American leadership in the development and commercialization of wireless technology. NGMN is an operator-driven global alliance that defines technical requirements and strategic roadmaps for next-generation mobile networks, including 5G and beyond.

[10] https://www.airtel.in/
[11] https://www.chinamobileltd.com/
[12] https://www.chinatelecom-h.com/
[13] https://www.docomo.ne.jp/
[14] https://www.telkomsel.com/
[15] https://www.grameenphone.com/
[16] https://www.mtn.co.za/
[17] https://www.ooredoo.qa/web/en/
[18] https://www.nokia.com/
[19] https://www.ericsson.com
[20] https://www.huawei.com
[21] https://www.samsung.com
[22] https://www.cisco.com
[23] https://www.apple.com
[24] https://www.gsma.com
[25] https://nextgalliance.org/
[26] https://www.ngmn.org/

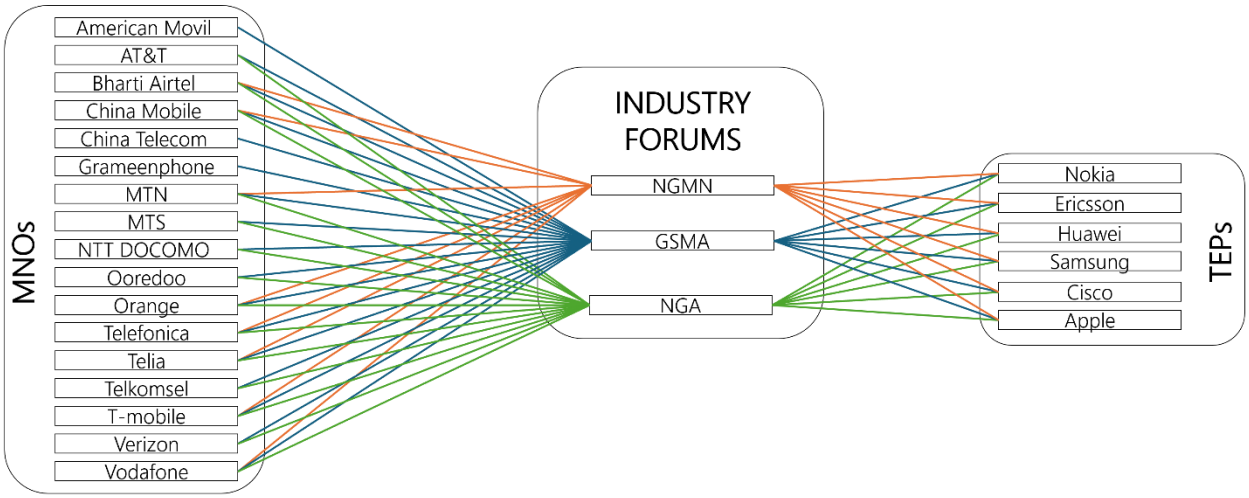


Figure 3.1: Relationships between key stakeholder groups

The relationships between the three considered forums and the companies within the MNO and TEP groups as members or contributors to the forums are shown in Figure 3.1. Companies are contributors and members of the industry forums, which are platforms for information sharing. Additionally, stakeholders within the MNO and TEP groups are interconnected through supplier and customer roles, which is omitted in this figure.

# 4

# Key identified environmental sustainability topics

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# 4 Key identified environmental sustainability topics

To assess the environmental sustainability impacts of the mobile communication sector, this study has identified key environmental sustainability topics through the analysis of stakeholder groups' environmental sustainability activities. The identified topics consistently emerged from the review of various sustainability reports/annual reports of the companies, and the publications of the forums. The main identified topic was "monitoring and reporting", which took place in several organizations and covering a multitude of environmental sustainability topics. Consequently, monitoring and reporting in this study is considered as an overarching topic which brings all other topics together. Additionally, the following six environmental sustainability topics were identified and further addressed in this report:

1. Greenhouse gas emissions
2. Energy management
3. Biodiversity, land, and water
4. Waste management
5. Circularity and material usage
6. Enablement

Figure 4.1 summarizes the identified topics, and their descriptions are provided in Table 4.1. The identified topics reflect environmental concerns that are associated with the manufacturing of mobile network equipment and infrastructure, network deployment, operation, and product end-of-life lifecycles. These concerns can be assessed and captured using various qualitative and quantitative indicators and metrics.


Figure 4.1: Key environmental sustainability topics around monitoring and reporting

Table 4.1: Key considered environmental sustainability topics and their descriptions.

| Key environmental sustainability topic | Description |
|---|---|
| Greenhouse gas emissions | Greenhouse gas emission is the release of gases that contribute to the natural greenhouse effect into the atmosphere through natural and man-made activities. The greenhouse gases are carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride (European Environment Agency, 2025). |
| Energy management | Energy management is the controlling of costs and integration of renewable energy into operations while continuing to meet demand and users' performance and quality expectations (Energy Management and Flexibility in Mobile Networks, 2024). |
| Biodiversity, land, and water | Biodiversity is the variety of plants, animals and microorganisms existing in one area (Hexa-X-II, 2023) (GSMA, 2024c).<br><br>Land use is how land is used for activities like infrastructure building of base stations, towers, data centres, offices and manufacturing plants and biodiversity preservation (European environmental agency, 2025) (GSMA, 2024e).<br><br>Water use is the extraction and consumption of water domestic, agricultural, industrial and environmental purposes for example it is used in manufacturing and cooling, as well as other operations (NGA, 2024c) (European Environment Agency, 2025). |
| Waste management | Waste management is the supervision of waste production, handling, processing, storage and transport from point of generation to final acceptable point of disposition (Hexa-X-II, 2023). |
| Circularity and material usage | Circularity is the ability of material to stay in use as long as possible through processes like recycling, reuse, refurbishment, maintenance, remanufacture and composting (Ellen MacArthur Foundation, 2025). |
| Enablement | Enablement is the positive impact that is achieved when the use of an ICT solution results in the reduction of greenhouse gas emissions (ITU-T, 2022). |

## 4.1 Monitoring and reporting

Monitoring and reporting are important sustainability activities for companies and other organizations as they present how the organizations make their environmental actions accountable. This includes identification of organization's key environmental sustainability impacts and related and their systematic monitoring. It also includes disclosing this information transparently for relevant stakeholders including customers, investors, regulatory and national authorities to analyse. Companies in particular have several motivations for reporting. Companies report on environmental sustainability to be compliant with regulatory requirements, and risk management. Second, monitoring and reporting are important for setting and managing targets. Net-zero and science-based targets require data collected over time on emissions, energy and other topics of environmental concern. Third, monitoring and reporting are important to increase the confidence of stakeholders, investors, customers and partners.

There are different reporting frameworks that organizations and countries use. The UN SDGs are the global framework for sustainable development that lists 17 goals that UN member states have adopted (United Nations, 2015) and countries report on. These goals aim to end poverty, reduce inequality, generate economic growth and preserve the earth's oceans and forests, among other things.

The Global Reporting Initiative (GRI) is a major standardized framework that companies have used for reporting their organization's sustainability impacts. Under the GRI framework, companies report on GHG emissions, energy consumption, biodiversity, climate change, materials, water and effluents, waste (GRI, 2025).

The European Union Corporate Sustainable Reporting Directive (EU CSRD) and the European - Sustainability Reporting Standards (ESRS) are European level frameworks that certain companies operating within the European Union must report under (European Commission, 2025). Under the EU CSRD, companies must report on environmental standards, social standards and governance standards. Under the environmental standards, companies must report on climate change, pollution, water and marine resources, biodiversity and ecosystems and resource use and circular economy.

Other reporting frameworks include the Taskforce on Nature-related Financial Disclosures (TNFD), which provides recommendations for nature-related disclosures, general requirements and disclosures structured around governance, strategy, risk and impact management, and metrics and targets (TNFD, 2025). Science-based target initiative (SBTi) framework is also used to set verified science-based targets to help mitigate negative environmental effects (Science Based Targets Initiative, 2025). Another reporting framework used is the Carbon Displacement Project (CDP, 2025).

There are also other financial frameworks like the Taskforce on Climate Disclosures (TCFD) which require companies to report on governance, strategy, risk management and metrics for climate-related risks and opportunities (Task Force on Climate-related Financial Disclosures, 2025). The Sustainability Accounting Standards Board (SASB) is also used for reporting on sustainability issues. SASB standards require sustainability-related risks and opportunities that affect the companies' finances to be disclosed (IFRS Foundation, 2025).

## 4.2 Greenhouse Gas (GHG) emissions

Greenhouse gases are gases that trap heat in the atmosphere, creating a greenhouse effect in the atmosphere that causes the earth to heat up, leading to global warming (European Environment Agency, 2025). GHG emissions management is the driver of environmental sustainability mitigation for the mobile sector. The mobile communication sector plays a role in global decarbonization efforts (GSMA, 2023b), while facing growing pressure to reduce its own emissions footprint (GSMA, 2023a). ICT sector accounts for between 1.5% to 4 % of total global emissions in year 2023 (World Bank Group, 2024). In response, the industry is accelerating efforts to de-couple growth from emissions. The Paris Agreement establishes a global objective to limit temperature increase to well below. The Science-Based Targets initiative helps to operationalize the climate objectives by providing a framework for companies to set targets based on climate science that fulfil these objectives.

Accounting for GHG emissions typically follows the GHG Protocol. The GHG Protocol is a global framework for businesses, governments and other entities on how to measure and report their greenhouse gas emissions transparently (GHG Protocol, 2025). Emissions are expressed in metric tons of carbon dioxide equivalent ($tCO_2e$) to cover all the gases including carbon dioxide. The other gases include methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and Sulphur hexafluoride. Emissions are classified into three scopes (GHG Protocol, 2025). Scope 1 emissions are direct emissions linked to company activities (GHG Protocol, 2025). Sources of these emissions include emissions from company fleet, on-site fuel use, refrigerant leakages. Scope 2 emissions are indirect emissions from the purchase of electricity, heating, or cooling (GHG Protocol, 2025). Sources of scope 2 emissions include use of purchased electricity to power data centres, networks, offices and manufacturing facilities. Scope 3 emissions other indirect GHG emissions which are the upstream and downstream emissions from the value chain/supply chain (GHG Protocol, 2025). They are also the largest emissions among the mobile communication sectors' companies (Apple, 2024), (Samsung, 2023), (Telefonica, 2024), (Nokia, 2024), (GSMA, 2023b).

## 4.3 Energy management

Energy management involves reducing energy consumption across networks and devices, while transitioning to renewable sources of energy. Traditionally, energy that powers mobile communication networks has been sourced from fossil fuels like coal, oil and natural gas. Burning these fuels to produce electricity releases carbon dioxide in the atmosphere, contributing to carbon emissions. The more electricity the mobile network consumes, the higher its scope 2 emissions. This makes energy consumption a significant contributor to the environmental footprint of mobile communication networks (European Commission, 2024), (GSMA, 2023b), (Nokia, 2024), (Ericsson, 2024). Energy performance in the mobile sector is measured using energy consumption (MWh), renewable energy share (%/MWh) and energy intensity (MWh/subscriber/revenue/data traffic). The telecommunication industry consumes about 2-3% of global electricity (NGA, 2023a) with projections indicating that adoption of AI will likely more than double the electricity consumption of data centres by 2030 (IEA, 2025).

With increase in GHG emissions linked to climate change, extreme weather events are becoming more common, and several stakeholders have identified this as a risk to network reliability (AT&T, 2024), (MTN, 2024), (Telia, 2024). Energy consumption is key consideration when planning for resilience of mobile communication networks to adverse climate conditions. Mobile communication networks run 24 hours a day, consuming energy throughout the day thus adding to the operating and maintenance costs of operators. Energy consumption is a contributor to the high operating costs of operators presenting between 20% - 40% of the network operating expenditure (GSMA, 2019). Consequently, reductions in energy consumption are financial incentives for the MNOs as well.

Energy consumption reduction is important for the mobile communication sector because reporting on energy consumption and management is required from most major mobile communication ecosystem stakeholders. This includes both MNOs and the vendors. The regulatory frameworks that demand reporting of energy management include the EU CSRD and GRI. Customers also require reporting on energy consumption of their devices and equipment. The MNOs are constantly requiring the TEPs to provide equipment with higher energy efficiency and lower energy consumption. Consumers are also increasingly demanding to know the energy consumption of their devices like mobile phones and laptops.

## 4.4 Biodiversity, land and water usage

The expansion of mobile communication networks increasingly intersects with the natural ecosystem, making biodiversity, land use and water consumption relevant environmental sustainability topics for MNOs and TEPs (Hexa-X-II, 2023). Biodiversity is the variety of living things in an area (Hexa-

X-II, 2023). Land and water usage is the use of land and water resources to manufacture, deploy, and operate networks. Proposed indicators for land include land-use intensity which measures the total area of land used by network infrastructure (China Mobile,2024), (América Móvil, 2023). Water use is mostly significant in data centres and manufacturing processes where efficient cooling and recycling systems are important (Apple, 2024), (Orange, 2025), (Samsung Electronics, 2023), (Telefónica, 2024), (NGA, 2023a). Data centres are out of scope in this study and considered in other VISIIRI project studies. Commonly used indicators for water usage are water consumption ($m^3$/gallons) and water usage effectiveness (WUE). Companies embed environmental impact assessments into site planning before deployment, with some even including mitigation measures (Telefónica, 2024), (Vodafone, 2024). These are reporting frameworks that require companies to disclose their impacts on species, land use, and habitat, along with actions to mitigate and restore ecosystems including the EU CSRD and the TNFD.

## 4.5 Waste management

Waste generated by the mobile communication sector comprises different types of electrical and electronic waste (e-waste), which occurs from e.g., end-user devices, customer premise equipment (CPEs) and network infrastructure (UNITAR, 2024). Additional waste streams include packaging waste from the equipment, hazardous waste like batteries, oils, waste gases from manufacturing and operational or office waste like paper, food waste, solid waste, and plastics. Common metrics for waste management include waste (tons), hazardous waste (tons), non-hazardous waste (tons). In 2022, 62 billion kilograms of e-waste was collected, up from thirty-four billion collected and recycled between 2010 to 2022 (UNITAR, 2024). Deployment of mobile networks uses large quantities of equipment which become obsolete within a few years. Without strong management systems, these materials end up disposed in landfill. Some of the equipment contains hazardous materials/liquid, or they contain valuable material that is lost when landfilled or incinerated, when it can be reused.

Waste management is important to the mobile communication sector because e-waste contains hazardous material that can contaminate the air, soil, water and cause harm to animals and human health. In addition, proper waste management is important for circularity. Waste is a secondary source of materials that can be used in the production of network and other equipment, or in case the waste is not e-waste, recovered, recycled material can be repurposed into other items. Waste management supports climate goals as well. Waste from manufacturing new materials, logistics or disposal processes contributes to GHG emissions.

## 4.6 Circularity and material usage

Circularity aims to keep materials at their highest possible value and for as long as possible along the supply chain (Ellen MacArthur Foundation, 2025). The aim is to avoid the use of natural resources as much as possible. This is especially important for critical raw materials (CRM) that are considered highly susceptible to supply chain disruption because they are critical to telecommunication, transport, ICT, and security sectors (European Commission, 2020). Common metrics used include expected lifetime (years), recycled devices/content (tons), repaired devices (tons) and reused devices (tons). Others include raw material depletion (tons) and waste heat recovery (MWh).

Circularity and material use also address the e-waste challenge by promoting treatment of e-waste by reusing, repairing, refurbishing, and recycling (European Commission, 2020) (European Commission, 2020). They also help to reduce pollution by reducing landfill waste. Once salvageable waste is further processed, the residual waste can be incinerated in controlled environments and the heat produced can be used for generating district heating, an approach known as waste-to-heat.

Circularity and material use can contribute to extending lifetime of equipment and materials. To reduce amount of waste taken to landfills, equipment that is at end-of-life can be repaired or refurbished and reused, or they can be broken down for individual parts which can be recycled. In the mobile communication sector, circularity is an opportunity to build resilient supply chains, reduce operational costs, add income streams through new business opportunities, and align with global sustainability goals. Collaboration within the supply chains can improve the circularity of material and reduce waste.

## 4.7 Enablement

Enablement refers to the use of ICT solutions to reduce environmental impacts outside its own value chain (ITU-T, 2022). It is commonly described as the environmental handprint of the ICT sector which comes from the use of the ICT solutions outside the ICT sector. The environmental handprint can be quantified through estimates of avoided emissions from the use of mobile communication solutions. GeSI estimates indicate that ICT can enable a 20% reduction of global $CO_2$ emissions by 2030, especially in transport, energy, and agriculture (GeSI, 2015).

The mobile communication sector has been shown to help decarbonize other sectors (GSMA, 2019b). When reporting on enablement, the mobile communication sector has focused on using mobile connectivity, IoT solutions, 5G, AI/ML and other digital services and technologies in supporting businesses, governments, utilities and consumers to reduce their GHG emissions and energy consumption, to optimize use of their resources and to maximize their handprint. Mobile

communications in 2018 was claimed to have enabled a reduction of 1.44 billion MWh of electricity and gas, and 521 billion litres of fuel globally in (GSMA, 2019b). This illustrates the potential environmental handprint of mobile communication technologies. Enablement also supports sustainable consumer and organizational behaviours like remote working, digital collaboration, telemedicine, virtual learning, smart-mobility systems through digitization. All these can help to reduce travel-related emissions and resource consumption, which in turn can help with decarbonization (V. Teamers, 2023)

In (GSMA, 2023f), among the key findings is the need for rapid decarbonization of global economy to avoid climate catastrophe. While the mobile sector has achieved improvements in energy efficiency, the rapid expansion of the digital economy due to cloud computing, AI, and data-intensive applications continue to increase energy demand. This results in a situation where efficiency gains are offset by the growing digital footprint. This makes enablement a strategic tool that interacts with all the key environmental topics discussed in this report. Different stakeholders have their roles to play in make the enablement effect possible. TEPs will need design and produce sustainable solutions that are used in different sectors for creating the enablement effects. MNOs deploy mobile communication networks to provide connectivity which is used in other sectors for the enablement effects. Finally, industry forums bring stakeholders together to develop enablement solutions and define frameworks and metrics supporting this development.

# 5

# Mobile network operators (MNOs)

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# 5 Mobile network operators (MNOs)

Mobile network operators (MNOs) build, operate and maintain the mobile communication infrastructure that enables mobile communication services. This infrastructure includes radio towers, base stations, fibre-optic and microwave backbones and data centres, all of which help to deliver voice, text and high-speed data services to subscribers worldwide and custom solutions to enterprises. As a result of the scale of their operations, MNOs acknowledge that environmental sustainability is of strategic importance to their operations. Some operators identify climate-related disruptions like extreme weather events as threats to reliable service. This is important because mobile communication networks are considered critical infrastructure by most governments due to their importance to national economies, social significance and digitalization of services, including services offered by governments.

Energy expenditure can account for as much as 20% of MNOs' operating costs, as reported by one MNO, implying the importance of energy consumption reduction efforts (Telefónica, 2024). MNOs also consider energy consumption reductions as improvements in business opportunities (Telefónica, 2024), further demonstrating why environmental sustainability is a concern due to associated financial costs. MNOs consider aiming at "environmental leadership" increasingly important to company's reputation, investor confidence and innovation. MNOs position their environmental sustainability programs as drivers of brand value and competitive edge improvement. Initiatives such as circular economy integration, energy efficiency and eco-design of equipment are highlighted as environmental sustainability requirements as well as a means of building customer trust, operational resilience and innovation (Telefónica, 2024).

MNOs are driven by regulatory requirements to monitor and report on environmental sustainability. MNOs are subject to national, regional and global laws and standards such as the CSRD in Europe, and other reporting frameworks like the GRI, CDP, etc. Thus, MNOs are driven to act to mitigate their environmental footprint. On the other hand, mobile communication networks are merging as drivers of enablement for other sectors. MNOs recognize this and as such, they also report on the handprint effect on how their networks and solutions help other sectors become more efficient while decarbonizing them. MNO company reports used in this study are shown in Table 5.1.

Table 5.1: MNO company reports on sustainability used in the study.

| Company | Report | Year |
|---|---|---|
| American Movil | AM Sustainability Enabling a better world Sustainability Report 2023, (América Móvil, 2023) | 2023 |
| AT&T | Connecting people to greater possibility 2024 Sustainability update 2024, (AT&T, 2024) | 2024 |
| Bharti Airtel | Customer driven digitally driven Integrated Report and Annual Financial Statements 2023-24, (Bharti Airtel, 2024) | 2023-2024 |
| China Mobile | 2024 Sustainability Report Sharing AI+ Driving Innovative Growth, (China Mobile,2024) | 2024 |
| China Telecom | Create a better future with digital technologies Sustainability report 2024 (ESG), (China Telecom, 2024) | 2024 |
| Grameenphone | Sustainability Report 2024 Our commitment towards a sustainable future, (Grameenphone, 2024) | 2024 |
| MTN | Doing for tomorrow today Sustainability report for the year ended 31 Dec 2024, (MTN,2024) | 2024 |
| MTS | Annual Report 2023, (MTS, 2023) | 2023 |
| NTT DOCOMO | NTT DOCOMO Group Sustainability report 2024, (NTT DOCOMO, 2024) | 2024 |
| Ooredoo | Inspiring action today for a sustainable tomorrow ESG Report 2023, (Ooredoo, 2024) | 2023 |
| Orange | Now 2024-2025 Integrated Annual Report, (Orange, 2025) | 2024 |
| Telefonica | Telefonica Consolidated management report 2024, (Telefónica, 2024) | 2024 |
| Telia | Annual Report 2024, (Telia, 2024) | 2024 |
| Telkomsel | Building Sustainable Business, Winning the Hearts of Indonesians 2024 Sustainability Report, (Telkomsel, 2024) | 2024 |
| T-mobile | Forward Together Connectivity with Purpose 2023 Corporate Responsibility Report, (T-Mobile, 2023) | 2023 |
| Verizon | Verizon ESG Report 2023, (V. Teamers, 2023) | 2023 |
| Vodafone | Vodafone Group PLC Annual Report 2024, (Vodafone, 2024) | 2024 |

Monitoring and reporting are essential for environmental management as they provide information that shows progress being made or gains being eroded regarding the efforts of the company. In telecoms, this means systematically tracking GHG emissions, energy, water, waste and circularity. For MNOs, monitoring and reporting are essential for environmental management as they provide information that shows progress being made or gains being eroded regarding the efforts of the company. MNOs identify several reasons for their monitoring and reporting practices. One reason is that reporting is a regulatory requirement. This is usually required by investors, customers, and

national, regional or even global requirements. Reporting provides transparency, accountability and data required to manage environmental impacts, and at the same time to demonstrate progress.

MNOs are increasingly aligning their reporting to recognized reporting frameworks. The most widely adopted reporting framework is the Global Reporting initiative (GRI). The SASB standard is used by Bharti Airtel, AT&T and Orange. The TCFD helps to report climate risk and has been used Bharti Airtel, Telefonica, AT&T, Orange, China Mobile, and China Telecom. The SBTi is used to set environmental based targets that will help reduce emissions and is used by Bharti Airtel, Telefonica, Orange, AT&T, China Mobile. Bharti Airtel, Telefonica, Orange, AT&T and China Telecom use the CDP framework. EU based MNOs like Telefonica, Orange and Vodafone, are required to report under the CSRD and the ESRS. All the MNOs reference the UN SDGs framework even though reporting on SDGs is conducted by governments. China Mobile, China Telecom, MTN and Bharti Airtel also comply with national ESG reporting requirements and local stock-exchange rules. It is common for a company to report under various reporting frameworks.

## 5.1 MNOs' GHG emissions reduction activities

MNOs recognize GHG emissions as one of their environmental impacts due to the energy-intensive nature of mobile networks, data transmission, data centres and all supporting infrastructure. As a result, GHG emissions management is one of MNOs environmental strategies in their effort to reduce their environmental impact. MNOs have adopted a wide range of activities to manage and reduce GHG emissions across their operations as shown in Table 5.2. MNOs manage emissions from their own operations as well as impact their supply chain by requiring environmental sustainability enhancements.

One major area of focus is shifting away from using diesel generators to using grid electricity, reducing emissions from fuel combustion. Efforts are also made to decarbonize MNOs' data centres by moving to the cloud and virtualizing infrastructure, using high efficiency cooling systems, using efficient rectifiers, and other solutions that reduce energy use. There are also significant emissions from logistics and transport solutions used by MNOs. This may mean for transport solutions, instead of using a normal fleet, they change to electric fleet, or switch from using fossil fuel to non-fossil fuel. Maintaining the fleet operates at optimum level also helps reduce operational emissions. Other interventions include providing electrical charging stations for new employees. Companies can also reduce emissions from the built environments they operate in. For example, switching to Light Emitting Diode (LED) lights, installing motion centres using low Volatile Organic Compounds (VOC) materials. Other measures include replacing boilers with electric heat pumps and using water-saving fixtures and sustainable construction practices.

The use of digital and smart solutions to improve operational efficiency is increasingly being leveraged. Energy Management Systems, IoT systems, AI-driven site management platforms and other such solutions help MNOs and their customers monitor and optimize energy use. Beyond their own operations, MNOs also help their value chain to reduce emissions. They do this by helping their suppliers set net science-based targets, encourage green procuring processes. They also collaborate with other partners to reduce emissions, for example, by engaging in infrastructure sharing and other carbon management strategies. Also, some MNOs engage the community energy management, MNOs also mobilize to acquire funds to finance various environmental initiatives including carbon sinks.

Table 5.2 GHG emission reduction activities and indicators reported by MNOs.

| Activities | Indicators | Sources |
|---|---|---|
| Reducing carbon emissions in sites. | scope 1 emissions ($tCO_2e$) | (Ooredoo, 2024) |
| Decarbonize data centre infrastructure by virtualizing infrastructure and migrating to cloud, setting up green data centres, using more efficient rectifiers, replacing older cooling equipment with energy-efficient ones, using free cooling and immersion cooling, deploying ACs with energy-friendly gases, using cold-aisle and hot-aisle containment, relocating heat-generating equipment outdoors, optimizing cooling systems using AI, using fresh-air cooling systems, use cooling towers and HVAC optimization for water efficiency. | scope 1 emissions ($tCO_2e$) | (América Móvil, 2023), (Telefónica, 2024), (Ooredoo, 2024), (V. Teamers, 2023) |
| Reduce transport emissions by transitioning to low-carbon fleet and mobility solutions by replacing gasoline vehicles with EVs, switching from diesel to non-fossil fuels, maintaining engines for optimal performance, using non-fossil fuels for generators, and supporting low-emission commuting with EV charging and shower stations for staff who bike. | Scope 1 emissions, Scope 3 emissions (tCO2e) | (AT&T, 2024), (NTT DOCOMO, 2024), (Ooredoo, 2024), (Telkomsel, 2024), (V. Teamers, 2023), (Vodafone, 2024) |
| Lower emissions from built environment by switching to LED lights, motion sensors, environmentally friendly furnishings, low-VOC paints, fitting water-saving fixtures, replacing oil-and-gas-fired boilers with heat pumps, using energy-efficient motors, deploying cooling towers | scope 3 emissions ($tCO_2e$) | (Bharti Airtel, 2024), (Ooredoo, 2024), (Telkomsel, 2024), (V. Teamers, 2023) |

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| and heat-soaked laminated glass to manage thermal loads, use recycled and reusable materials for constructing buildings. . | | |
| Leverage smart management technologies to improve operational efficiency and energy management by deploying Energy Management Systems for energy control, research AI based intelligent site management, deploying IoT sensor networks for building control, making customer management systems accessible via mobile phones and tablet. | scope 3 emissions ($tCO_2e$) | (China Mobile,2024), (NTT DOCOMO, 2024), (T-Mobile, 2023), (Telkomsel, 2024), (V. Teamers, 2023), (Vodafone, 2024) |
| Strengthen climate action through supply chain and stakeholder collaboration by encouraging suppliers to set emission reduction goals, promote green procurement and prioritize low-carbon technologies, collaborating with other industry players in infrastructure sharing, collaborating with communities on energy management, collaborate across regions, departments on carbon management, endorse activities (China Mobile,2024), (Bharti Airtel, 2024), (NTT DOCOMO, 2024), (Telefónica, 2024). | scope 3 emissions ($tCO_2e$) | (China Mobile,2024), (Bharti Airtel, 2024), (NTT DOCOMO, 2024), (Telefónica, 2024), (Telia, 2024) |
| Mobilize green financing to support various environmental initiatives including carbon sink projects. | funds availability (currency) | (China Mobile,2024), (Orange, 2025), (Telefónica, 2024), (V. Teamers, 2023), (Telkomsel, 2024), (Telia, 2024), |
| Strengthen environmental accountability by recording, monitoring and reporting on environmental effects. | water consumption ($m^3$), GHG emissions ($tCO_2e$), energy consumption (MWh) | (América Móvil, 2023), (AT&T, 2024), (MTN, 2024), (T-Mobile, 2023), (Telefónica, 2024), (V. Teamers, 2023) |

## 5.2 MNOs' energy management activities

Energy use directly affects cost, emissions and operations of MNOs. The transition to 5G and increased data traffic have increased energy use, hence the need to optimize amount of energy being used. Use of electricity to run the networks account for most of the energy use for MNOs, (China Mobile,2024), (AT&T, 2024), (Orange, 2025), (Telefónica, 2024), (Vodafone, 2024) with the radio access network (RAN) consuming the most. MNOs recognize that energy is one of their major operating expenses and a source of emissions, thus making consumption reductions essential from financial and environmental perspectives. Table 5.3 summarizes MNOs energy management activities.

A prominent area of focus is renewable energy and alternative energy sources. MNOs are integrating renewable energy into their base station sites, data centres and corporate facilities by installing photovoltaic and wind systems on site or purchasing renewable electricity. Other MNOs also explore alternative fuel options like hydrogenated fuel oil, methanol fuels and incorporating sodium-ion batteries for cleaner backup power and storage.

MNOs are modernizing their networks and infrastructure to improve energy efficiency and reduce energy consumption. They do this by phasing out legacy equipment like 2G and 3G, and copper lines, they deploy low-energy hardware and implement dynamic shutdown features. MNOs are also using technologies like AI/ML and smart metering to monitor and manage energy use in real time and using green software design to minimize energy consumption. They are also investing in reducing energy use in their facilities by using LED lighting, motion sensors, efficient heating and cooling systems, and encouraging changes like allowing hybrid work arrangements.

MNOs are also sharing physical sites with partners. MNOs also involve their supply chains in energy management initiatives by encouraging them to switch to renewable energy and to adopt low-carbon practices. They also ensure they meet green procurement requirements. MNOs also emphasize monitoring environmental performance, and report transparently on energy consumption, emissions and water use, in alignment with recognized reporting standards.

Table 5.3 Energy management activities and indicators reported by MNOs.

| Activities | Indicators | Sources |
|---|---|---|
| Integrate renewable and alternative energy solutions in buildings, sites, data centres by using photovoltaic and wind energy systems, purchasing renewable energy supply agreements like PPAs, EACs, Guarantees of Origin and REPAs, and adopting alternative energy solutions like | renewable energy consumption (MWh) | (América Móvil, 2023), (China Mobile,2024), (Bharti Airtel, 2024), (AT&T, 2024), (China Telecom, 2024), (Orange, 2025), (Grameenphone, 2024), |

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|---|---|---|
| researching switching to biofuels like hydrogenated vegetable oil, increasing natural gas use, using hydrogen and methanol fuels, implementing light hydrogen storage systems, testing hydrogen fuel cell technology, planning to use batteries like sodium-ion batteries, lithium-ion and VRLA batteries. | | (Telefónica, 2024), (Telkomsel, 2024), (Telia, 2024), (V. Teamers, 2023), (Vodafone, 2024) |
| Advance energy optimization across digital infrastructure by modernizing physical networks—deploying low-power equipment and 5G systems, retiring legacy technologies, minimizing redundant builds, and implementing intelligent shutdown features—and by leveraging digital solutions such as AI/ML analytics, smart meters, and sustainable software to manage consumption, refine energy standards, and develop high-efficiency, low-impact technologies for future networks. | energy efficiency (%), energy consumption (MWh), (network) energy intensity (MWh/PB or kWh per subscription) | (América Móvil, 2023), (China Mobile,2024), (Bharti Airtel, 2024), (AT&T, 2024), (China Telecom, 2024), (Orange, 2025), (NTT DOCOMO, 2024), (T-Mobile, 2023), (Telefónica, 2024), (V. Teamers, 2023), (Telkomsel, 2024), (Vodafone, 2024) |
| Lower energy demand in built environments by allowing hybrid working, using cold-aisle containment in data centres, LEDs motion sensors, modernize networks and data centres, simplifying network topology, equipment and machinery rooms. | energy consumption (MWh), (network) energy intensity (MWh/PB or kWh per subscription), Data Centre Efficiency, (PUE) | (China Mobile,2024), (Bharti Airtel, 2024), (NTT DOCOMO, 2024), (Ooredoo, 2024), (T-Mobile, 2023), (V. Teamers, 2023), (Telkomsel, 2024) |
| Optimize energy performance across network infrastructure by deploying modern energy-saving equipment and 5G networks, decommissioning legacy technologies such as 2G/3G and copper systems, minimizing duplicate 4G/5G construction, and dismantling, reallocating, and reusing existing equipment, implementing sleep and standby features, using AI/ML for auto shutdown, implementing auto-resource deactivation | energy efficiency (%), energy consumption (MWh), network energy intensity (MWh/PB or kWh per subscription) | (América Móvil, 2023), (China Mobile,2024), (Bharti Airtel, 2024), (AT&T, 2024), (China Telecom, 2024), (Orange, 2025), (NTT DOCOMO, 2024), (T-Mobile, 2023), (América Móvil, 2023), (Telia, 2024) |

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|---|---|---|
| during non-peak hours, implementing green base stations, sharing sites with partners. | | |
| Engage suppliers and supply chain on energy management by implementing green supply chain practices, engaging them on sourcing renewable energy and low-carbon operations. | renewable energy management (MWh), energy consumption (MWh) | (China Mobile, 2024), (AT&T, 2024), (Telia, 2024) |
| Deploying software and digital solutions for energy optimization and managing consumption by using smart meters and AI/ML analytics for energy data management, updating and refining standards for green and low-carbon energy technologies, researching 6G air interface energy-saving and networking technologies, developing and deploying high-efficiency, low-power technologies (e.g. green smartphones). | energy efficiency (%), energy consumption (MWh) | (China Mobile, 2024), (Orange, 2025), (V. Teamers, 2023), (AT&T, 2024), (Telkomsel, 2024), (Vodafone, 2024), (Bharti Airtel, 2024) |
| Strengthen environmental accountability by recording, monitoring and reporting on environmental effects. | water consumption ($m^3$), GHG emissions ($tCO_2e$), energy consumption (MWh) | (América Móvil, 2023), (AT&T, 2024), (MTN, 2024), (T-Mobile, 2023), (Telefónica, 2024), (V. Teamers, 2023) |

## 5.3 MNOs' biodiversity, land, and water conservation activities

MNOs acknowledge that their operations influence the natural environment and natural resources around their operations, including biodiversity, land and water. Table 5.4 summarizes the activities of MNOs regarding biodiversity, land and water conservation. One major area of focus is biodiversity conservation. MNOs take part in hands-on conservation efforts like planting trees and restoring native ecosystems. They combine it with educational outreach to raise awareness and encourage community MNOs also participation.

MNOs also work to reduce the environmental impact of their facilities and transportation options. They do this by reducing waste to the environment and increasing recycling rates. Other activities include safeguarding water resources by introducing renewable water sources like harvested

rainwater, recycling water for gardening and sanitation and avoiding unnecessary washing activities. MNOs also engage employees and local communities on water preservation through educational material or partnering with conservation organizations.

Table 5.4 Biodiversity, land, and water conservation activities and indicators reported by MNOs.

| Activities | Indicators | Sources |
|---|---|---|
| Support environmental stewardship by combining hands-on conservation efforts with education and outreach e.g. planting trees, restoring biodiversity projects, partnering with environmental organizations to raise awareness about environmental issues, align with national and international biodiversity goals and participate in biodiversity preservation activities, sharing educational content on environmental issues, educate population on conscious consumption. | people attending event (number of people), plant trees (number of trees planted or area of planted trees in $km^2$), preserved biodiversity (number of species or number of species per acre/square kilometre) | (América Móvil, 2023), (NTT DOCOMO, 2024), (Ooredoo, 2024), (MTS, 2023) |
| Manage resources responsibly to reduce environmental impact by increasing recycling rates, optimizing waste disposal and minimizing waste. | recycling rate (%) | (Telkomsel, 2024) |
| Introduce renewable water sources by harvesting rainwater, integrating desalination techniques or recycling used water for gardening and cleaning windows and conserve water by discharging responsibly, not washing company fleet on company premises, using rainwater to landscape and toilet flushing. | water consumption ($m^3$) | (Bharti Airtel, 2024), (NTT DOCOMO, 2024), (Ooredoo, 2024), (Telkomsel, 2024) |
| Deploy intelligent environmental management systems to monitor and manage marine life, forests, birds and animal species, pollution in water catchment areas and wildlife near human settlements. | area ($km^2$), preserved biodiversity (number of species) | (China Mobile,2024) |
| Raise awareness on water conservation through partnerships by educating employees on water conservation, | awareness activities (number of participants), | (América Móvil, 2023), (Bharti Airtel, 2024), (MTN, 2024), |

| | | |
|---|---|---|
| developing signage promoting responsible water use, partnering with conservation organizations to protect aquatic and fund projects to improve access to clean safe water for the community ecosystems. | protection initiatives developed, water consumption ($m^3$), funds for projects (USD) | (NTT DOCOMO, 2024) |
| Strengthen environmental accountability by recording, monitoring and reporting on environmental effects. | water consumption ($m^3$), GHG emissions ($tCO_2e$), energy consumption (MWh) | (América Móvil, 2023), (AT&T, 2024), (MTN, 2024), (T-Mobile, 2023), (Telefónica, 2024), (V. Teamers, 2023) |

## 5.4 MNOs' waste management activities

The MNOs spend efforts towards mitigating their waste focusing on minimizing waste production and promoting sustainable digital practices internally and externally. A summary of these activities is presented in Table 5.5. Minimizing waste across company operations includes activities like reducing packaging of their CPEs, unbundling wall chargers from devices on sale to prevent distribution of unnecessary accessories and organizing collection campaigns for equipment to treat them to extend their lifetime. Additional efforts include collecting, eliminating single-use plastics and reducing industrial waste from business operations.

MNOs also reduce waste by promoting digital practices like digitizing meeting documentation, promoting paperless meetings, and using digital displays for signage instead of paper. Other complimentary efforts include providing digital product start guides, switching to paperless billing of customers and paying via bank transfers instead of cheques, and so on. The above efforts help reduce amount of waste produced by companies.

Table 5.5 Waste management activities and indicators reported by MNOs

| Activities | Indicators | Sources |
|---|---|---|
| Minimize waste across operations by reducing packaging of CPEs, unbundling wall chargers from device purchases, running collection campaigns for used equipment, diverting waste from landfill to be treated in attempt to extend their life, eliminating use of single-use plastic, reducing industrial waste from business activities like plastics. | waste (tons) | (América Móvil, 2023), (Bharti Airtel, 2024), (AT&T, 2024), (Orange, 2025), (NTT DOCOMO, 2024), T-Mobile, |

| | | |
|---|---|---|
| | | 2023), (V. Teamers, 2023), (Telkomsel, 2024), (Vodafone, 2024) |
| Strengthen environmental performance by implementing waste and energy management systems, and establishing robust MRV (Monitoring, Reporting, and Verification) frameworks to support carbon control, emissions tracking, and internal carbon trading. | waste (tons), ghg emissions (tCO2e), energy consumption (MWh), energy efficiency (%) | (Ooredoo, 2024) |
| Promote digital work life practices e.g. digitizing internal meeting documents, promoting paperless meetings, using digital signage for advertising, encouraging customers to pay bills via bank transfer instead of by post, providing phone start guides, product use and maintenance guidelines on company websites, communicating individual paper use to encourage people to use less paper, switch from paper to digital communication. | waste (tons), raw material depletion (tons) | (T-Mobile, 2023), (NTT DOCOMO, 2024) |

## 5.5 MNOs' circularity and material usage activities

MNOs have adopted circular practices to reduce environmental impact of their products and services, to conserve resources and to extend the lifecycle of materials and equipment. The activities of MNOs that target circularity and material use are shown in Table 5.6. MNOs are doing this by encouraging design of products that are circular, by circular treatment of equipment after decommissioning and by collaborating with industry stakeholders to promote circularity. Designing products and solutions with circular principles means MNOs encourage product designs that incorporate environmental considerations like using environmentally friendly material to manufacture CPEs, reducing use of plastic on packaging, designing devices with lower volumes and improved recyclability. In addition, they encourage recycled and eco-certified materials for components and packaging. They also design energy-efficient and longer-lasting products.

When it comes to treatment of materials, equipment and other waste including e-waste, the treatment methods include recycling, repairing, refurbishing and repurposing the waste and materials. Other complimentary practices include encouraging employees to reuse company-issued devices, selling refurbished phones and CPEs. Recovered tarps from advertisements are also repurposed, for example, into tents that are used by refugees.

Finally, MNOs collaborate with other stakeholders to enhance circularity. They encourage their supply chain to use circular methods in their processes. Other activities include endorsing frameworks promoted by industry forums like GSMA.

Table 5.6 Circularity and material usage activities and indicators reported by MNOs

| Activities | Indicators | Sources |
|---|---|---|
| Design products and solutions with environmental consideration e.g. designing environmentally friendly CPEs, minimizing packaging impact by reducing plastic use, redesign equipment to lower packaging volume, use environmentally friendly and recycled materials, eliminate single -use plastic, use recycled content for shipping cartons, design energy-efficient products to extend life. | energy consumption (MWh), energy efficiency (%), waste (tons), raw material depletion (tons), expected lifetime (years), reused products (tons), repaired product (tons), refurbished products (tons), recycled content (%), remanufactured product (tons), GHG emissions ($tCO_2e$), waste (tons) | (Telefónica, 2024), (MTN, 2024), (América Móvil, 2023), (China Mobile,2024), (Vodafone, 2024), (V. Teamers, 2023), (Orange, 2025), (AT&T, 2024) |
| Extend lifecycle of materials, equipment and e-waste by implementing practices such as recycling, repairing, reusing, refurbishing and repurposing for instance, allowing employees to reuse mobile phones, selling refurbished phones and equipment, reusing CPEs and network equipment, recycle plastic from network equipment, reusing billboard materials e.g. repurposing tarps into tents for refugees, recycling discarded sim-cards into other products, recovering precious metals, glass, etc. and selling them to authorized recyclers. | recycled devices (tons), repaired devices (tons), reused devices (tons), refurbished devices (tons), remanufactured devices (tons), repurpose devices (tons) | (América Móvil, 2023), (China Mobile,2024), (Bharti Airtel, 2024), (AT&T, 2024), (MTN, 2024), (NTT DOCOMO, 2024), (T-Mobile, 2023), (Telefónica, 2024), (V. Teamers, 2023), (Vodafone, 2024), (Telkomsel, 2024) |
| Collaborate with industry stakeholders to promote circularity and also by endorsing activities suggested by GSMA. | GSMA activities being endorsed | (NTT DOCOMO, 2024) |

| | | |
|---|---|---|
| Encourage eco-rating of products to allow consumers to understand the environmental impact of their devices. | number of products with eco-rating label | (América Móvil, 2023), (Vodafone, 2024) |
| Strengthen environmental accountability by recording, monitoring and reporting on environmental effect. | water consumption ($m^3$), GHG emissions ($tCO_2e$), energy consumption (MWh) | (América Móvil, 2023), (AT&T, 2024), (MTN, 2024), (T-Mobile, 2023), (Telefónica, 2024), (V. Teamers, 2023) |

## 5.6 MNOs' enablement activities

The environmental topics discussed above including GHG emissions, energy management, biodiversity, land and water use, waste and circularity, and material use, describe activities that MNOs focus on to reduce their own environmental footprint. Enablement on the other hand describes activities that MNOs carry out to facilitate environmental sustainability and decarbonization across other sectors by using their network infrastructure and specialized services providing handprint. One example of enablement is the use of mobile communication networks and other infrastructure to monitor the environment. By using complimentary digital technologies, it is possible to develop various systems to monitor and react to environmental sustainability challenges including early warning weather systems. Mobile communication networks can also help support sorting of waste and tracing its origin. Big data, 5G and AI have been combined to help protect river basins for illegal construction and fire monitoring, cloud-based solutions help trace pollution sources, and give environmental warnings.

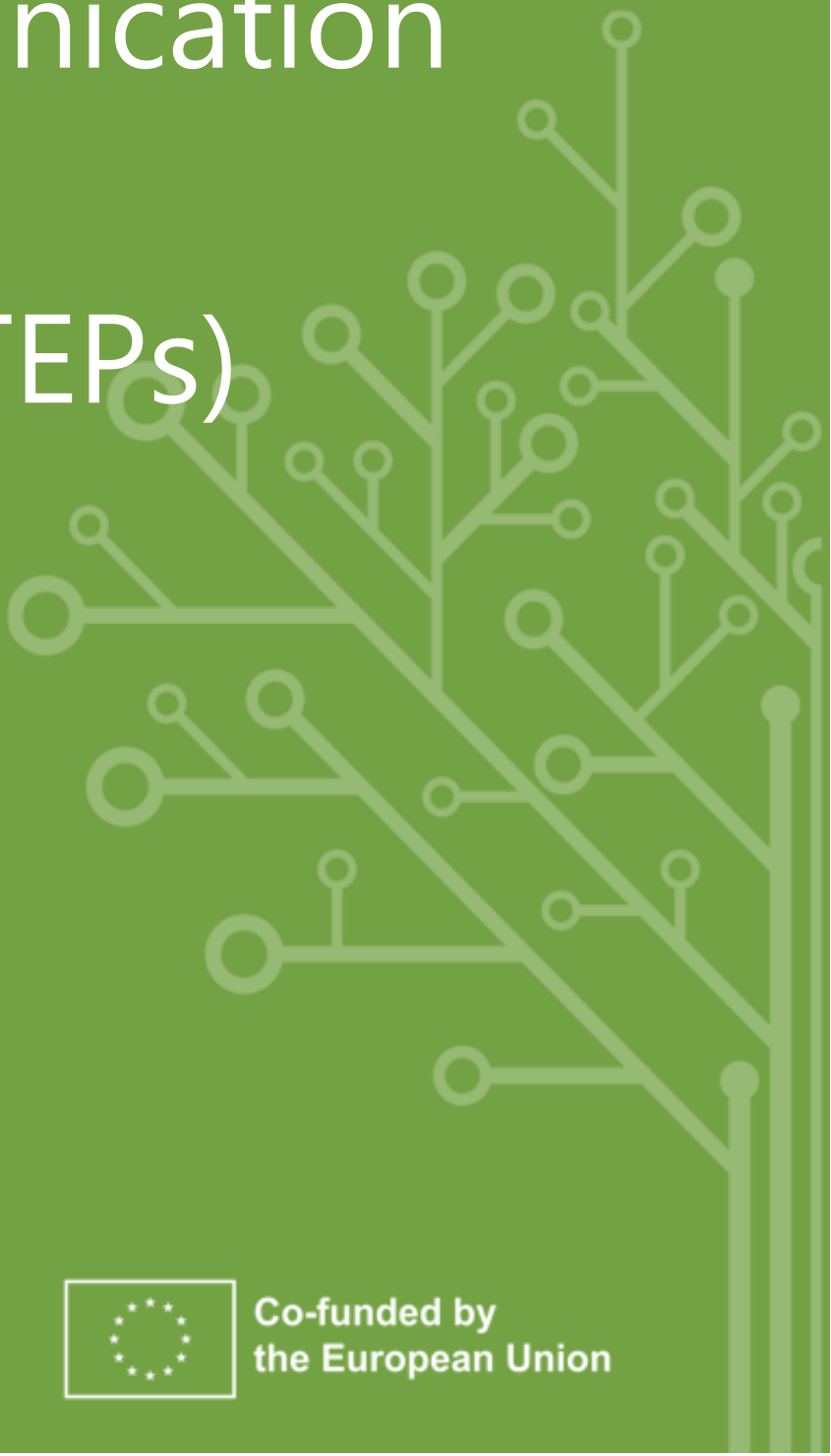
Similarly, MNOs use networks to provide different sectors of society (so called verticals) with solutions that help improve efficiency of their operations and reduce GHG emissions. For example, mobile communication networks can help the health sector with remote monitoring of patients and provide educational content in education and health sectors. Mobile communication networks also enable smart city solutions like intelligent lighting, traffic management, parking optimization and other solutions like smart meters, electric vehicle charging, enable remote working. Enablement requires extensive network coverage, which requires that the MNOs build networks in versatile areas. Enablement can also include specialized solutions to expand communication in critical communication situations, or when providing individual users improved connections in their homes, allowing the respective entities to be more efficient in their activities.

Table 5.7 Enablement activities and indicators for sustainability reported by MNOs

| Activities | Indicators | Sources |
|---|---|---|
| Harness mobile communication networks to drive emissions reduction across all industries e.g. using mobile networks in healthcare to monitor and evaluate patients remotely, provide smart city solutions, offer green digital solutions like smart meters, fleet management, EV charging, logistics, provide access to high quality education content, analytics and cloud services to provide smart farming services like monitoring soil moisture and water balance. | GHG emissions ($tCO_2e$) | (Telia, 2024) |
| Strengthen environmental monitoring and protection by leveraging digital networks and AI to support waste sorting and traceability, develop early warning systems using satellite data, monitor ecological risks such as illegal construction and fires, build MRV mechanisms for carbon control and trading, enable cross-regional collaborative carbon management, and deploy cloud-based platforms for atmospheric analysis, targeted pollution tracing, and intelligent command and dispatch, using climate aligned products and services', help in weather forecasting. | GHG emissions ($tCO_2e$) | (China Mobile, 2024), (MTN, 2024) |
| Expand digital access by expanding mobile network coverage in remote and forested regions, enabling self-installation of home internet to improve access, and supporting remote work and smart home solutions through enhanced mobile communication infrastructure. Expands mobile coverage for critical communication customers, convert copper DSL to fibre network. | GHG emissions ($tCO_2e$) | (América Móvil, 2023), (MTN, 2024), (V. Teamers, 2023) |
| Strengthening environmental performance by implementing waste and energy management systems, and establishing robust MRV (Monitoring, Reporting, and Verification) frameworks. | waste (tons), GHG emissions ($tCO_2e$), energy consumption (MWh), energy efficiency (%) | (Ooredoo, 2024) |

# 6

# Telecommunication Equipment Providers (TEPs)



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# 6 Telecommunication equipment providers (TEPs)

Telecommunication Equipment Providers (TEPs) supply the hardware and software solutions that enable mobile connectivity through the mobile communication networks. While their offerings provide connectivity and enablement effects, they contribute significantly to environmental footprint through e.g., GHG emissions and resource consumption from manufacturing processes and complex supply chains. This study has investigated the environmental sustainability activities of the following leading international TEPs: Apple, Cisco, Ericsson, Huawei, Nokia, and Samsung, using the reports shown in Table 6.1.

Table 6.1 TEPs' reports on sustainability used in the study.

| TEP | Report | Year |
|---|---|---|
| Apple | Environmental Progress Report, (Apple, 2024) | 2023 |
| Cisco | The power of purpose FY23 Purpose Report, (Cisco, 2023) | 2023 |
| Ericsson | Sustainability and corporate responsibility report Annual report 2024, (Ericsson, 2024) | 2024 |
| Huawei | Huawei Consumer Business Sustainability Progress Report 2023-2024, (Huawei, 2024) | 2023-2024 |
| Nokia | Nokia 2023 Sustainability Statement, (Nokia, 2024) | 2024 |
| Samsung | A journey towards a sustainable future Samsung Electronics Sustainability Report 2023, (Samsung Electronics, 2023) | 2023 |

TEPs activities span the entire lifecycle of their products-from extraction of materials through manufacturing and logistics, their use to end-of-life. TEPs therefore have an influence on scope 3 emissions of the mobile sector, in addition to scopes 1 and 2. Environmental sustainability is important for risk management and compliance with TEPs. TEPs report alignment with EU CSRD and ESRS frameworks, and they also report integrating climate-risk management and disclosure into their governance structure. Some TEP reports that its SBTi targets guide operations and product decisions. Monitoring and reporting ensure that the strategies employed by TEPs are measured, recorded, and reported transparently. This ensures accountability to a company's stakeholders, regulatory authorities, and other authorities. For TEPs, monitoring and reporting includes maintaining a list of banned and regulated substances and materials. TEPs monitor and report on their environmental sustainability performance for several reasons. One reason is to meet regulatory compliance. Some regulations that are mandatory for reporting include the EU CSRD, international frameworks like the GRI, CDP and TCFD.

TEPs also monitor and report to build trust and credibility with their customers, suppliers and investors, and they also monitor to track their environmental sustainability handprint and footprint.

TEPs consider energy use a factor in their operating costs, especially as a customer priority due to related energy costs. Electricity costs are a major component of network-operating expenses and the use of products is a major source for total GHG emissions (Nokia, 2024). TEPs claim that high-efficiency production and low-power components reduce both emissions and operational costs (Samsung Electronics, 2023). A TEP reports that energy costs form a significant share of their operating expenses at their manufacturing sites (Huawei, 2024) while another TEP (Cisco, 2023) links energy efficiency programs of their facilities directly to cost savings. TEPs consider environmental sustainability to be important for improving energy performance, which mitigates emissions and therefore lowers operating costs.

For TEPs, environmental sustainability topics like material sourcing, recycling and circular design are considered of strategic importance. In (Nokia, 2024) and (Apple, 2024), the TEPs commit to the responsible sourcing of rare-earth elements and conflict-free minerals, while (Samsung Electronics, 2023) and (Huawei, 2024) highlight that they recover materials from used devices. One vendor also notes that supplier environmental audits are part of its due diligence process. This shows the importance of sustainability to the supply chain.

TEPs also demonstrate that sustainability drives product innovation. 5G and future 6G solutions are increasingly designed with sustainability principles, focusing on modularity, repairability and recyclability. Companies (Apple, 2024), (Nokia, 2024), (Samsung Electronics, 2023), (Ericsson, 2024) integrate energy efficiency, modularity, recyclable design and lifecycle assessment into their products. For TEPS, the seven environmental topics are important for compliance with regulation and risk management. They also drive innovation, which designs products that are more energy-efficient and circular. They are additionally important because they help sustain their supply chains, which are important for business continuity.

## 6.1 TEPs' GHG emissions reduction activities

TEPs recognize that their operations and supply chains influence GHG emissions across the entire value chain over product lifecycles because they manufacture the devices and mobile communication network infrastructure. Their activities span material extraction, production of components, assembly, logistics, product use and end-of-life management, with each stage responsible for significant emissions. The activities of TEPs to reduce GHG emissions are summarized in Table 6.2. Over 80% of the smartphone's carbon footprint comes from manufacturing (Huawei, 2024). To manage their emissions, TEPs aim to decarbonize their own operations and transport facilities. They do this by using low-carbon infrastructure that implements energy saving in facilities and data centres through

actions like using efficient lighting and HVAC, transitioning to district heating. Other activities include reusing assets, certifying data centres for sustainability and optimizing energy use. Decarbonization of transport and logistics is addressed by reducing packaging, transitioning to electric fleet or using low-emission transport, using shipping instead of planes and using fleet management systems. They are obtaining sustainability-linked financing and disclosing science-based carbon reduction goals as well.

Other complimentary decarbonization efforts carried out by TEPs include investing in carbon removal, technologies, collaborating with organizations like Eco-Skies Alliance to indicate interest in use of Sustainable Aviation Fuels (SAFS), employing Environmental Management Systems and addressing emissions from fluorinated gases produced during manufacturing. TEPs mobilize their supply network to decarbonize and support them in their efforts by launching Supplier Energy efficiency Programs, helping them set science-based targets to decarbonize, share tools for emissions accounting and AI-driven optimization, and so on.

Table 6.2 GHG emission reduction activities and indicators reported by TEPs

| Activities | Indicators | Sources |
|---|---|---|
| Employ complementary climate strategies to address residual emissions and enable system-wide decarbonization like investing in carbon removal technologies and high quality nature-based carbon credits, introducing tools to show when the grid has cleaner energy, collaborating with Eco-Skies Alliance to indicate interest and investigate Sustainable Aviation Fuels, employ Environmental Management systems, address high-impact emissions from fluorinated gases during semiconductor manufacturing. (Apple, 2024), (Cisco, 2023), (Huawei, 2024), (Nokia, 2024), (Samsung Electronics, 2023), (Ericsson, 2024)(Ericsson, 2024) | GHG emissions ($tCO_2e$) | (Apple, 2024), (Huawei, 2024), (Nokia, 2024), (Ericsson, 2024) |
| Accelerate decarbonization in transport and logistics by addressing packaging, transitioning to electric fleet or low-emission vehicles, using shipping instead of planes and using fleet management systems and telematics. | scope 3 emissions ($tCO_2e$) | (Apple, 2024), (Huawei, 2024), (Nokia, 2024), (Ericsson, 2024) |
| Strengthen climate governance by establishing framework for sustainability-linked financing and disclosing science-based carbon reduction goals. | GHG emissions ($tCO_2e$) | (Apple, 2024), (Huawei, 2024), (Nokia, 2024), (Ericsson, 2024), |

| | | |
|---|---|---|
| | | (Cisco, 2023), (Samsung Electronics, 2023) |
| Employ complementary climate strategies to address residual emissions and enable system-wide decarbonization like investing in carbon removal technologies and high quality nature-based carbon credits, introducing tools to show when the grid has cleaner energy, collaborating with Eco-Skies Alliance to indicate interest and investigate Sustainable Aviation Fuels, employ Environmental Management systems, address high-impact emissions from fluorinated gases during semiconductor manufacturing. | GHG emissions ($tCO_2e$); carbon credits ($tCO_2e$) | (Apple, 2024), (Cisco, 2023), (Nokia, 2024) |
| Mobilize supply network to decarbonize by launching Supplier Energy Efficiency Programs, supporting suppliers in reducing energy use and setting science-based targets, and providing tools for emissions accounting and AI-driven operational optimization. Collaborate with initiatives like the Eco-Skies Alliance to explore Sustainable Aviation Fuels, signalling commitment to low-carbon innovation across hard-to-abate sectors. | renewable energy (MWh), energy consumption (MWh), ghg emissions ($tCO_2e$), scope 3 emissions ($tCO_2e$). | (Apple, 2024), (Cisco, 2023), (Nokia, 2024), (Ericsson, 2024), (Samsung Electronics, 2023), (Huawei, 2024) |
| Report on carbon emissions across operations and require business partners to disclose emissions and align with 1.5°C targets. | GHG emissions ($tCO_2e$) | (Apple, 2024) |

## 6.2 TEPs' energy management activities

For TEPs, manufacturing and testing of network devices and product operation in customer networks represent the largest energy consumption (Apple, 2024), (Cisco, 2023), (Huawei, 2024), (Nokia, 2024), (Ericsson, 2024). TEPs emphasize how energy performance of their products is important. They note that improving energy efficiency of both the production process and product operation is important for environment protection. A summary of the energy management activities by TEPs is in Table 6.3. TEPs prioritize strategies that enhance use of renewable energy, enhance energy efficiency and optimize the performance of the technologies they design and deploy. TEPs prioritize integrating renewable energy into their facilities and communities to reduce reliance on fossil energy. They either

generate renewable energy on site or purchase it. They also support their customers and suppliers to switch to renewable energy systems.

Also important to TEPs is optimization of the energy performance of their hardware, software and integrated solutions. This means selling products with high energy efficiency and low energy consumption. TEPs also manage the energy of their own operations, including that of their facilities and transport solutions for example by applying green building standards, they deploy virtual power plants and apply user-centred design. Other activities include targeting facilities by using energy saving lighting and HVAC, switching to district heating, replacing gas boilers with electric heating, getting certification for environmental performance and so on.

Table 6.3 Energy management activities and indicators reported by TEPs

| Activities | Indicators | Sources |
|---|---|---|
| Develop networks with reduced energy consumption and increased capacity to lower energy costs and lower emissions. | GHG emissions ($tCO_2e$), energy consumption (MWh) | (Ericsson, 2024) |
| Integrate renewable energy in facilities, communities, data centres to reduce reliance on fossil energy by purchasing renewable energy through PPAs, building renewable energy generation projects from solar, recover heat from incinerated waste, low-impact hydro projects and supporting customers and suppliers to switch to renewable energy, recover energy from incinerated waste. | renewable energy (MWh) | (Apple, 2024), (Cisco, 2023), (Ericsson, 2024), (Huawei, 2024), (Nokia, 2024), (Samsung Electronics, 2023), |
| Optimize energy performance across hardware, software and integrated solutions by improving energy performance of hardware and solutions that power smart buildings and other infrastructure. | Energy consumption (MWh), energy efficiency (%) | (Apple, 2024), (Cisco, 2023), (Ericsson, 2024), (Huawei, 2024), (Nokia, 2024), (Samsung Electronics, 2023), (Ericsson, 2024) |
| Enhance energy performance and reduce emissions across facilities by investing in electrification, applying green building standards, deploying virtual power plants, and optimizing user-centred design. Implement targeted measures such as conserving energy in lighting and HVAC systems, monitoring indoor | energy efficiency (%), energy consumption (MWh) | (Apple, 2024), (Cisco, 2023), (Huawei, 2024), (Nokia, 2024), (Samsung Electronics, 2023) |

| | | |
|---|---|---|
| environmental conditions, supporting hybrid work models, transitioning to district heating, and replacing gas boilers with electric heating. Advance sustainability in data centres through efficient design, energy management, asset recovery and reuse, responsible procurement, and certification for environmental performance. | | |
| Assess energy performance across operations and supply chain by auditing activities to identify reduction opportunities. | energy consumption (MWh), energy efficiency (%), renewable energy consumption (MWh) | (Apple, 2024) |

## 6.3 TEPs' biodiversity, land, and water conservation

TEPs' impact on biodiversity, land and water is due to extraction of raw materials by the upstream supply chain (Huawei, 2024) , and the footprint on the land where their facilities (factories, research and development centres, offices) are built (Cisco, 2023). Water is used for manufacturing, cooling facilities and for other operations as well. Table 6.4 summarizes the activities conducted by TEPs to manage their effects on biodiversity land and water use. Across the TEPs, the emphasis is on responsible land and resource use within its manufacturing sites and supply chains. TEPs report some activities that are aimed at supporting biodiversity and natural resources. These activities are actions that aim to restore/protect ecosystems near operational sites. They include activities like tree planting, conserving wildlife habitats, minimizing pollution and waste across operations, and so on.

Water conservation is addressed by TEPs as well. TEPs act to reduce their water footprint across their operations for example by reusing wastewater, capturing and recovery of water sources, eliminating liquid discharge hazards. To aid in their water conservation efforts, TEPs are engaging their suppliers to practice water conservation, and they also support local communities in safeguarding water, land and ecosystems near operational sites.

Table 6.4 Biodiversity, land, and water conservation activities and indicators reported by TEPs

| Activities | Indicators | Sources |
|---|---|---|
| Advance biodiversity protection by driving climate action and restoring ecosystems through initiatives like tree planting, conserving wildlife habitats, and minimizing pollution and waste across operations. | area covered by trees ($km^2$/acres), number of species maintained or increased (number of species), ecotoxicity (CTUe) | (Apple, 2024), (Cisco, 2023), (Ericsson, 2024), |
| Champion water stewardship across the supply chain by collaborating with suppliers to implement comprehensive water management practices, uphold rigorous discharge standards, and actively engage in the restoration of river basins and ecosystems. | water consumption ($m^3$/gallons), | (Apple, 2024), (Cisco, 2023), (Ericsson, 2024), (Nokia, 2024), (Samsung Electronics, 2023) |
| Reduce water footprint across operations by reusing wastewater, capturing and recovery water sources, conserving facility water use, restricting potable water to essential use and eliminating liquid discharge hazards e.g. also by (e.g. blending tanks, sphagnum moss-based treatment). | water consumption ($m^3$/gallons), water discharge (Million gallons) | (Apple, 2024), Cisco, 2023), (Samsung Electronics, 2023) |
| Support environmental resilience in local communities by safeguarding water, land, and ecosystems near operational sites, and advancing water security through partnerships that improve freshwater availability, quality, and equitable access via replenishment projects. | water consumption ($m^3$/gallons) | (Apple, 2024), (Cisco, 2023), (Samsung Electronics, 2023) |
| Monitor and report water usage across corporate operations and supply chains and participate in initiatives. | water consumption ($m^3$/gallons), water withdrawal (millions of gallons) | (Cisco, 2023), (Apple, 2024), (Ericsson, 2024), (Nokia, 2024), (Samsung Electronics, 2023) |
| Monitor biodiversity across operational sites and act proactively or reactively to protect the ecosystem. | number of species/areas | (Apple, 2024), (Ericsson, 2024) |

## 6.4 TEPs' waste management activities

For TEPs waste is an environmental concern because of the manufacturing and production of equipment, devices, semiconductors and other electronics. A summary of activities for waste management is shown in Table 6.5. Electronic waste for TEPs comes from several stages of their operations. They come from material extraction, manufacturing and fabrication, assembly packaging, distribution, and end-of-life treatment. In their reports, TEPs highlight their commitment to reduce waste by reducing waste generation, improving resource efficiency and promoting circular treatment of their waste. They do this by establishing various take-back schemes to collect e-waste before it reaches landfill. They also encourage treatment of this waste by promoting reuse, recycling, composting or donating.

In addition, TEPs, due to the nature of their operations manage a substantial share of hazardous waste including chemicals, solvents, plating material and residues from semiconductor manufacturing. They therefore promote hazardous material safety by eliminating hazardous chemicals and using ecofriendly options. They apply controls to hazardous materials when used, they maintain lists of banned and restricted substances, they engage suppliers on REACH substances, and they ensure proper treatment of waste effluent.

Table 6.5 Waste management approaches and indicators reported by TEPs

| Activities | Indicators | Sources |
|---|---|---|
| Drive proactive collection of e-waste by prioritizing systems that recover discarded electronics before they reach landfill by implementing take-back schemes, offering customer-first refusal policies, establishing convenient drop-off points, and promoting reuse, recycling, composting, or donation as key pathways for responsible disposal. | waste (metric tons) | (Apple, 2024), (Cisco, 2023), (Huawei, 2024), (Nokia, 2024), (Samsung Electronics, 2023), (Ericsson, 2024) |
| Promote hazardous material safety by eliminating hazardous chemicals and developing and using safer ecofriendly options that best serve product priorities, applying controls to materials that come into prolonged skin contact, gathering data on chemicals used to inform safe chemical management and maintaining a list of banned and restricted substances (e), managing harmful substances in raw materials e.g. wafers and supplementary materials e.g. PCB, EMC in compliance with international standards, process chemical waste and engage hardware suppliers to substitute REACH substances, EU Critical Raw | waste (metric tons) | (Apple, 2024), (Samsung Electronics, 2023), (Ericsson, 2024), (Huawei, 2024), (Nokia, 2024), (Cisco, 2023), |

| | | |
|---|---|---|
| Materials and Substances of Concern in Products (SCIP), ensuring proper treatment of waste effluent. | | |
| Disclose and account for hazardous and non-hazardous waste and material. | waste (metric tons) | (Apple, 2024), (Huawei, 2024), (Nokia, 2024), (Ericsson, 2024) |
| Monitor and assess environmental regulations across jurisdictions and supplier networks to ensure compliance with regards to hazardous substances. | waste (metric tons) | (Apple, 2024), (Cisco, 2023), (Ericsson, 2024) |

## 6.5 TEPs' circularity and material usage activities

TEPs are major users of metals, plastics and rare-earth elements, materials whose extraction carries significant environmental impacts , (Apple, 2024), (Cisco, 2023), (Huawei, 2024), (Nokia, 2024), Circularity uses waste as an input to maintain the cycle of keeping materials in use for as long as possible. This is important to vendors because of the sensitive supply chain of some of the materials they use in manufacturing of devices and equipment (Nokia, 2024). The activities by TEPs on circularity and material usage are summarized in Table 6.6.

TEPs integrate circular design and production in their manufacturing processes. By implementing sustainable design strategies and responsible material choices in their manufacturing processes, they extend the lifecycles of their products and reduce environmental impact of their actions. Examples of how this is done are by implementing durable and modular product architecture, using low-impact recyclable and renewable materials, implementing waste-minimizing production methods and using eco-conscious packaging. TEPs engage their suppliers on environmental sustainability by advocating policies that enable circular supply chains and promote conservation of natural resources. They also engage their employees by encouraging them to integrate circular design into their work.

Table 6.6 Circularity and material usage activities and indicators reported by TEPs

| Activities | Indicators | Sources |
|---|---|---|
| Extend product lifecycles and reduce environmental impact by implementing sustainable design strategies and responsible material choices—through Design-for-Environment programs, durable and modular product architecture, and the use of low-impact, recyclable, and renewable materials | expected lifetime (years), repaired products (tons), reused product (tons), remanufactured products (tons), refurbished products (tons) | (Apple, 2024), (Cisco, 2023), (Huawei, 2024), (Nokia, 2024), (Samsung Electronics, 2023), (Ericsson, 2024) |

| | | |
|---|---|---|
| supported by waste-minimizing production methods and eco-conscious packaging. | | |
| Engage suppliers in environmental stewardship by advocating for policies that enable circular supply chains and promoting conservation of natural resources —including fossil fuels, minerals, and virgin forest products—through modified production, maintenance, and facility processes, material substitution (use low-impact materials), and recycling. | recycled content (tons), waste (tons), raw materials depletion (tons) | (Apple, 2024), (Cisco, 2023), (Nokia, 2024), (Samsung Electronics, 2023), (Ericsson, 2024) |
| Empower employees to integrate circular design into their work by offering learning opportunities and encouraging the purchase of remanufactured products. | expected lifetime (years), reused products (number of products), repaired product (number of products), refurbished products (number of products); recycled content (%); remanufactured product (number of products); remanufactured products (number of products), reused products (number of products) | (Cisco, 2023), (Huawei, 2024) |

## 6.6 TEPs' enablement activities

TEPs enable sustainability through devices and connected systems. TEPs develop mobile communication solutions that can help increase efficiency and productivity, reduce use of resources and monitor metrics for various sectors. Table 6.7 offers a summary of the activities on enablement by TEPs. TEPs provide solutions that digitize and automate operations in sectors like manufacturing, health, agriculture and education, where examples include e.g. smart watches, precision agriculture, health monitoring. TEPs provide solutions for mobile network operators, as well as devices and solutions for stakeholders in other sectors that they can use to reduce their emissions through various digitalization solutions. These sectors vary from manufacturing to agriculture, health, education, utilities (energy, water), transport and others.

Like MNOs, when reporting on environmental sustainability topics, TEPs focus on their actions to mitigate their environmental footprint. TEPs also create positive environmental impacts through the technologies and solutions they offer to other sectors. This places them in a position to help other sectors reduce their emissions and create handprint. Thus, reporting on enablement is reporting on the activities that enable other sectors to reduce their environmental impact. TEPs report that their technologies enable automation, remote monitoring, smart manufacturing, smart grids, transport, energy monitoring, digital learning, health monitoring. TEPs highlight how their power saving technologies and AI optimization tools reduce network energy consumption for customers and enable monitoring of grids which enables utilities to identify potential problems and act pre-emptively towards the problem. In other instances, TEPs provide digital tools that help companies identify where they can reduce their environmental footprint. They produce wearables that support remote health monitoring. TEPs design products and use manufacturing processes that are less carbon intensive, contributing to reduced emissions. TEPs help transition to renewable energy and incentivize the use of electric vehicles.

Table 6.7 Enablement activities and indicators for sustainability reported by TEPs

| Activities | Indicators | Sources |
|---|---|---|
| Use of devices and other solutions to leverage mobile communication networks in other sectors like manufacturing, health, agriculture and education to digitalize and automate operations like smartwatches in health sector, provide infrastructure for smart factories and smart grids, establish learning centres to teach tech and provide access to learners to learn online. | GHG emissions ($tCO_2e$) | (Apple, 2024), (Cisco, 2023), (Huawei, 2024), (Samsung Electronics, 2023) |
| Transition to renewable energy sources in offices, retail stores, and data centres, base stations. | GHG emissions ($tCO_2e$), energy consumption (MWh) | (Apple, 2024), (Cisco, 2023), (Ericsson, 2024) |
| Designing products and manufacturing processes to become less carbon intensive and more energy efficient due to ultra-power-saving technology. | GHG emissions ($tCO_2e$) | (Apple, 2024), (Cisco, 2023), (Samsung Electronics, 2023) |
| Supporting suppliers to adopt renewable energy technologies, commonly termed as clean energy transition. | GHG emissions ($tCO_2e$), energy consumption (MWh) | (Apple, 2024), (Cisco, 2023), (Nokia, 2024) |
| Install high efficiency heating and cooling systems and transformers to reduce energy consumption from plug loads. | GHG emissions ($tCO_2e$), energy consumption (MWh) | (Apple, 2024) |

| | | |
|---|---|---|
| Incentivize the use of electric vehicles, moving toward mass transit coach services and bicycles. | GHG emissions ($tCO_2e$) | (Apple, 2024), (Ericsson, 2024) |
| Enable monitoring solutions in energy grids and pre-emptively address failures and faults. | energy consumption (MWh) | (Cisco, 2023) |
| AI/ML based optimization and automation to reduce energy use. | GHG emissions ($tCO_2e$), energy consumption (MWh) | (Nokia, 2024) |
| Private Wireless Sustainability Calculator- tool to help companies identify where they can reduce their environmental footprint and improve worker safety in private wireless networks. | GHG emissions ($tCO_2e$) | (Nokia, 2024) |

# 7

# Industry forums

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# 7 Industry Forums

Industry forums within the mobile communication sector coordinate the relevant stakeholder activities and advocate for the interests of their members within the sector and externally. They have played a crucial role in advancing sustainability across the sector by setting industry standards, facilitating research on industry-relevant issues, sharing best practices, facilitating collaboration among operators, equipment providers, and other stakeholders. Forums acknowledge that mobile communication networks impact the environment but can also be enablers of sustainability across different sectors. Forums aim to coordinate and harmonize sustainability practices across the sector.

Three major industry forums in the mobile communication sector are Next Generation Mobile Networks Alliance (NGMN), Next Generation Alliance (NGA), and Global System for Mobile Association (GSMA). NGA is an initiative focused on advancing North American wireless technology leadership in 6G and beyond and is working to embed sustainability principles throughout the 6G lifecycle from design to decommissioning. GSMA is a body that represents the interest of the mobile sector worldwide. GSMA is the main driver of the sector's commitment to be Net Zero by 2050. NGMN is a global consortium of operators, vendors, and research institutions focused on defining requirements for next-generation mobile networks. It's Green Future Networks group focuses on developing sustainable and environmentally conscious solutions. In (GSMA, 2023f) GSMA aims to provide a common framework for its members to consistently disclose climate targets. In (NGMN, 2024c) NGMN calls for environmental metrics and boundary definitions for MNOs and TEPs to be harmonized while in NGA (NGMN, 2024c) emphasizes a harmonized 6G vision that embeds energy efficiency, material use and lifecycle metrics from conception.

The forums highlight that knowledge sharing and capacity building in the mobile sector allows stakeholders to manage environmental impacts. In their report (GSMA, 2023h), GSMA shares best practices on device recovery and recycling options. In (NGA, 2024a), NGA highlights that there should be collaboration between research institutions and industry on sustainable next-generation networks. Forums help to shape regulations and policies. In (NGMN, 2024c), NGMN calls for alignment between sustainability standards and regional regulatory frameworks like the EU CSRD and ESRS. NGA recommends policy collaboration on the sustainability of next-generation networks (NGA, 2024a). Forums help highlight that sustainability is embedded in the design of future network generations (NGA, 2024a) and drives enablement (NGA, 2023a). Embedding lifecycle metrics early in technologies ensures their long-term environmental performance in the mobile sector as well as other sectors.

For forums, environmental sustainability topics define the standards and regulations that help mitigate emissions and decarbonize all sectors. They also help set standards and regulations that help

align policies, promote lifecycle thinking and transparency in reporting of the sector's environmental effects. Table 7.1 summarizes the industry forums' reports used in the study.

Table 7.1 Industry forum publications used in the study.

| Forum | Report | Year |
|---|---|---|
| GSMA | Going green: benchmarking the energy efficiency of mobile networks (GSMA, 2023i) | 2023 |
| | Achieving climate targets (GSMA, 2023a) | 2023 |
| | ESG Metrics for mobile (GSMA, 2024a) | 2024 |
| | ESG Metrics for mobile (GSMA, 2023c) | 2023 |
| | Climate action handbook (GSMA, 2023b) | 2023 |
| | Material sustainability issues for the mobile sector (GSMA, 2023d) | 2023 |
| | Mobile net zero 2023 State of the Industry on climate action (GSMA, 2023f) | 2023 |
| | Mobile net zero 2024 State of the Industry on climate action (GSMA, 2024b) | 2024 |
| | Strategy paper for circular economy: Mobile devices (GSMA, 2023h) | 2022 |
| | Strategy paper for circular economy: Network equipment (GSMA, 2023g) | 2022 |
| NGA | 6G Next G Alliance Report: 6G Sustainability KPI Assessment Introduction and GAP Analysis (NGA, 2024a) | 2023 |
| | 6G Next G Alliance Report: Evolution of Sustainability Indicators for -data Centres and Next Generation Core Networks White Paper (NGA, 2024c) | 2024 |
| | 6G Next G Alliance Report: Evolution of Sustainability Indicators for Next Generation Radio Network Technologies (NGA, 2024d) | 2023 |
| | Next G Alliance Report: Roadmap to 6G (NGA, 2024e) | 2022 |
| | Next G Alliance Green G: The Path Toward Sustainable 6G (NGA, 2023a) | 2022 |
| | 6G Next G Alliance Report: Sustainable 6G Connectivity-A Powerful Means of Doing Good (NGA, 2023b) | 2023 |
| | Next G Alliance Report: Sustainable AI in Telecom: Promises and challenges in 6G (NGA, 2024f) | 2025 |
| | 6G Next G Alliance Report: 6G Technologies (NGA, 2024b) | 2022 |
| NGMN | Green Future Networks Telco Supply Chain Sustainability (NGMN, 2023c) | 2023 |
| | Green Future Networks: KPIs and Target Values for Green Network Assessment (NGMN, 2023a) | 2023 |
| | Environmental Sustainability and Reporting (NGMN, 2024c) | 2025 |
| | Green Future Networks: A roadmap to energy-efficient mobile networks (NGMN, 2024a) | 2024 |
| | Reducing Environmental Impact (NGMN, 2023b) | 2022 |

Industry forums play a different role in environmental monitoring and reporting. While MNOs and TEPs report on their environmental effects, forums focus on identifying and defining common indicators and metrics, and frameworks that enable consistent reporting in the mobile sector globally. Forums typically do not report on their environmental handprint and footprint. Forums engage in knowledge-sharing. They help with industry coordination, benchmarking and policy alignment. They publish reports, opinions, white papers and roadmaps on subjects of concern in the mobile sector, including environmental sustainability. They advocate for monitoring and reporting in the sector, explicitly and implicitly. Monitoring and reporting by forums are done to promote knowledge-sharing among its members, helping members learn from each other. They offer guidance on how the sector can adopt practices that reduce the footprint or increase the handprint regarding the key environmental topic. Examples of the considered topics include circularity of network devices and mobile phones, energy management, GHG emissions of the sector and others. This enables members to benchmark their performance against each other, including on environmental sustainability topics. In addition, monitoring and reporting by forums provide a basis for sustainability claims in the sector.

## 7.1 Green House Gas (GHG) emission discussions in forums

Industry forums facilitate collaboration in the mobile communication sector by providing climate guidance on GHG emissions. Table 7.2 captures the GHG emission discussions and indicators in industry forums. Forums advocate for supporting long-term climate goals by prioritizing direct emissions oversetting while investing in carbon removal. They also support reusing technologies and contributing to decarbonization efforts of the grid. Forums also advocate for optimizing operations, facilities and transport solutions of their members. One way to do this is by harnessing capabilities to reduce facility-related emissions by designing environmentally friendly data centres, changing heating systems to electric heat pumps, improving facility efficiency through smart racks and high efficiency UPS systems and other activities.

Forums call for emissions from transport solutions to be managed by transitioning to electric vehicles and evaluating their full lifecycle. Like MNOS and TEPs, forums also advocate for engaging suppliers and supply chain, and partnerships with governments, policymakers and industry to tackle GHG emissions, increase use of renewable energy, consolidate infrastructure, embed sustainability into organizational strategy and aligning environmental targets.

Table 7.2 GHG emission activities and indicators reported by industry forums

| Activities | Indicators | Sources |
|---|---|---|
| Support long-term climate goals by prioritizing direct emissions reductions over offsetting, while investing in carbon removal and reuse technologies and contributing | GHG emissions ($tCO_2e$), | (NGMN, 2023b), (GSMA, 2023a), (NGA, 2024d) |

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|---|---|---|
| to grid decarbonization efforts. Planting trees and purchasing carbon credits. | total carbon offsets (tCO2e) | |
| Advance systemic climate action by partnerships with governments, policymakers, power grid governments, industry, and supply chains to tackle emissions and climate action by expanding access to renewable energy, consolidating infrastructure, aligning environmental targets, and embedding sustainability into organizational strategy and operations. | GHG emissions (tCO2e) | (GSMA, 2023a), (GSMA, 2023d), (GSMA, 2023i) |
| Harness mobile communication system capabilities to reduce facility-related GHG emissions by designing and operating environmentally responsible data centres, converting to automated LED lighting, improving building and equipment efficiency through smart racks and high-efficiency UPS systems, transitioning heating systems to electric heat pumps, installing refrigerant leak detection to prevent fugitive emissions, and assessing the environmental impact of processes, making data centres green, measuring environmental impact of activities of data centres and manufacturing activities to drive continuous sustainability improvements. | GHG emissions (tCO2e), carbon usage effectiveness (CUE) ($mtCO_2e/kWh$), Carbon Intensity Ratio ($kgCO_2e$/ per unit and time cycle) | (NGMN, 2023b) |
| Reduce transport-related GHG emissions by transitioning to battery electric vehicles and evaluating environmental impacts across the full lifecycle—including production, transportation, use, and end-of-life disposal—to inform more sustainable decision-making. | GHG emissions (tCO2e) | (GSMA, 2023a), (GSMA, 2023h) |
| Strengthening climate accountability by mandatory reporting of audited climate risks, emissions and energy data transparently with clear key performance indicators, including Joint-Ventures related emissions. | GHG emissions ($tCO_2e$) | (GSMA, 2023d), (GSMA, 2023a), (NGMN, 2023a) |

## 7.2 Energy management discussions in forums

Energy management is discussed in industry forums due to its direct linkage to GHG emissions and operational costs. Additionally, the switch to 5G has increased energy consumption of mobile communication networks. Table 7.3 summarizes activities that forums discuss for energy management. Forums offer guidance on how to reduce energy consumption of networks and thus reduce emissions of the sector. One theme is the optimization of hardware, software and service solutions to increase

energy efficiency. Forums are advocating designing future 6G networks and systems with energy-efficient architecture and lifecycle-aware principles for instance they advocate using low-power components, extend equipment lifespan, using simple infrastructure among other methods. They also suggest using mobile communication technologies to implement energy savings, for example, by virtualizing network functions, integrating intelligent energy management systems with smart grids and smart meters.

Forums suggest optimizing mobile communication network operations and protocols for energy efficiency for example by using techniques like dynamic resource shutdown, low frequency wake-up signalling, sustainability-qualified protocol and many other controls. In addition, forums encourage use of AI in mobile communications to optimize energy consumption across hardware, software and infrastructure. Forums are also big advocates of switching to renewable energy or to other unconventional sources of energy. With RAN being the biggest consumer of energy, energy management of the RAN involves optimizing infrastructure, spectrum use, hardware design and sign operations. Forums foster cross-sector collaboration on energy management by partnering with suppliers, utilities and tech startups, as well as other collaborators. They also promote the use of mobile communication networks for real-time monitoring of energy use, thus strengthening climate accountability.

Table 7.3 Energy management activities and indicators reported by industry forums

| Activities | Indicators | Sources |
|---|---|---|
| Design mobile communication networks and systems with lean, energy-efficient architectures, and lifecycle-aware principles—using simplified infrastructure, passive cooling, disaggregated RAN, and low-power components to improve scalability, extend equipment lifespan, and support net-zero energy goals from network to device. | energy consumption (MWh), energy efficiency (%) | (NGMN, 2023a), (GSMA, 2023i), (NGA, 2023a) |
| Use mobile communication technologies to implement energy savings by consolidating infrastructure, virtualizing network functions, deploying edge computing and sustainable cloud environments, integrating intelligent energy systems with smart grids and meters, designing low-power hardware, and enabling real-time, demand-driven operations for net-zero energy performance. | energy consumption (MWh), energy efficiency (%) | (NGA, 2023a), (NGA, 2023b), (NGA, 2024c), (NGA, 2024d), (NGA, 2024e), (NGMN, 2021) |
| Optimize mobile communication network operations and protocols for energy efficiency by embedding adaptive controls and sustainability-aware design— | energy consumption (MWh), | (GSMA, 2023i) (NGA, 2023a) |

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|---|---|---|
| using techniques such as dynamic resource shutdown, low-frequency wake-up signalling, sustainability-qualified protocols, encrypted environmental metrics, and QoE-linked performance benchmarking. | energy efficiency (%) | |
| Leveraging AI in AI-native solutions in future mobile communication systems to optimize energy consumption across hardware, software and infrastructure by using ML to predict | energy consumption (MWh), energy efficiency (%) | (NGMN, 2024a), (NGMN, 2023b), (NGA, 2023a), (NGA, 2024f), (NGA, 2024c), (NGA, 2024d) |
| Adopt renewable energy and other unconventional sources of energy to optimize energy use by transitioning facilities and data centres to clean sources like solar, wind, hydrogen, and hydropower, leveraging PPAs and green tariffs, diverting excess power to the grid, and exploring energy waste harvesting and reuse while unconventional sources include replacing carbon with hydrogen from renewable sources in technical processes, coupling renewable generation with battery storage at base stations, transitioning fixed network infrastructure to fibre, | renewable energy consumption (MWh) | (NGA, 2024c), (NGMN, 2023b), (NGA, 2023a), (GSMA, 2023a) |
| Improve energy management in Radio Access Network (RAN) by optimizing infrastructure, spectrum usage, hardware design, and site operations—through strategies such as pooled baseband units, high-efficiency transceivers, passive cooling, spectrum refarming, and traffic-aware deployment scenarios. | energy efficiency (%), energy consumption (MWh) | (NGA, 2024d), (NGMN, 2024a), (NGA, 2023a), (GSMA, 2023i) |
| Foster cross-sector collaboration for enhanced energy management by partnering with energy suppliers, utilities, and tech startups, promoting transparency and harmonization of sustainability metrics, supporting energy-savings-as-a-service business models, and encouraging joint efforts between operators, vendors, and regulators to share knowledge and align on low-impact solutions. | energy consumption (MWh), participate in joint ventures (diversity of stakeholder attendance) | (NGA, 2023a), (NGA, 2024d), (GSMA, 2023i) |
| Strengthening climate accountability by mandatory reporting of audited climate risks, emissions and energy data transparently with clear key performance indicators, including Joint-Ventures related emissions. | GHG emissions ($tCO_2e$) | (GSMA, 2023d), (GSMA, 2023a), (NGMN, 2023a) |

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|---|---|---|
| Using networks to enhance energy management through real-time monitoring. | energy consumption (MWh), energy efficiency (%) | (NGA, 2023a), (NGA, 2024d), (GSMA, 2023i) |

## 7.3 Biodiversity, land and water usage discussions in forums

Biodiversity, land and water use have increasingly become important aspects of environmental sustainability within the mobile communications sector. Forums help shape frameworks that guide how the mobile sector manages biodiversity, land and water use. Mobile communication systems claim to offer opportunities to support biodiversity protection by promoting sustainable land use. Forums also report that companies need to manage their impact on biodiversity. Then they promote biodiversity accountability across the entire value chain through reporting under CSRD and TFND

Forums promote responsible land use in mobile communication systems by leveraging mobile technologies to monitor infrastructure impacts, optimize RAN energy efficiency and apply LCA to evaluate environmental categories such as land use. To enhance water conservation, forums promote responsible water use across facilities and transport solutions, for example by reusing and recycling water resources and designing data centres that use water-efficient resources.

Table 7.4 Biodiversity, land, and water usage activities and indicators reported by industry forums

| Activities | Indicators | Sources |
|---|---|---|
| Enhance water use across owned facilities and transport operations by reusing and recycling water resources, and by designing and operating data centres with water-efficient cooling systems to reduce environmental impact. | water consumption ($m^3$), WUE ($kWh/m^3/kWh$) | (NGA, 2023b) |
| Promote responsible land use in mobile communication systems by leveraging mobile technologies to monitor infrastructure impacts, optimizing RAN energy efficiency to reduce emissions and data centre footprint, and applying life cycle assessment (LCA) to evaluate environmental categories such as land use and ecological impact across network components and operational sites. | land area ($km^2$) | (NGA, 2024a), (NGA, 2024b) |
| Manage company impact on biodiversity by engaging in activities like restoring altered natural habitats by integrating green living roofs on factories, buildings, data | number of species/acre, number of species, | (NGA, 2024a) |

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|---|---|---|
| centres, planting native species, avoiding lawns, creating bird habitats, minimizing fertilizer and pesticide use. | area of land/space ($km^2$) | |
| Use of mobile communication systems to support biodiversity protection by promoting sustainable land use and addressing ecological impacts across the full infrastructure footprint—including cell sites, network equipment, manufacturing facilities, data centres, and access corridors for backhaul and metro-area networks.6G systems must ensure sustainable land usage to counter biodiversity loss. | number of species/acre, number of species, area of land/space ($km^2$) | (NGA, 2024a) |
| Supporting biodiversity accountability through reporting biodiversity impacts under both CSRD and TNFD across the entire value chain. | species population size (number of species), species global extinction risk (number of species), land degradation (area), desertification (area), soil sealing , climate change ($tCO_2e$), land-use change (area in $km^2$/acres), fresh water-use change (volume in $m^3$ /gallons ), sea-use change (volume in $m^3$/gallons), direct exploitation (tons of material), invasive alien species (number of species), pollution (CTUe, CTUh) | (GSMA, 2023d) |

## 7.4 Waste management discussions in forums

Industry forums emphasize that waste management is important for a sustainable mobile communication sector. Table 7.5 shows activities discussed by forums on waste management. As networks expand, volumes of devices increase and technology lifecycles become shorter, material waste increases. A GSMA press release estimates that there are more than 5 billion unused mobile phones globally, further claiming that if recycled, 8 billion worth of gold, palladium, copper, rare earth elements and other critical minerals could be recovered, as well as enough cobalt for 10 million electric car batteries (GSMA, 2023e).

One strategy to manage waste is for devices and equipment to be designed for longevity, to be repairable, reusable, refurbishable and recyclable. This ensures that no waste ends up in landfill. Forums state that the mobile sector must champion sustainable use of materials to reduce waste. This is done by reducing product volumes, eliminating or recycling plastic, using biological precursors and avoiding fossil-based material in product design. Another strategy proposed by forums is to categorize waste and transparently report on it. This is especially important for hazardous and e-waste including further reporting according to recycled or reused content.

Table 7.5 Waste management activities and indicators reported by industry forums

| Activities | Indicators | Sources |
|---|---|---|
| Advance sustainable material use by reducing production volumes through componentization, eliminating or recycling plastics, adopting biological precursors, and avoiding fossil-based sources in material design to minimize environmental impact and promote resource circularity. | Waste (tons) | (NGMN,2023b) |
| Categorize waste and transparently reporting on it—including hazardous and non-hazardous telecom and electronic waste—tracking total waste generation and disclosing recycled and reused material percentages by product category to support circularity and regulatory compliance. | waste (tons), Recycled waste (tons), reused waste (tons) | (NGMN,2023b) |

## 7.5 Circularity and material usage discussions in forums

Industry forums frame circularity and material use as vital for achieving supply of finite natural resources required for future mobile networks (GSMA, 2023h). They state that the traditional linear take-make-dispose model must be replaced with a circular model (GSMA, 2023h). Table 7.6 summarizes the activities promoted by forums to enhance circularity and responsible material use. Forums advise that

mobile communication systems should be designed in a circular manner to be durable, modular, resilient, energy-efficient, customizable upgradeable, repairable, reusable, refurbishable, recyclable and recoverable. They advocate for adoption of business practices that minimize resource use by shifting away from virgin material, standardizing components, using renewable materials and energy and other practices.

Forums highlight the importance of collaborating with suppliers and other stakeholders to advance circularity. Forums raise awareness of circular economy goals by increasing consumer awareness of end-of-life treatment and longevity incentives. These actions position circularity as a waste-reduction strategy and as strategy to transition to a resilient value chain with low-impact.

Table 7.6 Circularity and material usage activities and indicators reported by industry forums

| Activities | Indicators | Sources |
|---|---|---|
| Design mobile communication systems in a circular manner to be durable, upgradeable, repairable, reusable, refurbishable, recyclable or recoverable, modular, resilient, energy efficient and customizable. | expected lifetime (years), reused products (number of products), repaired products (number of products), refurbished products (number of products); recycled content (%), remanufactured product (number of products), waste (tons) | (GSMA, 2023h), (NGA, 2024d), (NGA, 2024c), (NGA, 2024a) |
| Adopt material-conscious business practices that minimize resource use by shifting away from virgin materials, standardizing components, using renewable materials and energy, selecting compliant and responsibly sourced inputs, prioritizing recycled over primary metals, enabling low-impact production through innovative business models, decoupling value creation from physical output, and advancing recycling technologies. | raw materials depletion (tons), e-waste (tons), recycled/refurbished/ reused/ repaired components (tons), waste heat recovery (Joules) | (GSMA,2023g), (NGMN,2023b), (NGA, 2023a) |
| Collaborate with suppliers and other stakeholders to advance circularity by promoting equal consideration of refurbished devices, partnering with repairers and recyclers to treat equipment waste by reclaiming, repairing, | raw materials depletion (tons), e-waste (tons), recycled/refurbished/ reused/ repaired | (GSMA,2023h), (GSMA,2023g), (GSMA, 2023d) |

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|---|---|---|
| recycling, promoting equal consideration of refurbished devices in business devices, classification of products for labelling, improving regulation system by easing license and intellectual property regulations to enable reuse and repair, introducing harmonized ecolabelling, encourage sustainability driven procurement across operations. | components (tons), waste heat recovery (Joules) | |
| Raise awareness of circular economy goals by increasing consumer awareness of end-of-life treatment and longevity incentives. | extended lifetime (years), waste (tons), raw material depletion (tons), raw materials depletion (tons), e-waste (tons), recycled/refurbished/ reused/ repaired components (tons), waste heat recovery (Joules) | (GSMA, 2023h) |

## 7.6 Enablement discussions in forums

Enablement is positioned by industry forums as a tool for mitigating climate change through the use of the mobile communication solutions to lower energy consumption and GHG emissions among others. Table 7.7 summarizes activities that promote enablement. GSMA claims in (GSMA, 2023c) that if mobile and digital technologies are deployed at scale, carbon emissions would be reduced by just under 40% over the next 10 years. Forums discuss various ways in which mobile connectivity can be used to reduce emissions. One way is leveraging mobile communications to reduce emissions across various sectors through initiatives like traffic management, use of drones for remote sensing and spray application, use of smart water systems, use of industrial IoT solutions which will lead to increased job opportunities and adoption of smart grids. Other instances of enablement are use of IoT solutions for real-time monitoring of resource consumption, use of solutions that enable remote working like videoconferences, use of backup systems that support use of renewable energy, and use of AI/ML for power management. Enablement is also applied in supply chains by supporting real-time supply chain management and KPI reporting.

Table 7.7 Enablement impact activities and indicators reported by forums

| Activities | Indicators | Sources |
|---|---|---|
| Leveraging mobile communication to support cross-sectoral emissions reductions through increased adoption of IoT to create jobs, automated train operations, deployment of smart grids, use of smart water systems to optimize water use in households. | GHG emissions (tCO2e) | (NGA, 2023a), (NGA, 2023b) |
| Use of IoT devices which consume less power and can survive harsh conditions enabling deployment of sensor networks for real-time monitoring of resource consumption. Thereby benefit from innovative ICT solutions such as smart cities and smart grids to reduce overall GHG emissions. | energy consumption (MWh), | (NGA, 2023a), (NGA, 2023b) |
| Work-from-home solutions such as videoconferencing and telepresence solutions such as AR/VR help reduce GHG emissions associated with business travel. | GHG emissions (tCO2e) | (NGA, 2023b) |
| The use of digital twining to optimize networks replaces the need for excessive drive tests. | energy consumption (MWh), | (NGA, 2023b) |
| Switching entirely to renewable energies requires novel backup systems which rely on batteries or fuel cells, not on diesel generators. | GHG emissions (tCO2e) | (NGA, 2023b) |
| AI/ML enabled power management to optimize energy consumption and water consumption to decide on how to use a given mix of renewables effectively. | energy consumption (MWh), | (NGA, 2023b) |
| Dynamic optimization of resources to reduce energy consumption in base stations, devices, and core networks to ensure optimal availability of service without idle resources. | GHG emissions (tCO2e) | (NGA, 2024e) |
| Real-time supply chain management and KPI reporting through green credentials and metrics of the supporting communications infrastructure. | energy consumption (MWh), | (NGA, 2024e) |

# 8

# Conclusions

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# 8 Conclusions

The mobile communication sector plays an important role in environmentally sustainable development. It enables de-carbonization and efficiency improvements across other sectors of the economy, potentially leading to handprint effects. On the other hand, the sector itself contributes significantly to environmental sustainability footprint through global GHG emissions, resource use, and e-waste generation among others.

This study has considered three stakeholder groups including MNOs, TEPs and industry forums to study the mobile communication sectors' activities to improve environmental sustainability. The study finds that MNOs are setting net-zero and science-based targets and are proactively switching to renewable energy and optimizing their networks to effectively manage their energy consumption and requesting environmental sustainability enhancements in their value chain. TEPs are rethinking their product design and manufacturing to deliver sustainable and energy efficient products. TEPs are adopting circular economy principles and requiring their suppliers to comply with environmental standards. Industry forums in the mobile communication sector are developing shared frameworks, sharing best practices, measuring progress and promoting best practices across the sector.

While there are actions taken by many stakeholders in the mobile communication sector, the progress is un-even and more is needed. The supply chain is one of the biggest contributors to emissions. Influencing the supply chain to reduce emissions is a demonstration of the importance of collaboration. No single consumer, operator or equipment provider, or forum can achieve environmental sustainability transformation alone, but all can demand for the change and act accordingly. The change towards demanding environmental sustainability needs to extend to the government, regulatory and standardization bodies, the communities around areas of operations, research institutions, and vertical sectors using the solutions.

The activities and indicators summarized in this report serve as the starting point for further developing sustainability and energy efficiency enhancing operations within the mobile communication sector. The sector needs to incorporate environmental sustainability practices holistically into organizations' activities including business models, product lifecycles, innovation strategies, and lifestyle practices.

# References

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# References


| | |
|---|---|
| (América Móvil, 2023) | América Móvil, "Sustainability Report 2023", 2023. [Online]. Available: https://sostenibilidad.americamovil.com/portal/su/pdf/2023-Sustainability-Report.pdf |
| (Apple, 2024) | Apple Inc., "2024 Environmental Progress Report" 2024. [Online]. Available: https://www.apple.com/environment/pdf/Apple_Environmental_Progress_Report_2024.pdf |
| (AT&T, 2024) | AT&T, "Connecting People to Greater Possibility: 2024 Sustainability Update", 2024. [Online]. Available: https://sustainability.att.com/ViewFile?fileGuid=b4632aa0-6d0d-4740-85e5-9010a361bb9e |
| (Bharti Airtel, 2024) | Bharti Airtel, "Integrated Report and Financial Statements 2023–24",2024. [Online]. Available: https://assets.airtel.in/staticassets/cms/investor/docs/annual_results_2023_24/Integrated_Report_and_Financial_Statements.pdf |
| (CDP, 2025) | CDP, "About Us," 2025. [Online]. Available: https://www.cdp.net/en/about |
| (China Mobile,2024) | China Mobile, "2024 Sustainability Report: China Mobile Limited Sharing AI+ Driving Innovative Growth", 2024. [Online]. Available: https://chinamobileltd.com/en/ir/reports/ar2024/sd2024.pdf |
| (China Telecom, 2024) | China Telecom, "Create a better future with digital technologies", 2024. [Online]. Available: https://www.chinatelecom-h.com/en/ir/report/esg2024.pdf |
| (Cisco, 2023) | Cisco, "Cisco Purpose Report 2023", 2023. [Online]. Available: https://www.cisco.com/c/dam/m/en_us/about/csr/esg-hub/_pdf/purpose-report-2023.pdf |
| (Ellen MacArthur Foundation) | Ellen MacArthur Foundation, "Circular Economy Introduction" [Online]. Available: https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview |
| (Elkington, 1997) | J. Elkington. Cannibals with forks: The triple bottom line of 21st-century business. Capstone Publishing Ltd. 1997 [Online] Available: https://dn721609.ca.archive.org/0/items/BusinessMoneyBooksarchive/Cannibals%20With%20Forks%20-%20The%20Triple%20Bottom%20Line%20of%2021st%20Century%20Business.pdf |
| (Ericsson, 2024) | Ericsson, "Sustainability and Corporate Responsibility Report 2024," 2024. [Online]. Available: https://mb.cision.com/Main/15448/4111351/3285959.pdf |

| | |
|---|---|
| (European Commission, 2020) | European Commission, *Critical Raw Materials for Strategic Technologies and Sectors in the EU: A Foresight Study*. Luxembourg: Publications Office of the European Union, 2020. [Online]. Available: https://rmis.jrc.ec.europa.eu/uploads/CRMs_for_Strategic_Technologies_and_Sectors_in_the_EU_2020.pdf |
| (European Commission, 2025) | European Commission, "Corporate sustainability reporting,", 2025. [Online]. Available: https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en |
| (European Commission, 2019) | European Commission, "EUR-Lex - 52019DC0640 - EN - EUR-Lex," [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52019DC0640 |
| (European Commission, 2024) | European Commission, Joint Research Centre, *Identifying Common Indicators for Measuring the Environmental Footprint of Electronic Communications Networks (ECNs) for the Provision of Electronic Communications Services (ECSs)*, LU: Publications Office, 2024. [Online]. Available: https://data.europa.eu/doi/10.2760/093662 |
| (European Environment Agency, 2025) | European Environment Agency, "Greenhouse Gas," [Online]. Available: https://www.eea.europa.eu/help/glossary/eea-glossary/greenhouse-gas |
| (G. Brundtland, 1987) | G. Brundtland, "Our Common Future: Brundtland Report," 1987. [Online]. Available: https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html |
| (GeSI, 2015) | GeSI, Global e-Sustainability Initiative (GeSI) and Accenture, *SMARTer2030: ICT Solutions for 21st Century Challenges*, Brussels, Belgium, 2015. [Online]. Available: https://gesi.org/research/smarter2030 |
| (GHG Protocol, 2025) | GHG Protocol, "Standards & Guidance," [Online]. Available: https://ghgprotocol.org/standards-guidance |
| (Grameenphone, 2024) | Grameenphone, "Sustainability Report 2024," 2024. [Online]. Available: https://cdn01da.grameenphone.com/sites/default/files/2025-04/09.%20Sustainability%20Report.pdf |
| (GRI, 2025) | GRI, " GRI Standards, English", 2025. [Online]. Available: https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/ |
| (GSMA, 2019a) | GSMA, "Energy Efficiency: An Overview," [Online]. Available: https://www.gsma.com/solutions-and-impact/technologies/networks/gsma_resources/energy-efficiency-an-overview/ |

| | |
|---|---|
| (GSMA, 2019b) | GSMA, *The Enablement Effect: The impact of mobile communications technologies on carbon emission reductions*. London: GSMA, 2019. [Online]. Available: https://www.gsma.com/betterfuture/enablement-effect |
| (GSMA, 2023a) | GSMA, "Achieving Climate Targets Guide," 2023. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2023/09/Achieving-Climate-Targets-Guide.pdf |
| (GSMA, 2023b) | GSMA, "Climate Action Handbook 2023," 2023. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2023/12/GSMA-Climate-ActionHandbook-2023.pdf |
| (GSMA, 2023c) | GSMA, "ESG Metrics for Mobile: Insights from Early Adopters," 2023. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2023/12/ESG-Metrics-for-Mobile-insights-from-early-adopters.pdf |
| (GSMA, 2023d) | GSMA, "Material Sustainability Issues for the Mobile Sector – 2023 Update," 2023. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2023/04/Material-sustainability-issues-for-the-mobile-sector-%E2%80%93-2023-Update.pdf |
| (GSMA, 2023e) | GSMA, "Mobile Industry Eyes Five Billion 'Dormant' Phones Sitting in Desk Drawers for Reuse or Recycling," [Online]. Available: https://www.gsma.com/newsroom/press-release/mobile-industry-eyes-five-billion-dormant-phones-sitting-in-desk-drawers-for-reuse-or-recycling/ |
| (GSMA, 2023f) | GSMA, "Mobile Net Zero: State of the Industry on Climate Action 2023," 2023. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2023/02/Mobile-Net-Zero-%E2%80%93-State-of-the-Industry-on-Climate-Action-2023.pdf |
| (GSMA, 2023g) | GSMA, "Strategy Paper for Circular Economy in Network Equipment",2023. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/gsma_resources/strategy-paper-for-circular-economy-network-equipment/ |
| (GSMA, 2023h) | GSMA, "Strategy Paper: Circular Economy for Mobile Devices", 2023. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2023/02/Strategy-Paper-Circular-Economy-Mobile-Devices.pdf |
| (GSMA, 2023i) | GSMA, "Going green: benchmarking the energy efficiency of mobile networks (second edition)," 2023. [Online]. Available: https://prod-cms.gsmaintelligence.com/research-file-download?confluenceId=74384072&filename=280223-Going-Green-Second-Edition.pdf |

| | |
|---|---|
| (GSMA, 2024a) | GSMA, "ESG Metrics for Mobile – June 2024," 2024. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2024/06/ESG-Metrics-for-Mobile-June-2024.pdf |
| (GSMA, 2024b) | GSMA, "Mobile Net Zero: 2024 State of the Industry on Climate Action," 2024. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2024/06/Mobile-Net-Zero-2024-State-of-the-Industry-on-Climate-Action.pdf |
| (GSMA, 2024c) | GSMA "The Nature Tech Nexus: Bridging Biodiversity and Business — Strengthening Biodiversity Solutions through Mobile and Digital Technologies," GSMA, London, UK, Mar. 2024. [Online] Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/wp-content/uploads/2024/03/GSMA_The-Nature-Tech-Nexus_Bridging-biodiversity-and-business_2024-1.pdf.pdf |
| (Hexa-X-II, 2023) | Hexa-X-II, "Environmental, Social and Economic Drivers and Goals for 6G," 2023. [Online]. Available: https://hexa-x-ii.eu/wp-content/uploads/2023/07/Hexa-X-II_D1.1_final-website.pdf |
| (Huawei, 2024) | Huawei, "Huawei Consumer Business Sustainability Progress Report (2023–2024)," 2024. [Online]. Available: https://www-file.huawei.com/-/media/corp2020/pdf/sustainability/others/huawei-consumer-business-sustainability-progress-report-2023-2024-en.pdf |
| (IEA, 2025) | International Energy Agency (IEA), "Energy and AI," 2025. [Online]. Available: https://build-up.ec.europa.eu/system/files/2025-04/PChtNmAZVk_11_04_2025_145800.pdf |
| (IFRS Foundation, 2025) | IFRS Foundation, "About us," 2025. [Online]. Available: https://sasb.ifrs.org/about/ |
| (ITU-T, 2022) | ITU-T, "ITU-T L.1480 (12/2022) Enabling the Net Zero Transition: Assessing How the Use of Information and Communication Technology Solutions Impact Greenhouse Gas Emissions of Other Sectors", 2022. [Online]. Available: https://www.itu.int/rec/T-REC-L.1480-202212-I |
| (ITU and WBA, 2025) | ITU and WBA, "Greening Digital Companies 2025: Monitoring Emissions and Climate Commitments", Geneva, Switzerland, and Amsterdam, Netherlands: International Telecommunication Union (ITU) and World Benchmarking Alliance (WBA), 2025 [Online] Available: https://www.itu.int/en/ITU-D/Environment/Documents/Publications/2025/ITU-WBA-Greening-Digital-Companies-2025.pdf |
| (MTN, 2024) | MTN, "Doing for tomorrow today," MTN Group, 2024. [Online]. Available: https://mtn.com/wp-content/uploads/2025/04/2024-Sustainability-Report.pdf |

| | |
|---|---|
| (MTS, 2023) | MTS, "Annual Report 2023," 2023. [Online]. Available: https://storage.ir.mts.ru/mts-ir/images/Annual_Report_2023_eng.pdf |
| (NGA, 2023a) | Next G Alliance, "Green G: The Path Towards Sustainable 6G," NGA, 2023. [Online]. Available: https://nextgalliance.org/white_papers/green-g-the-path-towards-sustainable-6g/ |
| (NGA, 2023b) | Next G Alliance, "Sustainable 6G Connectivity: A powerful means of doing good," Next G Alliance, 2023. [Online]. Available: https://nextgalliance.org/white_papers/sustainable-6gconnectivity-a-powerful-means-ofdoing-good/ |
| (NGA, 2024a) | Next G Alliance, "6G Sustainability KPI Assessment: Introduction and Gap Analysis," NGA, 2024. [Online]. Available: https://nextgalliance.org/white_papers/6g-sustainability-kpi-assessment-introduction-and-gap-analysis/ |
| (NGA, 2024b) | Next G Alliance, "6G Technologies Report,", 2024. [Online]. Available: https://nextgalliance.org/white_papers/6g-technologies/ |
| (NGA, 2024c) | Next G Alliance, "Evolution of Sustainability Indicators for Data Centers and Next Generation Core Networks," NGA, 2024. [Online]. Available: https://nextgalliance.org/white_papers/evolution-of-sustainability-indicators-for-data-centers-and-next-generation-core-networks/ |
| (NGA, 2024d) | Next G Alliance, "Evolution of Sustainability Indicators for Next Generation Radio Network Technologies," NGA, 2024. [Online]. Available: https://nextgalliance.org/white_papers/evolution-of-sustainability-indicators-for-next-generation-radio-network-technologies/ |
| (NGA, 2024e) | Next G Alliance, "Roadmap to 6G," NGA, 2024. [Online]. Available: https://nextgalliance.org/white_papers/roadmap-to-6g/ |
| (NGA, 2024f) | Next G Alliance, "Sustainable AI in Telecom: Promises and Challenges in 6G," NGA, 2024. [Online]. Available: https://nextgalliance.org/white_papers/sustainable-ai-in-telecompromises-and-challenges-in-6g/ |
| (NGMN, 2021) | NGMN, "Green Future Networks – Network Energy Efficiency," NGMN Alliance, 2021. [Online]. Available: https://www.ngmn.org/wp-content/uploads/211009-GFN-Network-Energy-Efficiency-1.0.pdf |
| (NGMN, 2023a) | NGMN, "KPIs Target Values," NGMN Alliance, 2023. [Online]. Available: https://www.ngmn.org/publications/green-future-networks-kpis-and-target-values-for-green-network-assessment.html |
| (NGMN, 2023b) | NGMN, "Reducing Environmental Impact," NGMN Alliance, 2023. [Online]. Available: https://www.ngmn.org/wp-content/uploads/GFN_Reducing_Environmental_Impact.pdf |

| | |
|---|---|
| (NGMN, 2023c) | NGMN, "Supply Chain Sustainability," NGMN Alliance, 2023. [Online]. Available: https://www.ngmn.org/wp-content/uploads/230117-NGMN-GFN_Supply-Chain-Sustainability_v1.0.pdf |
| (NGMN, 2024a) | NGMN, "Energy Efficiency Roadmap," NGMN Alliance, 2024. [Online]. Available: https://www.ngmn.org/wp-content/uploads/GFN_Energy_Efficiency_Roadmap_V1.0.pdf |
| (NGMN, 2024b) | NGMN, "Energy Management and Flexibility in Mobile Networks," NGMN Alliance, 2024. [Online]. Available: https://www.ngmn.org/wp-content/uploads/2507_NGMN_GFN_Energy-Management-and-Flexibility-in-Mobile-Networks_v1.0.pdf |
| (NGMN, 2024c) | NGMN, "Environmental Sustainability and Reporting," NGMN Alliance, 2024. [Online]. Available: https://www.ngmn.org/wp-content/uploads/Environmental-sustainability-and-reporting_V1.0.pdf |
| (NGMN, 2024d) | NGMN, "Metering Virtual RAN Infrastructure," NGMN Alliance, 2024. [Online]. Available: https://www.ngmn.org/wp-content/uploads/GFN_Metering-Virt.-RAN-Infrastructure_V1.0.pdf |
| (Nokia, 2024) | Nokia, "Nokia 2024 Sustainability Statement," 2024. [Online]. Available: https://www.nokia.com/sites/default/files/2025-03/nokia-2024-sustainability-report.pdf |
| (NTT DOCOMO, 2024) | NTT DOCOMO, "NTT DOCOMO Group Sustainability Report 2024," 2024. [Online]. Available: https://www.docomo.ne.jp/english/binary/pdf/corporate/csr/about/pdf/e_csr2024w_all.pdf?ver=1740117613 |
| (Ooredoo, 2024) | Ooredoo, "ESG Report 2023," 2024. [Online]. Available: https://www.ooredoo.com/wp-content/uploads/2024/06/300624_v2_2023-_ESG-Report_Ooredoo.pdf |
| (Orange, 2025) | Orange, "Integrated Annual Report 2024–2025," 2025. [Online]. Available: https://gallery.orange.com/element?id=420675 |
| (Samsung Electronics, 2023) | Samsung Electronics, "Sustainability Report 2023," 2023. [Online]. Available: https://www.samsung.com/global/sustainability/media/pdf/Samsung_Electronics_Sustainability_Report_2023_ENG.pdf |
| (Science Based Targets Initiative,2025) | Science Based Targets Initiative, "How to Set Science-Based Targets," [Online]. Available: https://sciencebasedtargets.org/how-to-set-science-based-targets |
| (T-Mobile, 2023) | T-Mobile, "T-Mobile 2023 Corporate Responsibility Report," 2023. [Online]. Available: https://www.t-mobile.com/content/dam/digx/tmobile/us/en/non-dynamic-media/pdf/T-Mobile_2023_Corporate_Responsibility_Report.pdf |

| | |
|---|---|
| (Task Force on Climate-related Financial Disclosures, 2025) | Task Force on Climate-related Financial Disclosures, "Task Force on Climate-Related Financial Disclosures," 2025. [Online]. Available: https://www.fsb-tcfd.org/ |
| (Telefónica, 2024) | Telefónica, "Consolidated Management Report," 2024. [Online]. Available: https://www.telefonica.com/en/shareholders-investors/financial-reports/integrated-annual-report/ |
| (Telia, 2024) | Telia, "Annual Report 2024," 2024. [Online]. Available: https://mb.cision.com/Main/40/4132417/3374317.pdf |
| (Telkomsel, 2024) | Telkomsel, "Building Sustainable Business: Winning the Hearts of Indonesians," 2024. [Online]. Available: https://www.telkomsel.com/sites/default/files/upload/Telkomsel-Sustainability-Report--2024-EN.pdf |
| (TNFD, 2025) | Taskforce on Nature-related Financial Disclosures, "Disclosure recommendations," 2025. [Online]. Available: https://tnfd.global/recommendations/#requirements |
| (UNFCCC, 2019) | UNFCCC, "The Paris Agreement," [Online]. Available: https://unfccc.int/process-and-meetings/the-paris-agreement |
| (UNITAR, 2024) | UNITAR, "Global E-Waste Monitor 2024," 2024. [Online]. Available: https://api.globalewaste.org/publications/file/297/Global-E-waste-Monitor-2024.pdf |
| (United Nations, 2015) | United Nations, Department of Economic and Social Affairs, "Sustainable Development Goals", New York, September 2015, [online] available at https://sdgs.un.org/goals |
| (V. Teamers, 2023) | V. Teamers, "Verizon ESG Report 2023," 2023. [Online]. Available: https://www.verizon.com/about/sites/default/files/Verizon-2023-ESG-Report.pdf |
| (Vodafone, 2024) | Vodafone, "Vodafone Group Plc Annual Report 2024," 2024. [Online]. Available: https://reports.investors.vodafone.com/view/197179846/ |
| (World Bank Group, 2024) | World Bank Group, *Measuring the Emissions and Energy Footprint of the ICT Sector: Implications for Climate Action*, in Other Environmental Study. Washington, D.C.: The World Bank, 2024. doi: 10.1596/41238. |

# 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 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)