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Measuring the Emissions & Energy Footprint of the ICT Sector

IMPLICATIONS FOR CLIMATE ACTION

A Joint ITU/WB Report

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CONTENTS

BOXES

TABLES

FIGURES

FOREWORD

The Information and Communication Technology (ICT) sector finds itself at a pivotal moment — while propelling digital transformation across the globe, it is also contributing to climate change. Enabling more people to get online and to use the internet productively can help deliver massive development payoffs, including by helping communities become more resilient to climate change through improved access to information and service delivery. Despite the sector's remarkable growth, 2.6 billion people remain offline. In addition, the sector's greenhouse gas (GHG) emissions rival those of the aviation industry, and its energy requirements often impose pressure on resources. Therefore, the pressing global challenge lies in closing the connectivity gap and leveraging digital technologies for climate action in an environmentally sustainable manner.

In most countries, data collection and analysis of the ICT sector's GHG emissions and energy consumption is limited. As a result, evaluating its climate impact relies heavily on estimations, which are often available only at an aggregate global level. In the absence of this information, policy makers will encounter challenges in making well-informed decisions about reducing ICT sector emissions and managing energy resources.

This joint report by the International Telecommunication Union and the World Bank, which contributed to the Green Digital Action at COP28 and beyond, aims to address this data gap. It provides comprehensive GHG emissions and energy consumption data for the ICT sector, particularly for telecommunications and data centers. The report compiles emissions data at a country level from publicly accessible sources within the thirty most emitting countries' telecommunications operators. Its goal is to unravel the emissions and energy usage patterns within the sector while exploring their implications for climate action, as well as to make the case for this data becoming readily available in all countries.

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ACRONYMS

2G	Second generation of cellular networks
3G	Third generation of cellular networks
4G	Fourth generation of cellular networks
5G	Fifth generation of cellular networks
ADEME	National Agency for the Ecological Transition (France)
AI	Artificial intelligence
ARCEP	Regulatory Authority for Electronic Communications, Postal Affairs, and Print Media Distribution (France)
ATM	Automatic Teller Machines
AWS	Amazon Web Services
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP	Conference of the Parties
DG	Distributed Generation (Brazil)
EIA	Energy Information Administration
EMA	Energy Markets Authority (Singapore)
eMBB	Enhanced mobile broadband
EMEA	Europe, Middle East, and Africa
EPA	Environmental Protection Agency (United States)
ESG	Environmental, social, and governance
FGVces	Fundação Getúlio Vargas
GEF	Grid Emissions Factor
GeSI	Global Enabling Sustainability Initiative
GHG	Greenhouse gas
GRI	Global Reporting Initiative
GSMA	Global System for Mobile Communications Association
GW	Gigawatts
GWh	Gigawatt hour
HFC	Hydrofluorocarbon
ICT	Internet and communication technology
IFRS	International Financial Reporting Standards

IMDA	Infocomm Media Development Authority (Singapore)
IoT	Internet of Things
ISO	International Organization for Standardization
ITU	International Telecommunication Union
LAC	Latin America and the Caribbean
LCA	Life Cycle Assessment
LMICs	Low and middle-income countries
M2M	Machine-to-machine
MW	Megawatts
MWh	Megawatt hour
N_2O	Nitrous oxide
PB	Petabytes
PC	Personal computer
PFC	Perfluorocarbon
PLDT	Philippine Long Distance Telephone Company
REC	Renewable Energy Certificates
RURA	Rwanda Utilities Regulatory Authority
SBTi	Science Based Targets initiative
SECR	Streamlined Energy and Carbon Reporting Regulation
SF_6	Sulfur hexafluoride
SGX	Singapore Exchange
SME	Small and Medium Enterprise
TCFD	Task Force on Climate-related Financial Disclosures
TV	Television
TW	Terawatt
TWh	Terawatt hour
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

EXECUTIVE SUMMARY

Digitalization is increasing rapidly worldwide, requiring more energy and resulting in greenhouse gas (GHG) emissions. According to ITU two thirds of the world's population are now online.[1] Estimates of the ICT sector's share of global carbon emissions vary across the literature ranging from 1.5 to 4 percent.[2] Based on the data and estimates in this report at least 1.7 percent of global emissions stem from the ICT sector.

Meanwhile, one-third of the world's population, or 2.6 billion people, remain unconnected to the internet. The large majority, about 94 percent, live in low and middle-income countries (LMICs), and less than 20 percent of LMICs have modern data infrastructure, such as co-location data centers and access to cloud computing.[3] Connecting people in these countries will require more infrastructure and devices, which will further increase demand for scarce energy resources and drive emissions even higher if targeted interventions are not implemented.

Global climate goals call for almost halving of emissions from the broader information and communications technology (ICT)[4] sector by 2030.[5] The ICT sector accounted for 60 percent of renewable power purchases in 2021.[6] Four ICT sector companies are among the top 20 corporate consumers of electricity worldwide,[7] and on the positive side, the sector is among the world's biggest users of renewable energy; six of the top 10 corporate purchasers of renewable energy in 2022 were tech companies.[8] This points to potential avenues to control and abate the increasing emissions from the ICT sector while connecting the still unconnected people in the world.

Making policies to achieve these two ambitious goals—reducing emissions from the fast-growing ICT sector while connecting the unconnected—requires better data on ICT sector energy use and emissions. In contrast to other sectors, no comprehensive data on country-based ICT sector emissions exists. Global and regional estimates of ICT energy use and emissions exist based on partial data sources, models, and assumptions rather than country-level data. Data on the main ICT subsectors—telecommunications, connectivity networks, data centers, and consumer devices—is necessary to inform overall ICT sector interventions.

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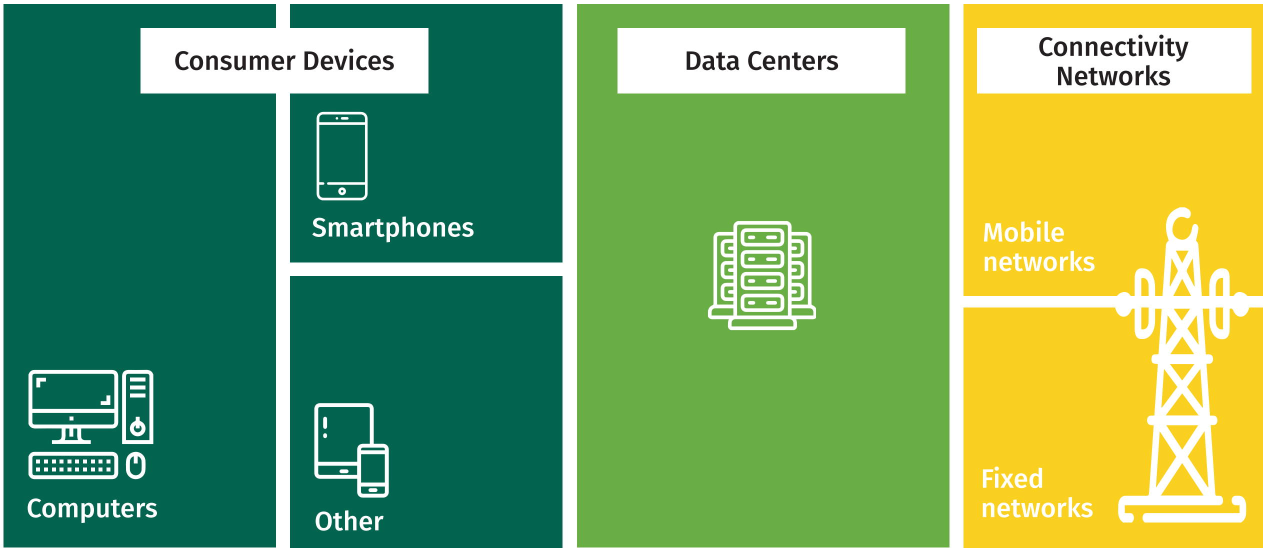
1 ITU. 2023. "Population of global offline continues steady decline to 2.6 billion people in 2023. *Press Release*, 12 September. https://www.itu.int/en/mediacentre/Pages/PR-2023-09-12-universal-and-meaningful-connectivity-by-2030.aspx
2 World Bank. 2023. *Green Digital Transformation: How to Sustainably Close the Digital Divide and Harness Digital Tools for Climate Action*.
3 World Bank. 2021. *World Development Report 2021: Data for Better Lives*. Washington, DC: World Bank. doi:10.1596/978-1-4648-1600-0.
4 The ICT sector is defined in the International Standard Industrial Classification and consists of three main industries: manufacturing, telecommunications and IT software and services. See: United Nations. 2008. *International Standard Industrial Classification of All Economic Activities*, Revision 4. https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf
5 ITU. 2020. "ICT industry to reduce greenhouse gas emissions by 45 per cent by 2030." *Press Release*, 20 February. https://www.itu.int/en/mediacentre/Pages/PR04-2020-ICT-industry-to-reduce-greenhouse-gas-emissions-by-45-percent-by-2030.aspx
6 See "Global renewable energy power purchase agreements by sector, 2010-2021" at: https://www.iea.org/data-and-statistics/charts/global-renewable-energy-power-purchase-agreements-by-sector-2010-2021
7 ITU and WBA. 2023. *Greening Digital Companies 2023*. https://www.itu.int/en/ITU-D/Environment/Pages/Greening-Digital-Companies-2023.aspx
8 BloombergNEF. 17 March 2023. "Tech Firms Seal US Dominance in Corporate Clean Power Purchasing." https://about.bnef.com/blog/tech-firms-seal-us-dominance-in-corporate-clean-power-purchasing/

Figure ES.1: Sources of ICT sector emissions



Efforts are being made to standardize ICT sector-specific methodologies and reporting frameworks. France is the only country where a regulator currently compiles telecommunications sector emissions and energy use.[9] In contrast, for other key economic sectors governments are mandated to submit their national GHG inventories, which include assessments of both emissions and emissions reductions, to international bodies like the United Nations Framework Convention on Climate Change (UNFCCC) as part of agreements such as the Kyoto Protocol and the Paris Agreement.

The objective of this report is two-fold. First, the report breaks down the energy and emissions profile of the sector and assesses the 30 highest emitting countries for telecommunications while providing global estimates for other ICT sector segments. The report uses a key framework for categorizing energy use and emissions, the Greenhouse Gas Protocol Corporate Standard.[10]

- **Scope 1 Emissions** are direct emissions from owned or controlled sources.
- **Scope 2 Emissions** are indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the firm.
- **Scope 3 Emissions** are all indirect emissions, upstream or downstream, (not included in Scope 2) that occur in the firm's value chain.

Second, the report addresses the policy and regulatory implications inferred from this data and the examination of these issues through several country case studies.

[9] ARCEP. 2023. "Achieving digital sustainability: Arcep publishes the second edition of its annual inquiry." *Press Release*, 18 April. https://en.arcep.fr/news/press-releases/view/n/environnment-180423.html

[10] World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD). 2004. *GHG Protocol Corporate Accounting and Reporting Standard.* https://ghgprotocol.org/corporate-standard

KEY POLICY TAKEAWAYS

Data-driven decision making: Access to data on emissions and energy usage, reported by companies in a common format, is crucial for governments to make informed policy decisions, set realistic emission reduction targets, and monitor progress. Collaboration across government entities such as ICT and energy sector regulators and environment agencies is vital for maximizing synergies to address the carbon footprint of the ICT sector and manage energy resources.

Government oversight and engagement: Governments play a fundamental role in upholding environmental responsibility. Engaging with the ICT sector ensures accurate emissions reporting and effective reduction measures. High-level recognition of the importance of emissions data is essential for implementing necessary policies and regulations.

Data disclosure and assessment: Addressing emissions from the ICT sector requires data disclosure, aggregation, and assessment. The ICT regulator can play a key role in this process, but capacity building will be needed. Disparities in GHG emissions and energy consumption exist between countries, emphasizing the need for global data collection efforts.

Technology transitions and inclusive planning: Technology transitions in the ICT sector have the potential to reduce emissions, but careful planning is required to ensure inclusivity and prevent the marginalization of vulnerable populations. Balancing sector growth with emission reduction involves planning transitions, such as decommissioning older networks, while also considering the impact on coverage, device costs, and the conversion of machine-to-machine devices to the Internet of Things (IoT).

Regulatory modifications and collaboration: Regulatory modifications, along with incentives and collaboration between the ICT and energy sectors, can help reduce emissions and promote sustainable energy access. Regulations and financial incentives can play a role in reducing emissions, with examples like South Africa's energy market liberalization and Brazil's Direct Generation (DG) regulation leading to increased use of clean energy in the ICT sector.

Energy management: ICT emissions reflect sector maturity and the local energy mix. While the sector's emissions are relatively low in many developing countries the current and future strain on energy resources can be high. Therefore, enhancing data collection related to the sector's energy use is important for energy resource management.

1. INTRODUCTION

The International Telecommunication Union (ITU) set the goal in 2020 to reduce the total emissions from the Information and Communication Technology (ICT) sector by 45% by 2030 in order to contribute proportionally to the reduction of global warming following a 1.5°C trajectory.[11] Estimates of the ICT sector's share of global carbon emissions vary across literature ranging from 1.5 to 4 percent.[12] Based on the data and estimates in this report at least 1.7 percent of global emissions stem from the ICT sector. However, these are a conservative estimate as there is a lack of regulated emissions reporting from the sector. This means that ICT sector emissions are not typically addressed in national climate action plans and there is an unprecise estimate of the sector's climate impact.

This lack of data makes it difficult to develop strategies to achieve emission reduction targets and account for the sector's environmental impact. Yet, digitization is increasing rapidly, requiring more energy consumption and producing more GHG emissions in most cases.[13] The ITU estimates that the number of internet users has increased 17 percent between 2020 and 2023, and 5.4 billion people today—67 percent of the world's population—are online.[14] Wired and wireless broadband internet subscriptions increased 14 percent between 2020 and 2022, and connected data centers increased 72 percent between 2018 and 2022.[15] This substantial growth adds to the climate footprint of the sector and strains scarce energy resources in many countries, but the precise extent remains uncertain.

Although the sector is growing rapidly, one-third of the world's population, or 2.6 billion people, still remains unconnected to the internet, and less than 20 percent of low and middle-income countries (LMICs) have modern data infrastructure, such as co-location data centers and access to cloud computing.[16] The large majority, about 94 percent, of unconnected individuals live in LMICs, where the cost of internet-enabled mobile devices is among key barriers[17], along with reliable and affordable energy to power ICT infrastructure and devices.[18],[19] Therefore, connecting the unconnected will require more infrastructure and devices, which will further increase demand for energy and drive emissions even higher without targeted interventions.

In contrast to other sectors, reliable ICT emissions data[20] is largely unavailable. High-emitting sectors—such as transport, energy, and forestry—have well-established measurement to inform mitigation efforts. The

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11 ITU. 2020. "ICT industry to reduce greenhouse gas emissions by 45 per cent by 2030." *Press Release*, 20 February. https://www.itu.int/en/mediacentre/Pages/PR04-2020-ICT-industry-to-reduce-greenhouse-gas-emissions-by-45-percent-by-2030.aspx
12 World Bank. 2023. *Green Digital Transformation: How to Sustainably Close the Digital Divide and Harness Digital Tools for Climate Action.*
13 European Parliament. 25 September 2022. "The EU climate strategy for the ICT sector." https://www.europarl.europa.eu/doceo/document/E-9-2022-002947_EN.html
14 ITU. 2023. "Population of global offline continues steady decline to 2.6 billion people in 2023. *Press Release*, 12 September. https://www.itu.int/en/mediacentre/Pages/PR-2023-09-12-universal-and-meaningful-connectivity-by-2030.aspx
15 World Bank. *Digital Progress Report* (forthcoming).
16 World Bank. 2021. *World Development Report 2021: Data for Better Lives.* https://www.worldbank.org/en/publication/wdr2021
17 GSMA. 2017. *Accelerating Affordable Smartphone Ownership in Emerging Markets.* https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/08/Accelerating-affordable-smartphone-ownership-in-emerging-markets-2017_we.pdf
18 World Bank . 2023. *Affordable Devices for All Innovative Financing Solutions and Policy Options to Bridge Global Digital Divides*. https://www.worldbank.org/en/topic/digitaldevelopment/publication/affordable-devices-for-all-innovative-financing-solutions-and-policy-options-to-bridge-global-digital-divides
19 In Mozambique, the World Bank is supporting investments in renewable energy powered broadband services for government offices, schools, and health centers, as well as joint deployments of home solar systems and renewable energy powered mobile networks covering up to 1.3 million individuals in rural communities.
20 The ICT sector is defined in the International Standard Industrial Classification and consists of three main industries: manufacturing, telecommunications and IT software and services. See: United Nations. 2008. *International Standard Industrial Classification of All Economic Activities, Revision 4*. https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

limited measurement of ICT emissions is a result of historical priorities, data complexities, and comparably lower emissions. However, this situation is changing due to rapid digitalization. Four ICT sector companies are now among the top 20 corporate consumers of electricity, the only ones outside the traditional high-emitting industries: chemicals, construction, metals and mining, oil and gas, and utilities.[21]

The objective of this report is two-fold. First, the report assesses the energy and emissions profile of the ICT sector. Second, the report addresses the policy and regulatory implications inferred from this data and examines these issues through several country case studies.

Private sector companies, which are the main drivers of growth and innovation in the ICT sector, are making progress on addressing the sector's emissions and energy challenges. Globally, the ICT sector accounted for 60 percent of renewable power purchases in 2021,[22] and six of the top 10 corporate purchasers of renewable energy in 2022 were tech companies.[23] The public sector also has an important role in managing the finite resources and ensuring a conducive enabling environment for sustainable digitalization. To meet the goal of reducing the sector's emissions by almost half within less than seven years, they must be tracked to inform national policies and climate actions.

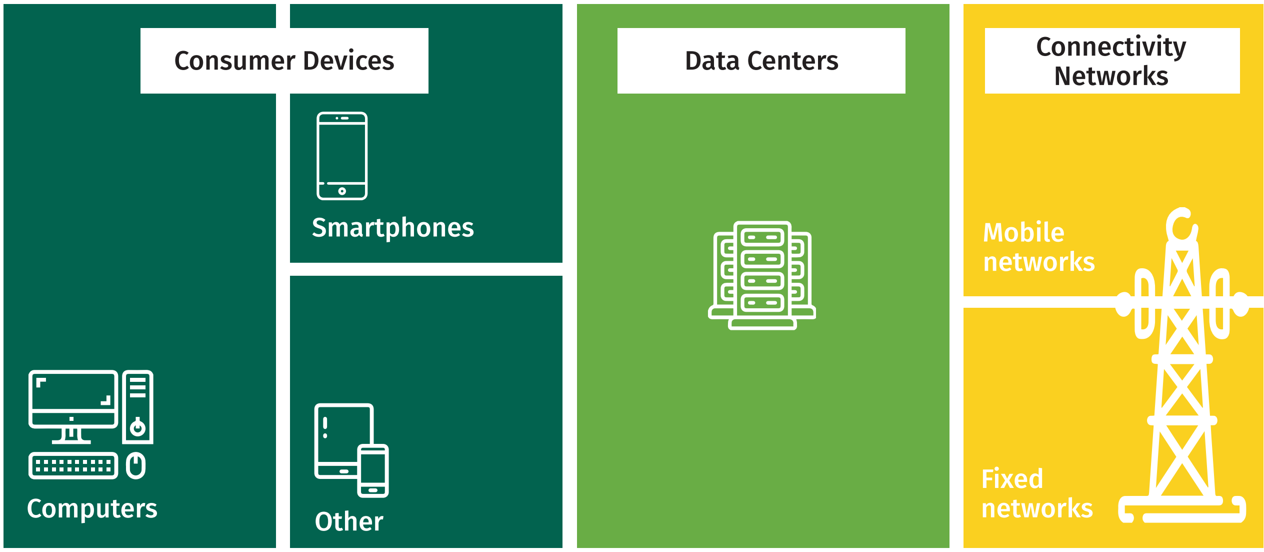
21 ITU and WBA. 2023. *Greening Digital Companies 2023*. https://www.itu.int/en/ITU-D/Environment/Pages/Greening-Digital-Companies-2023.aspx
22 See "Global renewable energy power purchase agreements by sector, 2010-2021" at: https://www.iea.org/data-and-statistics/charts/global-renewable-energy-power-purchase-agreements-by-sector-2010-2021
23 BloombergNEF. 17 March 2023. "Tech Firms Seal US Dominance in Corporate Clean Power Purchasing." https://about.bnef.com/blog/tech-firms-seal-us-dominance-in-corporate-clean-power-purchasing/

2. MEASURING THE ICT SECTOR EMISSIONS AND ENERGY DEMAND

Making informed decisions on reducing emissions and managing ICT sector energy demands requires various types of data. At the country level, sector energy consumption data can help governments manage finite energy resources and devise policies and regulatory measure to reduce the sector's carbon footprint. No comprehensive data on country-based ICT sector emissions currently exists, except for France.[24] Since the sector operates across borders, producing regional data is also helpful for assessing energy needs and providing a regional perspective. Ultimately, global data is needed to understand the total footprint of the sector and how this grows over time.

Data on the main ICT subsectors is also necessary to inform overall ICT sector interventions. The main market segments of the sector include connectivity networks, data centers, and consumer devices (Figure 2.1). Distribution of ICT sector emissions across market segments depends on the country's position in the sector's value chain. For example, devices, which generate emissions during the manufacturing process, are made in a small number of countries. Similarly, hyperscale data centers serving global markets are located in relatively few countries. In these countries, corporate climate commitments, effective government policies, and use of renewable energy represent effective ways of lowering global ICT emissions. For most developing countries, the primary near-term focus will be on connectivity networks although investments in data centers are becoming an increasingly important emissions factor.

Figure 2.1: Sources of ICT sector emissions



[24] ARCEP. 2023. "Achieving digital sustainability: Arcep publishes the second edition of its annual inquiry." *Press Release,* 18 April. https://en.arcep.fr/news/press-releases/view/n/environnment-180423.html

2.1 EMISSIONS REPORTING AND TRACKING

France is the only country where the electronic communications regulator compiles telecommunications sector emissions and energy use.[25] In contrast, for sectors such as energy, waste, and agriculture, governments are mandated to submit their national GHG inventories, which include assessments of both emissions and emissions reductions, to international bodies like the United Nations Framework Convention on Climate Change (UNFCCC). These obligations are part of agreements, such as the Kyoto Protocol and the Paris Agreement.

Efforts are being made to develop standardized ICT sector-specific methodologies and reporting frameworks, and some countries are taking steps to address these emissions in their climate action plans. But more needs to be done to ensure a “green” digital transition is compatible with the Paris agreement objectives. For example, the ITU has developed standards using science-based targets[26] to achieve net-zero ICT emissions. This includes guidance for ICT companies to reach the 1.5° C target in the Paris Agreement (ITU-T L.1470), including decarbonization pathways for mobile networks, data centers, and manufacturers, which was developed in cooperation with Science Based Targets initiative (SBTi), Global Enabling Sustainability Initiative (GeSI) and Global System for Mobile Communications Association (GSMA).[27] Specific net-zero guidance for ICT companies (ITU-T L.1471) aligns with initiatives such as the “Race to Zero” campaign. ITU also provides technical standards for assessing energy consumption and GHG emissions for ICT organizations (ITU-T L.1420). Methodologies for the assessment of the environmental impact of the information and communication technology sector (ITU-T L.1450) and Enabling the Net Zero transition: assessing how the use of information and communication technology solutions impact GHG gas emissions of other sectors (ITU-T L.1480).

Nearly all major publicly listed ICT companies publish environmental, social, and governance (ESG) reports with climate data. In some cases, this is in response to mandatory reporting requirements from financial authorities. Sometimes sustainability-linked financing bonds require ESG reporting. Shareholder pressure and reputation are other factors driving disclosure. In contrast, privately-owned, unlisted companies and fully state-owned enterprises rarely disclose data, although they are estimated to account for a small portion of global ICT sector revenue. Company-level data can be aggregated in a "bottom-up" approach to compiling country data.[28] Almost all companies use the Greenhouse Gas Protocol to record their emissions (Box 2.1).

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25 Telecommunication operators deploy energy using infrastructure to support their services. This includes mobile base stations, fiber optic cable, vehicle fleets, and in many cases data centers for their own use and/or to provide hosting for clients. Telecommunications also includes the extensive fiber optic and satellite networks across the globe.

26 The Science Based Target initiative (SBTi) reviews company emissions reduction targets to assess whether they are aligned with the Paris Agreement goals. As of April 2023, almost 5,000 companies around the world had submitted targets of which 2,600 have been approved as being aligned with a 1.5 degree pathway. See: https://sciencebasedtargets.org/companies-taking-action#dashboard

27 ITU. 2020. *Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement*. https://www.itu.int/rec/T-REC-L.1470

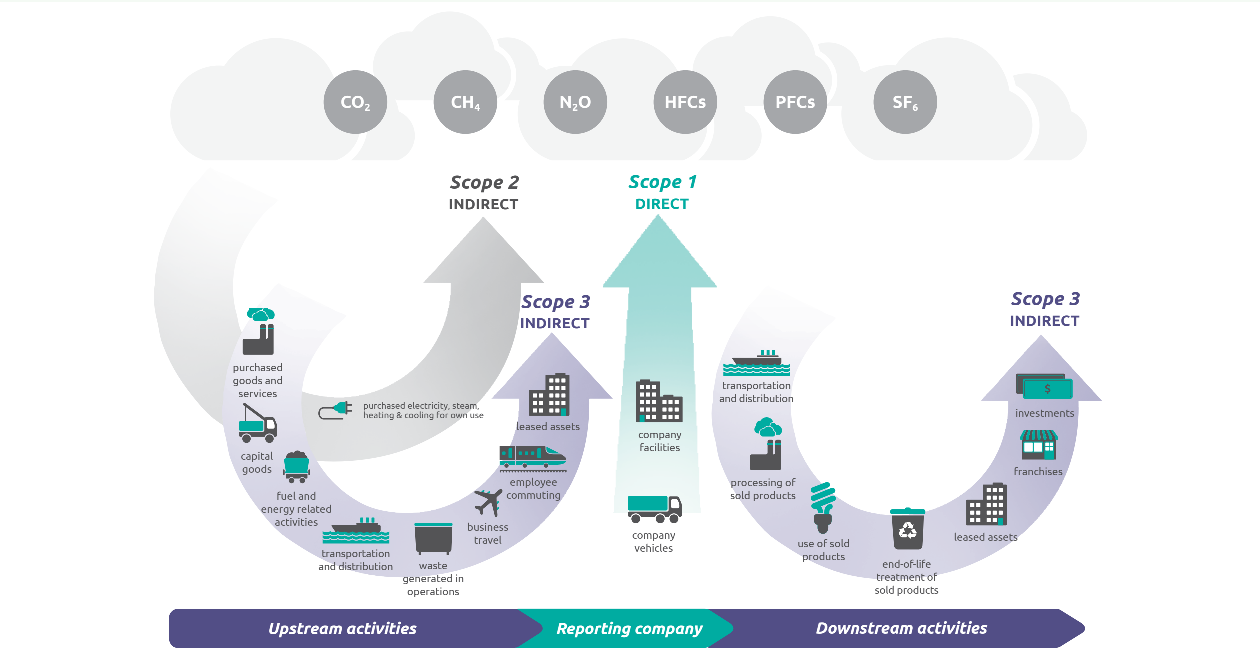
28 Using firm level data for analyzing carbon emissions dates back to 2014 (Heede, R. Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010. *Climatic Change* 122, 229–241 (2014). https://doi.org/10.1007/s10584-013-0986-y). More recently, the World Bank used the bottom up approach to analyze the effect of multinational enterprises on climate change (Steenbergen, Victor, and Abhishek Saurav. 2023. *The Effect of Multinational Enterprises on Climate Change: Supply Chain Emissions, Green Technology Transfers, and Corporate Commitments*. Washington, DC: World Bank. doi:10.1596/978-1-4648-1994-0.).

BOX 2.1: THE GREENHOUSE GAS PROTOCOL

The Greenhouse Gas Protocol Corporate Standard,[29] a joint World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) initiative, classifies a firm's GHG emissions into three scopes (WRI and WBCSD 2004):

- **Scope 1 Emissions** are direct emissions from owned or controlled sources. Direct GHG emissions are principally the result of activities such as (i) generating electricity, heat, or steam; physical or chemical processing; transportation of materials, products, waste, and employees; and (ii) fugitive emissions, such as equipment leaks from joints, seals, packing, and gaskets.
- **Scope 2 Emissions** are indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the firm.
- **Scope 3 Emissions** are all indirect emissions (not included in Scope 2) that occur in the firm's value chain. These include upstream emissions, which relate to the purchase and use of goods, services, energy, and capital in the production process. They also include downstream emissions, which mostly relate to the transport, processing, use, and disposal of sold products. This also includes emissions from services such as leased assets, franchises, and investments.

Figure 2.2: Emissions associated with firms' activities within Scope 1, 2 and 3



Source: WRI/WBCSD Corporate Value Chain (Scope 3) Accounting and Reporting Standard (WRI and WBCSD 2004).
Note: WBCSD = World Business Council for Sustainable Development; WRI = World Resources Institute. CO_2 = Carbon dioxide; CH_4 = Methane; HFCs = Hydrofluorocarbons; N_2O = Nitrous oxide; PFCs = Perfluorocarbons; SF_6 = Sulfur hexafluoride.
Box attribution: Steenbergen, Victor, and Abhishek Saurav. 2023. *The Effect of Multinational Enterprises on Climate Change: Supply Chain Emissions, Green Technology Transfers, and Corporate Commitments.*

[29] https://ghgprotocol.org/corporate-standard

As noted, most countries do not collect GHG emissions and energy consumption data for the ICT sector. This report will discuss some of the few emerging exceptions. As a result, data on the sector's climate impact are very rough estimates.

This report estimates GHG emissions and electricity consumption for the ICT sector's main industries: telecommunications and data centers. It also estimates emissions from the production and use of devices. However, since only country estimates can be made for the telecommunications industry, there are limited country breakdowns for the other industries, so this report can only provide global estimates.

2.2 TELECOMMUNICATIONS GHG EMISSIONS AND ENERGY CONSUMPTION

An abundance of climate data exists for the telecommunications sector, referred to as a "climate disclosure leader".[30] To calculate country-level data for the telecommunications industry, this report has collected publicly available company data to estimate emissions and energy data for telecommunication operators from the 30 largest GHG emitting economies.[31] These operators account for 95 percent of global telecommunication revenues in 2022.[32] They are the largest in each country considered and generally account for all telecommunications revenue and/or subscriptions (See Annex).

It is estimated that telecommunications operators generated 133 million tCO_2e of operational emissions in 2022 (Scope 1 and Scope 2 location based), accounting for 0.4 percent of total global GHG emissions from energy (Figure 2.3).[33] Emissions dropped around 1 percent annually between 2020 and 2022. The Asia Pacific region accounts for the largest share of GHG emissions reported by telecommunication operators, representing 69 of global emissions from the sector. The three operators from China accounted for almost half the emissions.[34] The main reason for Asia Pacific's large share is that the region accounts for a significant amount of global mobile and broadband subscriptions while having electrical grids that are mainly powered by fossil fuels. Nine countries experienced an increase in emissions between 2020 and 2022; all but one (South Africa) were from the broader Asia region. Seven of the nine countries experiencing rising emissions are low and middle-income nations. Asian telecom operators have also been comparatively slower to decarbonize their operations and establish ambitious emissions reduction targets.[35]

30 EY. 1 June 2020. "How telecommunications sector emerged as a climate disclosure leader." https://www.ey.com/en_nl/climate-change-sustainability-services/how-telecommunications-sector-emerged-as-a-climate-disclosure-leader

31 The Russian Federation, Iran, Vietnam and Pakistan were excluded due to a lack of data.

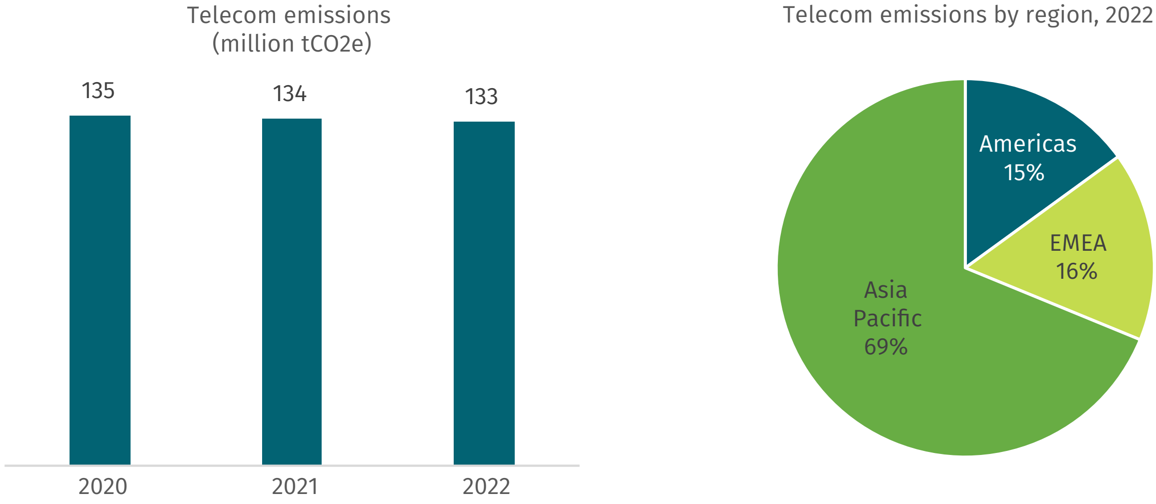
32 "IDC Telecom Services Tracker Finds the Market Growth is Speeding Up as the Effects of Inflation are Becoming Visible in All Global Regions." *Press Release*, 5 May 2023. https://www.idc.com/getdoc.jsp?containerId=prUS50644723

33 It is important to note that the figures do not take into account the initiatives developed by numerous telecommunication operators to source their electricity from renewable sources, thus reducing significantly their market-based Scope 2 emissions.

34 One reason is that they have significant data center operations.

35 Greenpeace East Asia. 2021. *Race to Green*. https://www.greenpeace.org/static/planet4-eastasia-stateless/2021/12/a29b3a1d-race-to-green-report.pdf

Figure 2.3: Estimated telecommunication GHG emissions



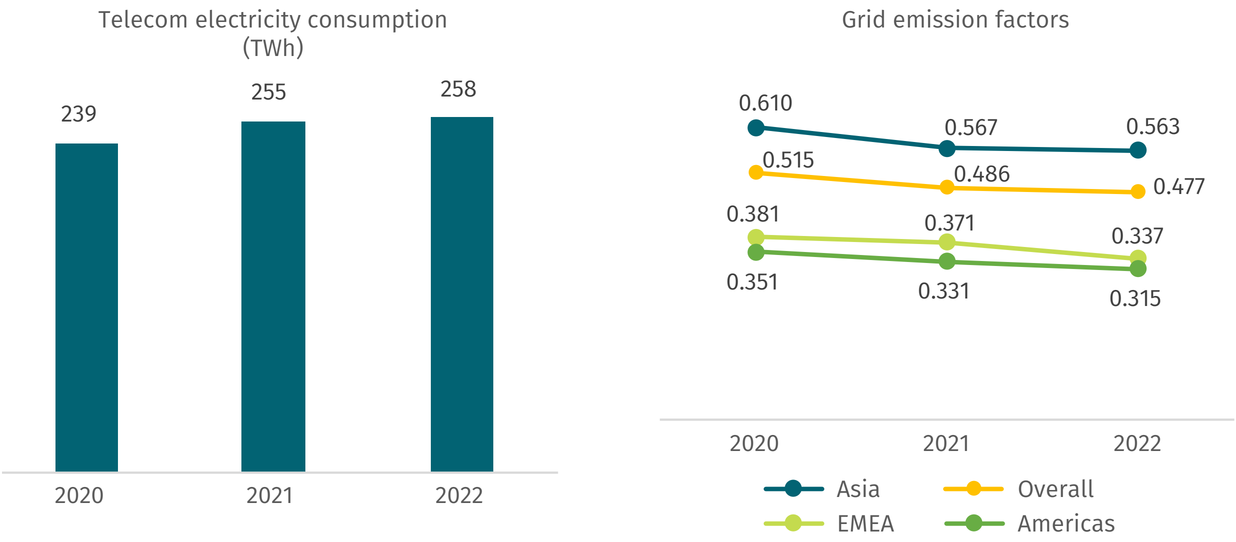
Note: Scope 1 and Scope 2 location-based. Asia-Pacific includes East and South Asia; EMEA = Europe, Middle East and Africa.
Source: Company reports (see Annex).

In contrast to GHG emissions, electricity consumption by telecommunications operators continues to grow, rising 6.9 percent between 2020 and 2022 (Figure 2.4, right). Some 258 TWh of electricity was used to power telecommunication networks in 2022, around 1 percent of total world electricity consumption. The main reason that higher electricity consumption did not translate into equivalent growth in emissions is that grids are being updated to be "greener". The Grid Emissions Factor (GEF), which measures the mix of energy sources to power the grid,[36] dropped 7.4 percent between 2020 and 2022 (Figure 2.4, right). Asia has the highest GEF, 1.8 times higher than the Americas, the region with the lowest GEF.

While electricity is the biggest source of energy use in telecommunications, operators also use fuels to power network equipment, their vehicles, and also as backup. Emissions from the use of fuels are included in Scope 1. GHG emissions from fuel accounted for just 5 percent of the total in 2022 and 1 percent or less in a number of East Asian countries. Nonetheless, Scope 1 accounted for a fifth or more of emissions in a few countries. This includes high-income countries such as Canada, France, and the United Kingdom where fuel for large vehicle fleets generates significant emissions or where the electricity grid is relatively decarbonized. It also includes middle-income countries such as Egypt and Iraq where diesel fuel powers mobile base stations in unelectrified locations. In the high-income countries, moving to electric vehicles would mitigate emissions, while in the middle-income countries either moving to renewable-powered base stations or extending the grid would lower emissions.

[36] Scope 2 location-based emissions (tCO2e) ÷ electricity consumption (MWh)

Figure 2.4: Estimated telecommunications electricity consumption and grid emissions factors



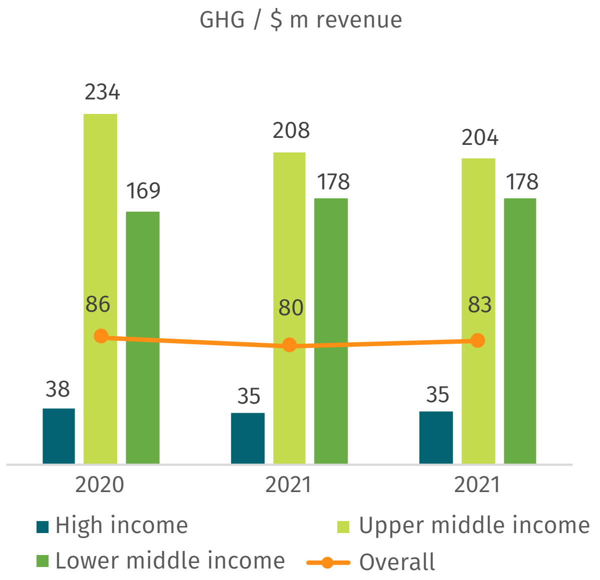
Source: Company reports (see Annex).

2.2.1 CARBON AND ENERGY INTENSITY

Intensity ratios provide a comparable metric for assessing emissions and energy performance. Energy intensities in particular provide one method of accessing whether countries are becoming more energy efficient in their use of ICT. Revenue is the most common intensity denominator because it is universally available. Average carbon intensity ($tC0_2e$ ÷ US$ million revenue) for the telecommunications sector among the 30 countries assessed was 83 in 2022 (Figure 2.5, left). This is an increase from 2021 but lower than 2020. Middle-income countries have higher carbon output per unit of revenue than high-income countries; carbon intensity in the lower middle-income nations included in the assessment was 5.1 times higher than high-income countries in 2022, while for upper middle-income countries it was 5.8 times higher. Carbon intensities ranged from 8 in France to 246 in Indonesia.

Since most of the telecommunication operators' overall operational emissions are from electricity, one would expect a correlation between carbon intensity and the grid emissions factor (Figure 2.5, right). There is somewhat of a relationship to the extent that countries with the cleanest grids also have low carbon intensities. However, countries with a GEF greater than 0.6 generally have higher carbon intensity than expected. This suggests greater use of fuels, as well as network inefficiencies.

Figure 2.5: GHG emissions / $million revenue and relationship between carbon intensity and GEF



Note: GEF = Grid Emissions Factor.
Source: Company reports.

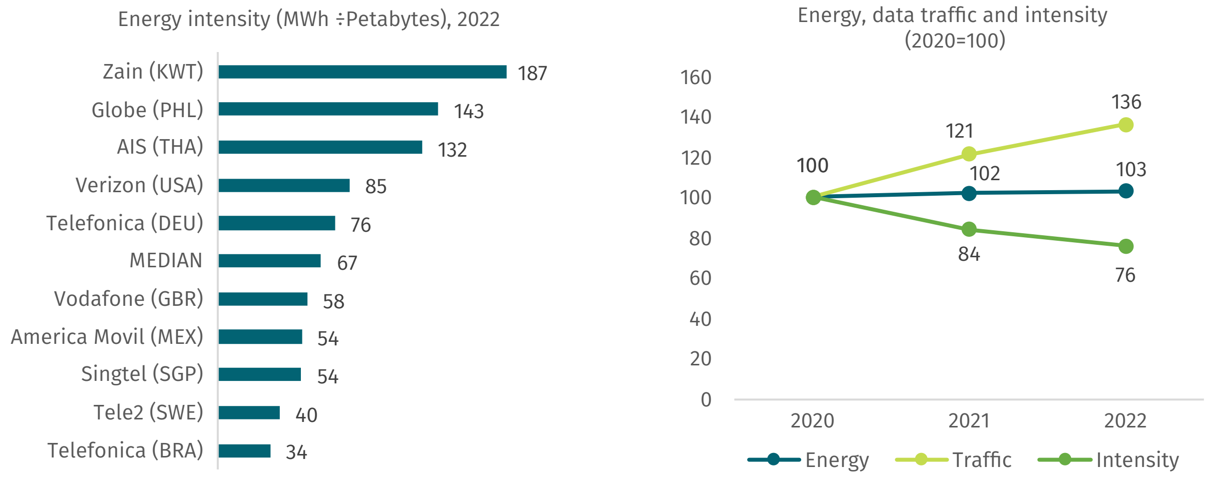
Energy intensity reflects efficiency. Given that data is the main driver of activity over telecommunications networks, it is relevant to use it as the denominator for the intensity metric (that is, energy use ÷ data traffic). One challenge is that few countries disclose the total amount of data traffic, both fixed and mobile. At the firm level, the International Financial Reporting Standards (IFRS) Foundation has industry specific guidance on climate disclosures for the telecommunications sector with relevant indicators for measuring energy intensity.[37] These include total energy consumption and network traffic in petabytes (PB). A number of telecommunications operators use the standard for their reporting.[38] However many do not disclose network traffic stating that it is confidential, proprietary, or competitively sensitive.

Energy intensity varies widely among companies that report the data (Figure 2.6, left). The median among this group was 67 MWh/PB in 2022. Energy efficiency improved by 24 percent among this group between 2020 and 2022, while data traffic increased 36 percent and energy use 3 percent (Figure 2.6, left). Despite burgeoning data traffic, energy intensity is improving.

[37] This is based on the Sustainability Accounting Standards Board (SASB) disclosure. See: IFRS. 2023. *Industry-based Guidance on implementing Climate-related Disclosures-Volume 59—Telecommunication Services.* https://www.ifrs.org/content/dam/ifrs/publications/pdf-standards-issb/english/2023/issued/part-b/ifrs-s2-ibg-volume-59-telecommunication-services-part-b.pdf?bypass=on

[38] See "Companies reporting with SASB Standards" at: https://sasb.org/company-use/sasb-reporters/

Figure 2.6: Energy intensity among telecommunications operators



Note: Text in parenthesis is the ISO country code of where the company is headquartered. The right chart shows the aggregate for the ten companies.
Source: Company reports.

2.2.2 NETWORK EFFICIENCIES

Network infrastructure is becoming more energy efficient per unit of data. According to the Swedish telecommunications hardware vendor Ericsson: "By 2022, Ericsson's 5G product portfolio will be 10 times more energy-efficient for the same transferred data than its 4G portfolio (baseline 2017) for an enhanced mobile broadband (eMBB) use case. Results from 2020 show that the company's current 5G radios are already approximately 6.6 times more energy-efficient."[39]

The challenge is that data traffic grows rapidly in response to the greater capacity and speeds of new generations of mobile infrastructure. Ericsson concedes this showing rising energy consumption as network capacity increases (Figure 2.7, left). It estimates the annual global energy cost for running mobile networks in 2020 to be about US$ 25 billion[40] and forecasts that mobile data traffic will rise 26 percent per year between 2022 and 2028, while fixed data traffic will increase 14 percent per year.[41] According to Ericsson, three elements are needed for "breaking the energy curve": (i) good planning; (ii) modernizing existing networks; and (iii) optimizing network capacity to fluctuating data traffic.[42]

Evidence from UAE operator ***du*** indicates that its 2G network uses by far the most energy per unit of data even though it accounts for less than 1 percent of total traffic (Figure 2.7, right). However its 5G network has higher energy intensity than its 4G network, likely due to not yet achieving the needed scale. Given that 2G and 3G account for just over 2 percent of data traffic but 46 percent of energy, migrating users to 4G and 5G

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[39] Ericsson. 2021. *Decarbonizing industries with connectivity & 5G*. https://www.ericsson.com/4a98c2/assets/local/about-ericsson/sustainability-and-corporate-responsibility/environment/mit-technology-review-decarbonizing-industries-with-connectivity-and-5g.pdf

[40] Ericsson. 2020. "Breaking the energy curve: how to roll out 5G without increasing energy consumption." *News*, March 11. https://www.ericsson.com/en/news/2020/3/breaking-the-energy-curve

[41] Ericsson. 2023. *Mobility Report*. https://www.ericsson.com/49dd9d/assets/local/reports-papers/mobility-report/documents/2023/ericsson-mobility-report-june-2023.pdf

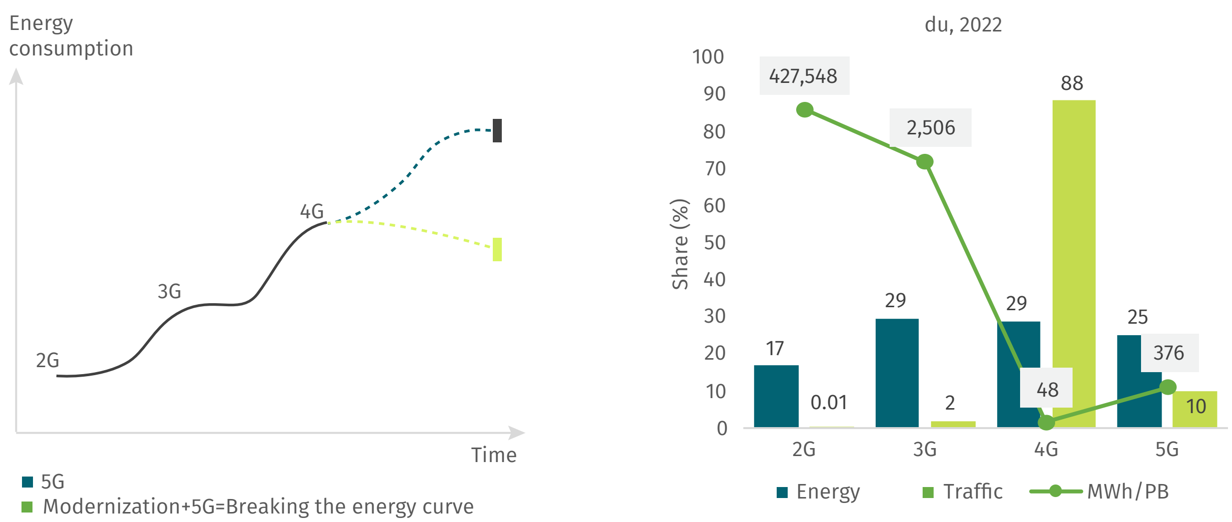
[42] Ericsson. 2022. *On the road to breaking the energy curve*. https://www.ericsson.com/4aa14d/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2022/breaking-the-energy-curve-report.pdf

networks over time would increase emissions efficiency. ***du's*** 16-year-old 2G network is being shut down at the end of 2023.[43] This migration is appropriate in high income economies and will progressively become so in developing countries with appropriate safeguards in place to ensure inclusion.

In France, 2G and 3G networks consume 17 percent of telecom operators' energy consumption despite accounting for less than 2 percent of data traffic. A study supported by the country's electronic communications regulator implied the desirability of eliminating 2G and 3G networks, from an energy efficiency perspective.[44] There would be an initial increase in embedded emissions for those who need to purchase new devices. However, the breakeven point between 4G/5G carbon decrease benefits compared negative carbon impacts is estimated to be reachable in less than six months. The climate benefit of moving to 4G/5G should also be considered when assigning spectrum.[45]

In response to network efficiencies, policies—especially longer-term interventions—should reflect market innovations. As Figure 2.7 shows, the transition from 3G to 4G resulted in far greater traffic while keeping energy usage flat. Therefore, the transition from 3G to 4G has both energy efficiency benefits, and has unlocked an increasing array of use cases requiring more data, such as early-warning capabilities, that can have significant benefits for vulnerable communities. However, availability and affordability of 4G devices is a critically important factor to facilitate and incentive this transition.[46]

Figure 2.7: Mobile network equipment energy consumption and "du" energy intensity 2022



Source: Ericsson. 2021. Decarbonizing industries with connectivity & 5G. https://www.ericsson.com/4a98c2/assets/local/about-ericsson/sustainability-and-corporate-responsibility/environment/mit-technology-review-decarbonizing-industries-with-connectivity-and-5g.pdf and Emirates Integrated Telecommunications Company. 2023. *Sustainability Report 2022*. https://www.du.ae/sustainability/our-reports

[43] See "Goodbye 2G" at: https://www.du.ae/2g-shutdown
[44] Technical Expert Committee on Mobile Networks. 2023. *Assessing the carbon footprint of shutting down 2G and 3G networks and migrating their services to 4G/5G.* https://en.arcep.fr/uploads/tx_gspublication/2G-3G-shutdown-carbon_footprint_summary_sept2023.pdf
[45] GSMA. 2023. *Spectrum: The Climate Connection*. https://www.gsma.com/spectrum/wp-content/uploads/2023/05/Spectrum_Climate_Connection.pdf
[46] Rami, Amin; Gallegos, Doyle. 2023. *Affordable Devices for All: Innovative Financing Solutions and Policy Options to Bridge Global Digital Divides*. Washington, DC: World Bank. http://hdl.handle.net/10986/40166

2.3 OTHER SOURCES OF EMISSIONS FROM ICT SUBSECTORS

Emissions and electricity use from the other ICT subsectors are difficult to compile at the country level because few countries collect the data and companies operating in these segments rarely disaggregate data by country. Instead, this report produces global estimates. This includes data centers as well as emissions from manufacturing of devices and equipment and their use. Ideally, country level data for these segments will also be reported regularly as this data is critical for more informed decision making.

2.3.1 DATA CENTERS

Data centers are facilities where organizations store and exchange data. There is little agreement on the number of data centers in the world. One reason is the variety ranging from small company owned facilities to gigantic hyperscale data centers. In respect to the ICT sector, boundaries are critical since only data centers owned and operated by companies formally part of the ICT sector should be included. In France, up to 60 percent of data centers are owned by companies and government agencies outside the ICT sector.[47] For the analysis here, data centers are those offered for colocation, those used for cloud computing, and facilities used to store large amounts of data generated by users from social media apps.

Growing electricity consumption by data centers has implications for energy capacity and security, particularly given the simultaneous trend towards electrification of vehicles, heat, and other areas, with some countries imposing temporary moratoriums on new construction of data centers as a blunt means to slow demand growth.[48] Box 2.2 highlights challenges Ireland faced as their data center market growth increased pressure on energy supply, and the government policy interventions in response.

BOX 2.2: IRELAND – COORDINATING THE "TWIN TRANSITIONS" OF DIGITALIZATION AND DECARBONIZATION

Ireland is one of the densest data center hubs in the world due to a cool climate and favorable tax incentives. The country has over 80 data centers, with most of them in the Dublin area.[49] In 2022, data centers already consumed almost one-fifth of the country's electricity, an increase from 5 percent in 2015 and an increase of 4 percentage points from 2021. Growing electricity consumption of data centers has raised alarm, with the country's grid operator forecasting that data centers could make up between 25 percent and 33 percent of Ireland's electricity demand by 2030. The Government of Ireland is seeking to find a balance between the "twin transitions" of digitalization and decarbonization.[50] This is important because Ireland's Climate Action Plan calls for 80 percent of electricity generation to come from renewable sources by 2030.[51] And the ICT sector is a key engine of the economy accounting for 6.4 percent of employment and one-fifth of corporation tax revenue in 2021.[52]

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[47] ADEME and ARCEP. 2022. "The digital environmental footprint in France: ADEME and Arcep submit their first report to the Government." *Press Release*, 19 January. https://en.arcep.fr/fileadmin/user_upload/04-22-english-version.pdf

[48] Afiq Fitri. 2023. "Inside the data centre moratorium movement." TECH MONITOR, 29 June. https://techmonitor.ai/technology/cloud/inside-the-data-centre-moratorium-movement

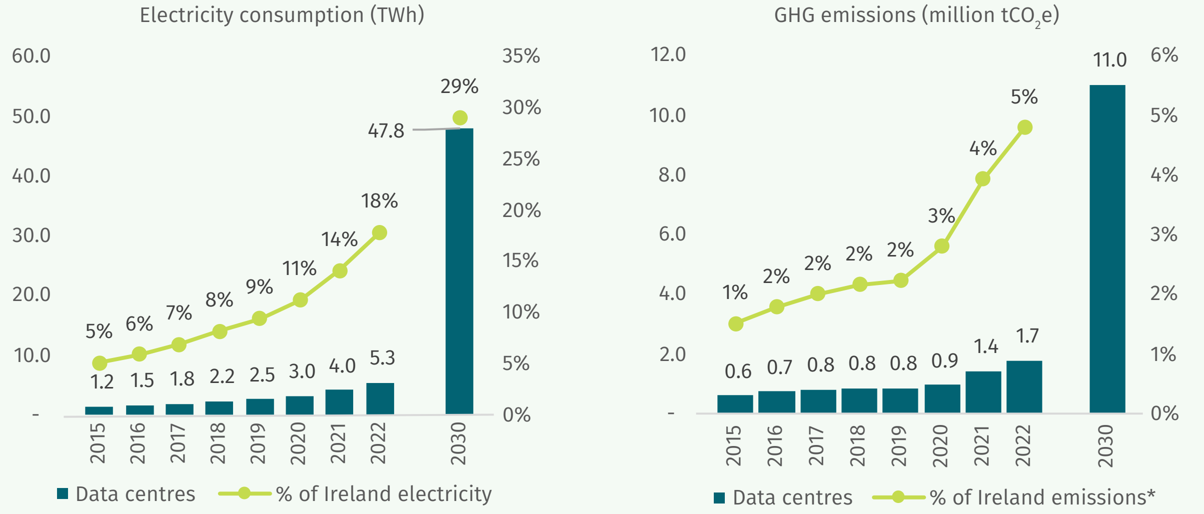
[49] Caoimhe Bermingham. n.d. "Data centres and their impact on the price and supply of electricity." https://www.bonkers.ie/guides/gas-electricity/data-centres-and-their-impact-on-the-price-and-supply-of-electricity/

[50] Government of Ireland. 2022. *Government Statement on the Role of Data Centres in Ireland's Enterprise Strategy.* https://enterprise.gov.ie/en/publications/government-statement-on-role-of-data-centres-in-enterprise-strategy.html

[51] Government of Ireland. 2022. *Climate Action Plan 2023.* https://www.gov.ie/en/publication/7bd8c-climate-action-plan-2023/

[52] Central Bank of Ireland. 2023. *The Role of the ICT Services Sector in the Irish Economy.* https://www.centralbank.ie/docs/default-source/publications/quarterly-bulletins/quarterly-bulletin-signed-articles/the-role-of-ict-services-sector-irish-economy.pdf

Figure 2.8: Electricity consumption and GHG emissions of data centers in Ireland



Note: GHG emissions refer to Scope 2 location-based using the Sustainable Energy Authority of Ireland Grid Emissions Factor (GEF). The GEF has been forecast based on the 2022/21 change.* Refers to emissions from energy.
Source: Irish Central Statistical Office and government forecasts.

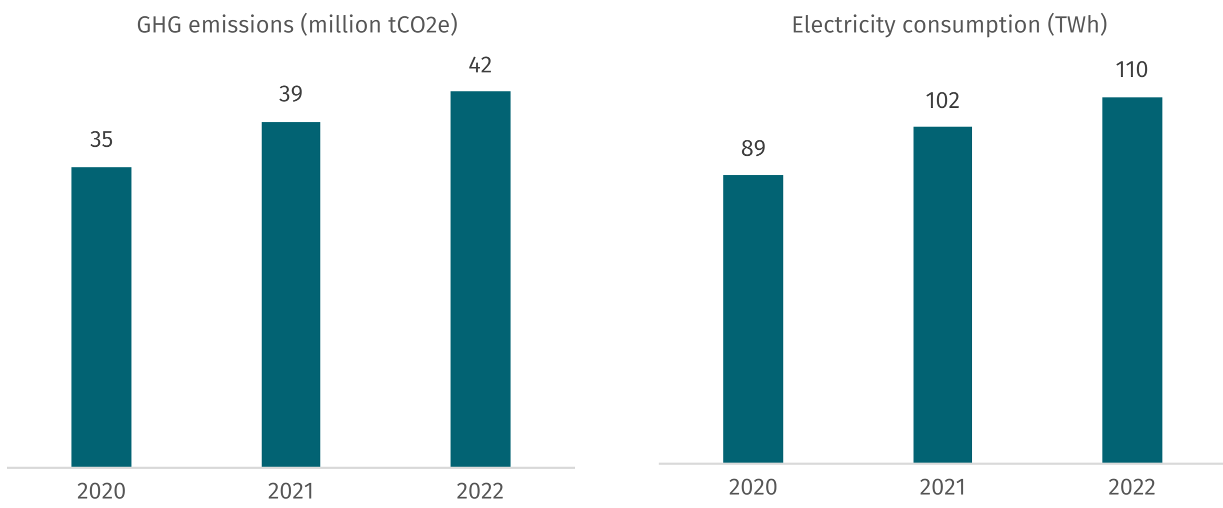
Rather than place a moratorium on data centers, the Government has put forth the following principles for sustainable data center development:

- ECONOMIC IMPACT: The Government has a preference for data center developments associated with strong economic activity and employment.
- GRID CAPACITY AND EFFICIENCY: The Government has a preference for data center developments that make efficient use of the electricity grid, using available capacity and alleviating constraints.
- RENEWABLES ADDITIONALITY: The Government has a preference for data center developments that can demonstrate the additionality of their renewable energy use in Ireland.
- CO-LOCATION OR PROXIMITY WITH FUTURE-PROOF ENERGY SUPPLY: The Government has a preference for data center developments in locations where there is the potential to co-locate a renewable generation facility or advanced storage infrastructure with the data center, supported by Corporate Power Purchase Agreements, private wire, or other arrangement.
- DECARBONIZED DATA CENTERS BY DESIGN: The Government has a preference for data centers developments that can demonstrate a clear pathway to decarbonize and ultimately provide net-zero data services.
- SME ACCESS AND COMMUNITY BENEFITS: The Government has a preference for data center developments that provide opportunities for community engagement and assist Small and Medium Enterprises (SMEs), both at the construction phase and throughout the data center lifecycle.

2.3.1.1 Colocation data centers

Colocation data centers, usually connected to the internet, provide hosted organizations and internet service providers a facility to exchange data and access cloud computing facilities. Globally, there were 3,831 connected colocation data centers in 2022.[53] Market size by revenues was US$64.9 billion in 2022,[54] serving as the basis to derive a global estimate based on the colocation operators that disclose data. It is estimated that emissions from colocation data centers grew by 20 percent between 2020 and 2022, while electricity consumption rose 22 percent (Figure 2.9). Note that the figures refer only to colocation data centers and not all data centers. They also exclude telecommunication operators who also provide colocation services; those emissions are captured under the telecommunications industry discussed. Another consideration is that attribution of emissions varies: some colocation companies assume all emissions and electricity use, while others allocate them to customers (Scope 3).

Figure 2.9: GHG emissions and electricity consumption of connected, colocation data centers



Note: Emissions refer to Scope 1 and Scope 2 location-based.
Source: Company reports.

2.3.1.2 Cloud computing and social media applications

Cloud companies offer access to databases, artificial intelligence (AI) algorithms, and other computational services. Customers can also store their data on the cloud but, unlike collocation data centers, they are not tenants. Therefore, energy consumption related emissions are fully allocated to the cloud providers Scope 1 and 2 and the clients Scope 3.

The top three cloud providers—Amazon Web Services (AWS), Microsoft Azure, and Google Cloud—accounted for 68 percent of foundational cloud services revenue (US$169 billion in 2022).[55] One challenge is that all three offer different services in addition to access to the cloud: Microsoft sells software; Google offers advertising

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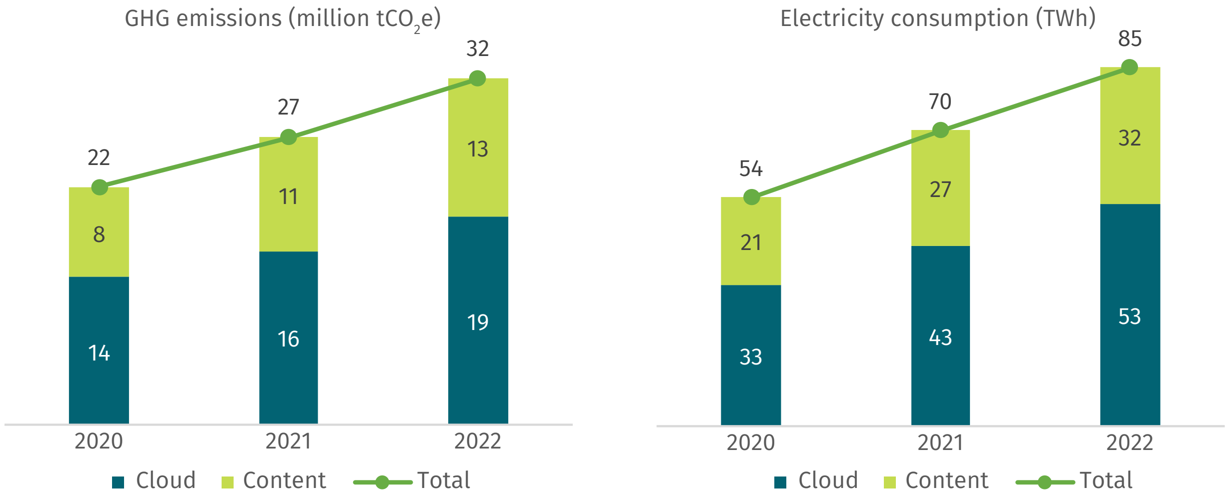
[53] Extrapolated from https://www.peeringdb.com/.
[54] https://structureresearch.net/product/2023-global-data-centre-colocation-interconnection-report-copy/
[55] IDC. 2023. "Worldwide Public Cloud Services Revenues Surpass $500 Billion in 2022, Growing 22.9% Year Over Year, According to IDC Tracker." *Press Release*, 6 July. https://www.idc.com/getdoc.jsp?containerId=prUS51009523#:~:text=Worldwide%20Public%20Cloud%20Services%20Revenues,Year%2C%20According%20to%20IDC%20Tracker

and content, such as through YouTube; while Amazon provides a retail sales platform. Although all three disclose their emissions at a global level, they do not break them down by line of business. However, data centers are likely to account for a large portion. Microsoft reported 90 percent of its emissions coming from data centers in the fiscal year ending June 2021.[56] Google also operates its own non-cloud data centers for content storage. In addition to its 39 hyperscale cloud centers around the world,[57] Google has two dozen of its own data centers.[58] All of Microsoft's and Google's activities fall under the ICT sector definition. Amazon presents a challenge given that it also offers e-ecommerce services. Emissions and electricity consumption have been estimated based on the proportions for its UK operations where it is required to disclose emissions.

Growing social media posts with photos and videos need to be stored and accessible around the world. Leading social media platforms have their own data centers. The four largest social media applications are owned by Alphabet (parent of Google) and Meta (Facebook, YouTube, WhatsApp, and Instagram, with 26 data centers), followed by Tencent (WeChat), and ByteDance (TikTok).[59] Climate data are available for all except ByteDance, an unlisted company notable for its lack of climate transparency.[60]

Results show that cloud and social media content data centers, were responsible for 32 million tons of emissions in 2022 and consumed 85 TWh of electricity (Figure 2.10). Emissions grew 45 percent between 2020 and 2022, while the increase for electricity was 57 percent. Increases reflect the trend of organizations moving their computing needs to the cloud as well as ever increasing social media usage.

Figure 2.10: Emissions and electricity consumption of cloud and content data centers



Source: Company reports (see Annex).

Cognizant of their climate impact, the major cloud providers along with Meta have been purchasing massive amounts of clean energy. Amazon, Microsoft, Alphabet, and Meta are the four largest corporate purchasers of renewable energy in the world.[61] In 2022, the share of renewables in their electricity consumption amounted to

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56 Microsoft Corporation. 2022. *CDP Climate Change Questionnaire 2022*. https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE2EWBx
57 https://cloud.google.com/about/locations#multi-region
58 https://www.google.com/about/datacenters/locations/
59 "23 Top Social Media Sites to Consider for Your Brand in 2023." https://buffer.com/library/social-media-sites/
60 Greenpeace East Asia. 2022. "ByteDance (owner of TikTok) among lowest scoring companies in new Greenpeace China tech ranking." Press Release, July 12. https://www.greenpeace.org/eastasia/press/7467/bytedance-among-lowest-scoring-companies/
61 BloombergNEF. March 17, 2023. "Tech Firms Seal US Dominance in Corporate Clean Power Purchasing." https://about.bnef.com/blog/tech-firms-seal-us-dominance-in-corporate-clean-power-purchasing/

83 TWh, equivalent to the total electricity consumption of Finland. Amazon purchases 90 percent renewables for its electricity consumption while the other three all purchase 100 percent renewables' generated electricity. The main barrier to the companies renewable energy purchases translating into zero emissions is that they cannot always get the renewable energy they purchased on the grids they are operating on. For instance Google reports that despite purchasing 100 percent renewable energy, it only gets 64 percent clean electricity to power its operations on an hourly basis.[62] Hence efforts are needed to reengineer grids so that renewable energy purchases are made fully available to the purchasers. This is the goal of the UN's 24/7 Carbon-free Energy Compact which has Google and Microsoft as signatories.[63]

These companies' huge purchases are helping to grow the economies of scale for renewable energy markets. For instance, Amazon has over 400 renewable energy projects around the world including in India, Indonesia, and South Africa. Its 10 MW solar project in South Africa was the biggest ever purchase of renewables in the country.[64] Once the 400 projects are operational, they will account for 57 TWh of Amazon's electricity use, equal to the total electricity consumption of Switzerland.

2.3.2 EMBEDDED AND PRODUCT USE EMISSIONS

Embedded emissions [from the manufacturing process] and product use emissions from use of ICT equipment (that is, servers, mobile phones, computers, and others) form part of the ICT sector footprint. Supply chain and product use emissions (Scope 3, Category 1 and Category 11, respectively) of the leading device and network equipment vendors serve as the basis to estimate embedded and product use emissions globally. Note that embedded emissions are used as an alternative to determining the sectoral emissions of the ICT manufacturing industry. Life Cycle Assessment (LCA) usually considers the materials goods are made of, the manufacturing process, transportation, use and end of life, but note that transportation and end-of-life emissions are excluded from this analysis.

Vendors of branded ICT equipment design and sell products but outsource much of their manufacturing and assembly. [65] As a result, they have low operational emissions (that is, Scope 1 and 2). Their Scope 3, Category 1 emissions (purchased goods and services) reflect their supply chain footprint. Branded equipment vendors rarely supply products and services among themselves, so double counting is limited. Apart from omitting transportation and end-of-life emissions, there are other constraints with this approach. Device and equipment vendors may sell other products besides those in scope, but they do not disaggregate emissions by product line since these additional emissions are considered immaterial to the products in scope. Another issue is "second-degree emissions", referring to supply chain emissions from the vendor's direct suppliers who in turn use other companies to supply materials. These second-degree emissions are also not included in this analysis.

2.3.2.1 Personal computers (PCs)

The top six vendors of PCs accounted for 85 percent of the market in 2022, selling 243 million of the world total of 286 million.[66] The remainder for other vendors is estimated from this market share. All leading PC vendors

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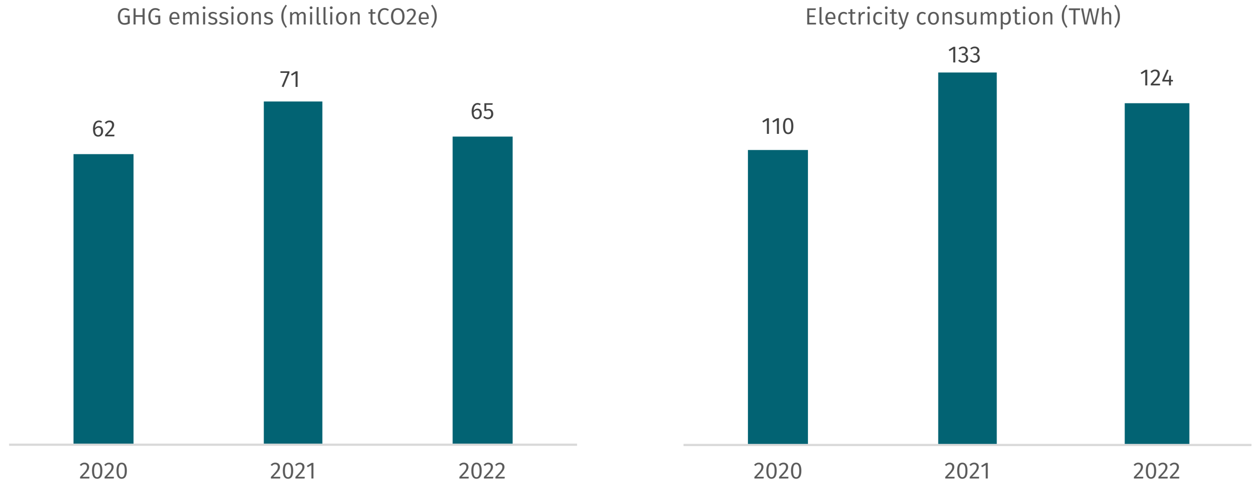
[62] Google. 2023. *Environmental Report.* https://sustainability.google/reports/google-2023-environmental-report/
[63] See 24/7 Carbon-free Energy Compact" at: https://www.un.org/en/energy-compacts/page/compact-247-carbon-free-energy
[64] "Amazon's first South African solar plant delivers energy and opportunity." News, 22 February 2022. https://www.aboutamazon.com/news/aws/amazons-first-south-african-solar-plant-delivers-energy-and-opportunity
[65] For instance Apple iPhone chips are manufactured by Qualcomm, Broadcom and TSMC, camera by Sony, etc. See: https://www.lifewire.com/where-is-the-iphone-made-1999503
[66] "Gartner Says Worldwide PC Shipments Declined 28.5% in Fourth Quarter of 2022 and 16.2% for the Year." *Press Release,* 11 January 2023. https://www.gartner.com/en/newsroom/press-releases/2023-01-11-gartner-says-worldwide-pc-shipments-declined-28-percent-in-fourth-quarter-of-2022-and-16-percent-for-the-year

disclose their own Scope 1 and 2, supply chain, and product use emissions. Emissions from manufacturing (that is, "embedded") were 65 million tCO_2e in 2022, down from 2021 due to a decrease in demand after the COVID-19 pandemic during which home quarantines triggered high PC sales.

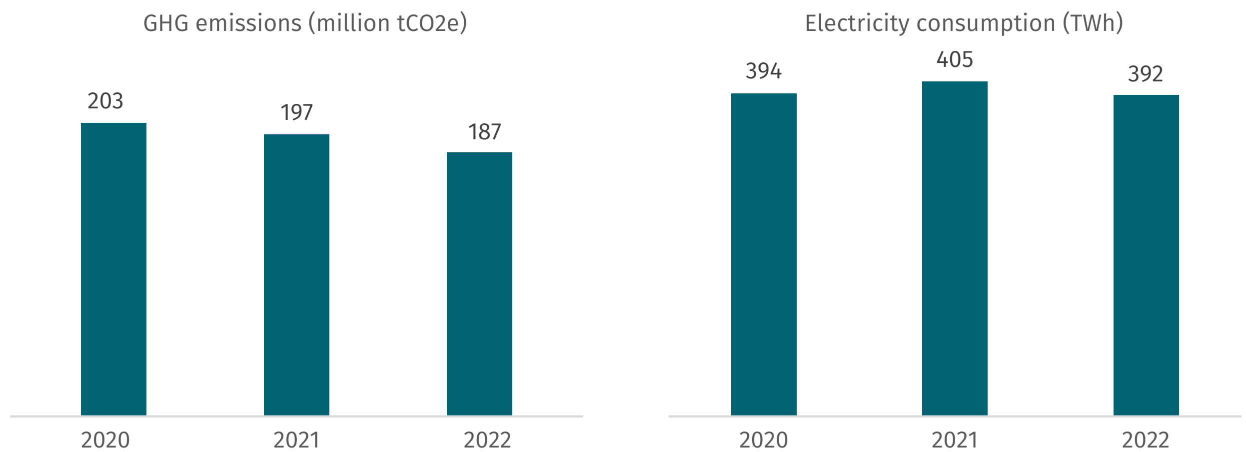
Figure 2.11: Estimated GHG emissions and electricity consumption from PC manufacturing



Source: Company reports (see Annex).

Vendors of ICT equipment report their product use emissions (Scope 3, Category 11, Use of Sold Products) for products manufactured that year, so it does not include PCs still in use. Therefore, it is necessary to estimate how many years a PC is in use, on average, and sum the product use emissions for those years to obtain emissions for a specific year. For instance, Apple reports an average product use of four years for a PC,[67] so product use for 2022 is the sum of product use for 2019-2022. GHG emissions from use of PCs were 187 million tCO_2e in 2022 and electricity consumption 392 TWh, down from 2021 largely due to waning COVID-19 pandemic.

Figure 2.12: Estimated GHG emissions and electricity consumption from PC product use



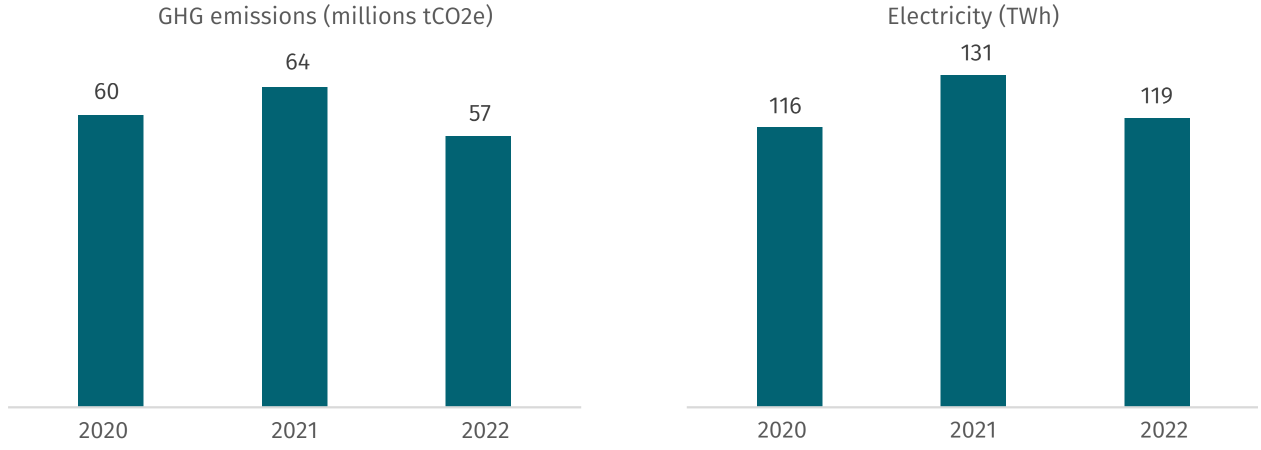
Source: Company reports (see Annex).

[67] Apple. 2023. *Product Environmental Report Mac Pro.* https://www.apple.com/in/environment/pdf/products/desktops/Mac_Pro_PER_June2023.pdf

2.3.2.2 Smartphones

Estimating smartphone production emissions is not straightforward due to several factors. Emissions data are available for the top three vendors.[68] However, Samsung and Apple also sell other products: televisions and other home products in the case of Samsung, and computers and wearables in the case of Apple. These two companies do not provide disaggregated emissions data for their smartphone segment. Therefore, manufacturing emissions are estimated based on the life cycle emissions published by Apple and Samsung for their popular selling smartphones and applied to the other companies in this group. Smartphone manufacturing (that is, "embedded") emissions are estimated at 57 million tCO_2e and electricity use at 119 TWh in 2022, both notable declines from the previous year (Figure 2.13). The drop is associated with higher smartphone purchases during COVID-19, supply bottlenecks in 2022 due to the war in Ukraine, and greater use of renewables among suppliers.

Figure 2.13: Estimated GHG emissions and electricity consumption from smartphone manufacturing



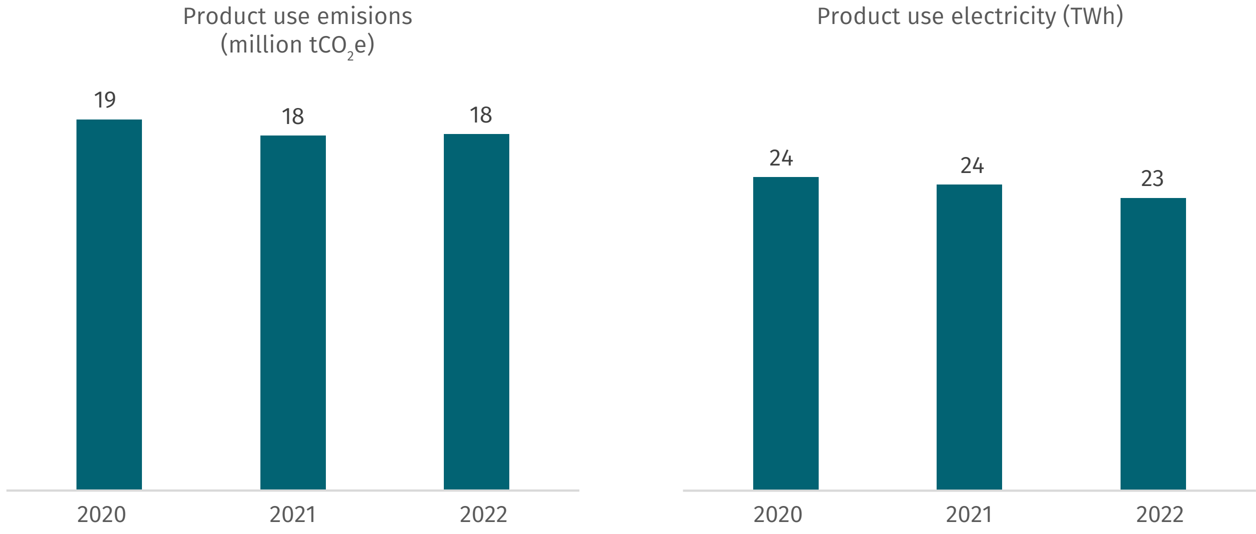
Source: Company reports (see Annex).

Product use emissions and electricity use have been estimated based on the smartphone daily charging electricity factor from the United States Environmental Protection Agency (EPA).[69] There were 5.2 billion smartphones in 2022, according to shipment data over the last four years (assuming a smartphone is in service for an average of four years). Smartphone recharging is estimated to have consumed 23 TWh of electricity in 2002, generating 18 million tons of GHG emissions, figures that have held steady over the last three years (Figure 2.14).

[68] IDC. 2023. "Worldwide Smartphone Shipments Continue to Decline with 7.8% Drop in the Second Quarter, According to IDC Tracker." *Press Release*, 27 July. https://www.idc.com/getdoc.jsp?containerId=prUS51088223

[69] See "Greenhouse Gases Equivalencies Calculator - Calculations and References" at: https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Figure 2.14: Estimated GHG emissions and electricity consumption from smartphone product use



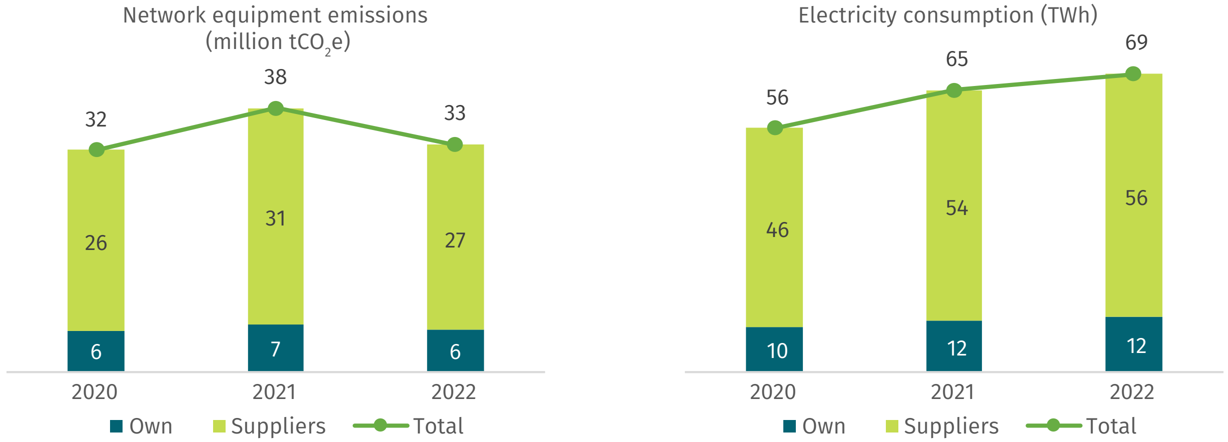
Note: Based on US EPA emission factor and estimated smartphones in use.
Source: See Annex.

2.3.2.3 Network equipment

The network communications equipment sub-industry covers the manufacturing of goods such as mobile network base stations, switches, servers, and similar products. The top five vendors account for 70 percent of industry revenues.[70] Product use is largely accounted for in the operational emissions of telecommunications operators and therefore not calculated. Scope 1 and 2 location-based emissions are estimated at 6 million tCO_2e and electricity use at 12 TWh in 2022 for the companies in this industry. Supply chain emissions are estimated to be 4.5 times greater (27 million tCO_2e), and supply chain electricity use 4.6 times higher, illustrating the high degree of outsourcing. Total emissions dropped 17 percent in 2022, likely due to several reasons, such as supply chain disruptions from the Russia-Ukraine conflict, vendor pressure on suppliers to use more renewable energy, and greater energy efficiency of the products.

[70] This equipment includes the following categories: "Broadband Access, Microwave & Optical Transport, Mobile Core & Radio Access Network, SP Router & Carrier Ethernet Switch (CES)." See: Dell'Oro Group. 2023. " Worldwide Telecom Equipment up 3 Percent in 2022 " https://www.delloro.com/worldwide-telecom-equipment-up-3-percent-in-2022/

Figure 2.15: Estimated GHG emissions and electricity consumption from network equipment manufacturing



Note: Own refers the vendors operational (Scope 1 and 2) emissions while Suppliers refers to supply chain emissions (Scope 3 Category 1). Totals may be different due to rounding.
Source: Company reports.

2.4 ICT SECTOR GLOBAL GHG EMISSIONS AND ELECTRICITY EVOLUTION

Telecommunications emissions plus the global estimates for data centers, cloud computing and embedded and product use emissions shown above have been combined to generate a world estimate of the ICT sector footprint. Given the broad boundaries, inconsistencies in emissions attributions, and omission of transportation, end of life, and fuel- and energy-related emissions, the figures are rough estimates and underrepresent the total. Analysis for this report estimates that ICT sector emissions were 567 million tCO_2e in 2022 or 1.7 percent of the world total. Electricity consumption was estimated at 1,183 TWh in 2022; ICT sector electricity use was estimated to account for 4.7 percent of the world total in 2021.

As noted, it is not yet possible to make country estimates for industries other than telecommunications. Also given the broad boundaries and the fact that companies operate in multiple areas, the figures are rough estimates. Finally, companies are inconsistent in their allocation of emissions to the different scopes. All of these circumstances speak to the need for countries to take charge of ICT sector emissions and energy data compilation as they are in a good position to overcome these obstacles.

Embedded and product use account for the bulk of ICT sector emissions at 63 percent in 2022, with telecommunications accounting for 23 percent and colocation, cloud, and content data centers accounting for 13 percent. Most parts of the value chain exhibited moderate or even negative growth in emissions between 2020 and 2022. The exceptions were colocation data centers where emissions grew 20 percent, and cloud and content data centers where emissions grew 46 percent. Virtually all of the ecosystem segments showed an increase in electricity consumption with cloud and content data centers in particular exhibiting a sharp rise of 63 percent.

Table 2.1: Global estimates of ICT sector emissions, 2022

Industry	Emissions 2022/2020 (million tCO_2e)			Change 2022/2020 %	Electricity (TWh)			Change 2022/2020 %
	2020	**2021**	**2022**		**2020**	**2021**	**2022**	**22/20 %**
Telecommunications operators	135	134	133	-1%	239	255	258	8%
Colocation data centers	36	40	43	20%	89	100	109	22%
Cloud & content	22	27	32	46%	54	70	85	63%
Subtotal	**193**	**201**	**208**	**8%**	**382**	**425**	**442**	**18%**
% of world	0.6%	0.6%	0.6%		1.60%	1.70%	1.70%	
ICT Equipment	**154**	**173**	**154**	**0.5%**	**282**	**329**	**311**	**10.6%**
- PCs	62	71	65	4.8%	110	133	124	
- Smartphones	60	64	57	-5.1%	116	131	119	**2.5%**
- Network	32	38	33	2.4%	56	65	69	**22.0%**
Product use	222	215	205	-7.5%	430	442	430	**-0.1%**
- PCs	203	197	187	-7.9%	394	405	392	**-0.5%**
- Smartphones	19	18	18	-3.4%	36	37	38	**4.3%**
Subtotal	**375**	**388**	**359**	-4.2%	**712**	**771**	**741**	**4.1%**
% of world	**1.2%**	**1.1%**	**1.0%**		**3.0%**	**3.0%**		
TOTAL	**568**	**589**	**567**	-0.2%	**1094**	**1196**	**1183**	**8.2%**
% of world	1.8%	1.7%	1.7%		4.6%	4.7%		

Source: From the calculations above for telecommunications, data centers, cloud, embedded and product use emissions and electricity use above (see Annex for detailed methodology).

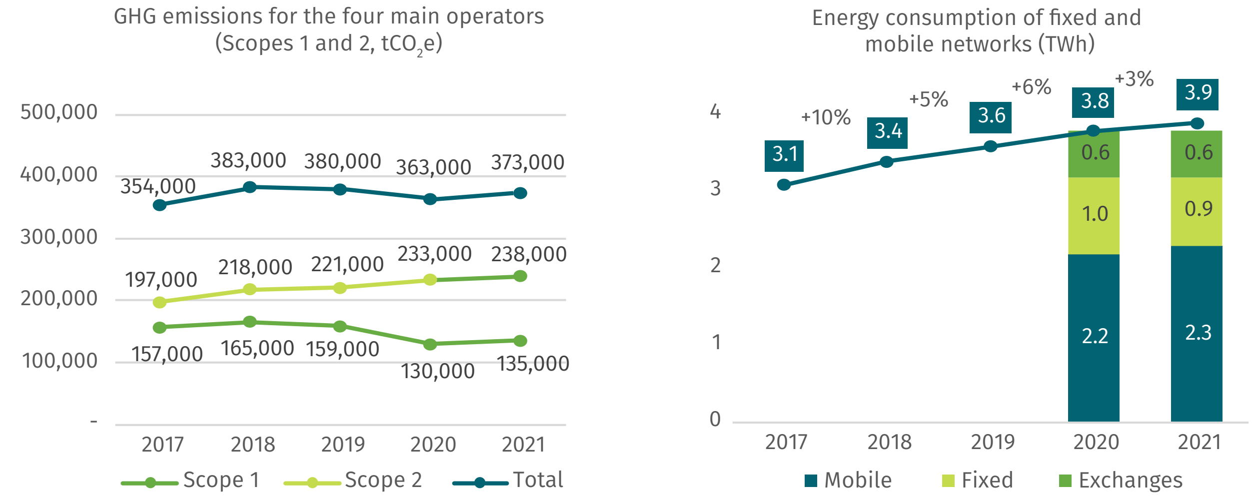
3. COUNTRY CASE STUDIES

Several countries have been selected for examples of their ICT sector climate data compilation and reporting. They illustrate a variety of approaches to collecting climate data for the sector. Thus far, France is the only country in the world where the electronic communications regulator compiles and disseminates climate data based on obligatory responses from firms. Rwanda is one of the few LMICs where the multisector regulator publishes statistics on the electricity consumption of telecommunications towers and data centers. Singapore also uses electricity data broken down by economic sectors to estimate Scope 2 emissions of data centers. In Brazil, a voluntary initiative makes the climate data of firms, including those from the ICT sector, publicly available on a portal. Finally, the United Kingdom mandates that most publicly listed and private companies disclose their emissions and energy use, with the data publicly available through the country's online company registry.

FRANCE

In 2022, France's electronic communications regulator, the Regulatory Authority for Electronic Communications, Postal Affairs and Print Media Distribution (ARCEP), became the first in the world to publish climate and energy data for the telecommunication sector.[71] Some insights emerged from the data. For instance, on French networks, mobile uses twice the energy of fixed networks, and copper networks use four times more than fiber optic. ARECP's second report covering the climate and energy use of the countries four telecom operators was published in 2023. The data showed that GHG emissions increased 5.4 percent between 2017 and 2021 while energy consumption grew 26 percent.

Figure 3.1: GHG emissions and energy consumption, telecom sector, France

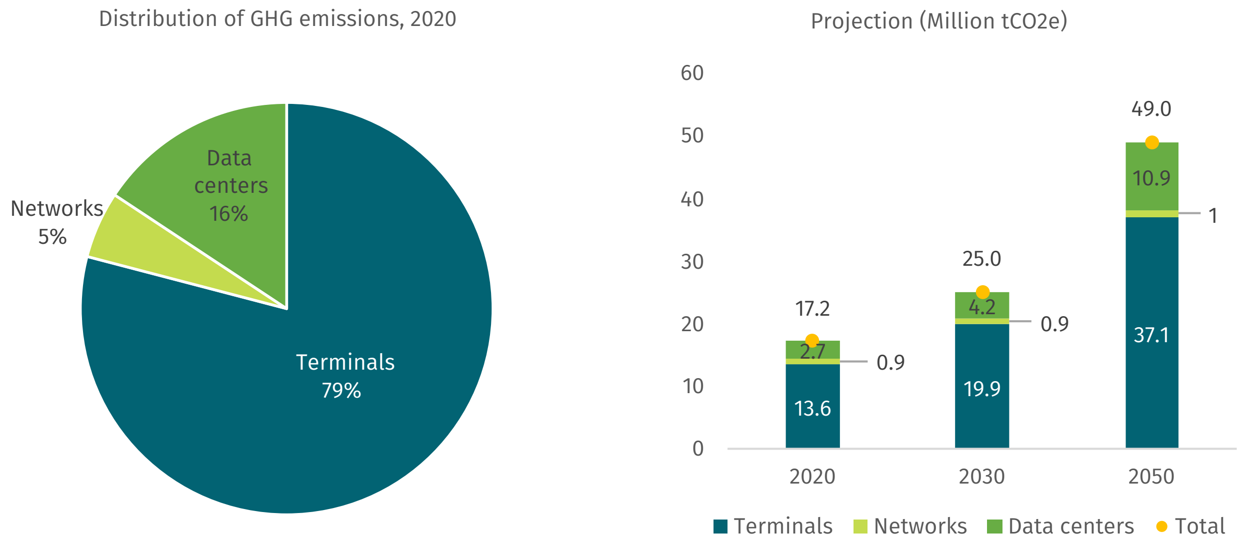


Source: ARCEP. 2023. Enquête annuelle "Pour un numérique soutenable". https://www.arcep.fr/cartes-et-donnees/nos-publications-chiffrees/impact-environnemental/derniers-chiffres.html

71 ARCEP. 2022. "Achieving digital sustainability": Arcep publishes the first edition of its annual inquiry." Press Release, 25 April. https://en.arcep.fr/news/press-releases/view/n/the-environment-first-annual-inquiry-250422.html

Publication of the climate and energy use data for the telecommunications sector has its roots in a note published in 2019 by ARCEP about the country's ICT carbon footprint.[72] In 2020, the Government assigned ARCEP and France's National Agency for the Ecological Transition (ADEME) the task of measuring the ICT environmental footprint in France. In December 2020, ARCEP published a report outlining the results of industry workshops and its vision for a sustainable ICT sector.[73] A January 2022 report by ARCEP and ADEME found that ICT was responsible for 2.5 percent of the carbon footprint in France and growing.[74] To perform this estimate, ARCEP and ADEME chose to rely upon the methodological framework developed by the ITU in the L.14xx series of Recommendations.[75] The final volume of the report featured an estimate of the growth of the ICT footprint through 2050. Embedded emissions from devices account for most of the carbon impact at 79 percent in 2020, followed by data centers and then telecommunication networks. The report found that without mitigating measures, the ICT carbon footprint would almost triple between 2020 and 2040.

Figure 3.2: ICT carbon footprint in France



Source: ARCEP and ADEME. "Etude ADEME Arcep Analyse prospective de l'impact environnemental du numérique en France" https://www.arcep.fr/uploads/tx_gspublication/Etude-ADEME-Arcep-presentation-conference_06_03_23.pdf

While ARCEP has for years collected subscription, traffic, revenue, and other data from telecommunications operators,[76] its remit did not extend to companies outside that industry. To collect data from the even higher emitting device and data center industries, a change to its mandate was voted by the French legislature in December 2021 (Law No. 2 of 23 December 2021).[77] The law allowed ARCEP to also collect data from data centers and equipment manufacturers, which was then operationalized by ARCEP through a Decision issued

72 ARCEP. 2019. Note n° 5 "L'empreinte carbone du numérique." *Réseaux du future Note n° 5*, 21 October. https://www.arcep.fr/uploads/tx_gspublication/reseaux-du-futur-empreinte-carbone-numerique-juillet2019.pdf

73 ARCEP. 2020. *Achieving Digital Sustainability*. https://en.arcep.fr/uploads/tx_gspublication/achieving-digital-sustainability-report-dec2020.pdf

74 ADEME and ARCEP. 2022. "The digital environmental footprint in France: ADEME and ARCEP submit their first report to the Government." *Press Release*, 19 January, https://en.arcep.fr/fileadmin/user_upload/04-22-english-version.pdf

75 See "L.1400 : Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies" at: https://www.itu.int/rec/T-REC-L.1400

76 ARCEP. 2022. *Les Services de Communications Electroniques en France.* https://www.arcep.fr/fileadmin/cru-1677573101/reprise/observatoire/march-an2021/obs-marches-annee-2021-definitif_dec2022.pdf

77 LOI n° 2021-1755 du 23 décembre 2021 visant à renforcer la régulation environnementale du numérique par l'Autorité de régulation des communications électroniques, des postes et de la distribution de la presse. https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000044553569

in November 2022.[78] A questionnaire asking for climate data was sent to telecommunications operators and the new companies (that is, equipment manufacturers and data center operators) in January 2023 with the results expected to be published before the end of 2023.

Several initiatives have been aimed at devices given their major effect on France's ICT carbon footprint. Besides GHG emissions and energy use, ARCEP also collects data on mobile phone and TV set-top boxes recycling and reconditioning by the operators. A labelling law came into effect in 2022 requiring operators to disclose to customers their carbon footprint based on the amount of data used for mobile users and per subscription for fixed users.[79]

SINGAPORE

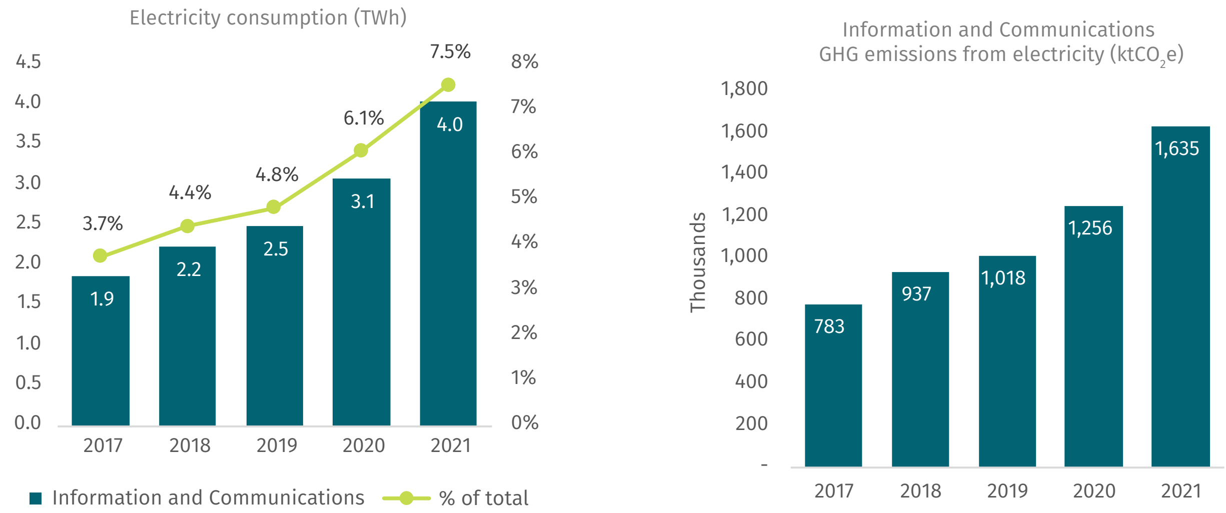
The ICT sector plays a crucial role in driving innovation and enabling digital transformation across Singapore’s industries. Data centers strengthen Singapore’s position as an international connectivity hub, for example, by attracting subsea cables. As data centers are also large emitters of GHGs, contributing to 82 percent of the ICT sector’s emissions, and are intensive users of water—for cooling, for example—it is imperative to manage the data center ecosystem to promote environmentally sustainability while supporting business needs. Making good use of data has helped inform Singapore’s policies in these areas.

Singapore’s Energy Markets Authority (EMA) compiles energy statistics featuring a breakdown of electricity consumption by economic sector, including Information and Communication (differs from ICT sector by excluding manufacturing and adding broadcasting and film). Electricity consumption of the Information and Communications sector grew over 100 percent between 2017 and 2021 and its share of total electricity consumption in Singapore increased from 2.7 percent in 2017 to 7.5 percent in 2021.

[78] Décision n°2022-2149 de l’Autorité de régulation des communications électroniques, des postes et de la distribution de la presse en date du 22 novembre 2022 relative à la mise en place d’une collecte annuelle de données environnementales auprès des operateurs de communications électroniques, de centres de données et des fabricants de terminaux. https://www.arcep.fr/uploads/tx_gsavis/22-2149.pdf

[79] For mobile networks the carbon calculation formula was Carbon footprint (in gCO2e/month) = Quantity of data consumed by the user (in GB/month) x Average ratio of CO2e per GB on mobile networks in France (gCO2e/GB); in 2022 the figure was estimated at 50 gCO2e/GB. For fixed networks, the figure is 3.95 kgCO2e/month per subscriber. See ADEME. "L’affichage environnemental" at: https://expertises.ademe.fr/economie-circulaire/consommer-autrement/passer-a-laction/reconnaitre-produit-plus-respectueux-lenvironnement/dossier/laffichage-environnemental/affichage-environnemental-secteur-numerique

Figure 3.3: Electricity consumption and emissions from electricity, Information and Communications sector, Singapore



Source: Energy Market Authority. Singapore Energy Statistics (https://www.ema.gov.sg/singapore-energy-statistics/).

The main infrastructure-based telecommunications operators in Singapore are Singtel, StarHub, and M1. The three operators disclose GHG emissions in compliance with the Singapore Exchange (SGX) reporting requirements.[80] Emissions methodology is based on the GHG Protocol (which is also recommended by the SGX) and the operators use the operational control method, meaning they report 100 percent of their subsidiaries' energy and emissions. Reporting aligns with Global Reporting Initiative (GRI) disclosure 302 for energy[81] and 305 for emissions.[82]

Total emissions for these operators was 186,000 tCO_2e and electricity consumption was 441,000 in 2022. Both figures declined from 2020. However, M1 divested its mobile network assets to M1 Network Private Limited in 2022, roughly halving its emissions and electricity consumption. M1 Network Private is a private company. Although a subsidiary of the Keppel Group, its emissions and electricity consumption are not separately disclosed, illustrating the challenge of compiling climate statistics from firm level data.

Table 3.1: Telecommunications GHG emissions and electricity consumption, Singapore

	Scope 1+2 (tCO_2e)			Electricity (MWh)			Scope 1+2 / $ million revenue		
Company	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
M1	26,705	28,079	14,836	63,675	65,785	34,236	34	34	17
StarHub	58,052	59,605	56,848	137,324	142,800	137,200	39	39	34
Singtel	119,884	113,961	114,070	269,991	268,468	269,681	22	20	22
Total	**204,641**	**201,645**	**185,754**	**470,989**	**477,053**	**441,117**	**27**	**25**	**24**

Note: M1 divested its mobile infrastructure in 2022. Figures for Singtel refer to year beginning 1 April. Scope 2 refers to location-based emissions.
Source: Company reports.

80 See "Sustainability Reporting" at: https://www.sgx.com/sustainable-finance/sustainability-reporting
81 https://www.globalreporting.org/standards/media/1009/gri-302-energy-2016.pdf
82 https://www.globalreporting.org/standards/media/1012/gri-305-emissions-2016.pdf

Electricity use reported by telecommunications operators in Singapore was a little over 10 percent of the Information and Communications total. Given that film and broadcasting do not consume much, it is likely that data centers account for the vast majority of Information and Communications electricity use in the country.

As the regulator overseeing the development of the ICT sector in Singapore, the Infocomm Media Development Authority (IMDA) is responsible for promoting the sector's continued growth in a manner that is sustainable and in harmony with environmental and climate goals. By accurately measuring carbon emissions, IMDA can set targets, develop strategies to reduce the ICT sector's carbon footprint, and monitor the sector's progress towards sustainability.

IMDA has investigated data center energy consumption. The more than 70 operational data centers in Singapore accounted for approximately 5.3 percent (2.75 TWh, or TWh) of Singapore's total electricity consumption in 2019. Against the backdrop of the COVID-19 pandemic and increased digitalization, this increased 1.7 percentage points to approximately 7 percent (3.40 TWh) in 2020. As the pace of digitalization accelerates across all domains, total data center electricity consumption is projected to increase, in line with global trends.

UNITED KINGDOM

The Streamlined Energy and Carbon Reporting Regulation (SECR), introduced in 2019, mandates that businesses incorporated in the United Kingdom report on their energy and carbon emissions every year. This includes all listed companies as well as large private companies meeting at least two of three following criteria: 250 employees, annual revenues of more than £36m, and annual balance sheet of over £18m. The government provides guidance on compiling the data[83] as well as the energy conversion factors to use.[84] Company disclosures are publicly available on the Companies House website.[85]

Challenges exist in retrieving the data, such as knowing the incorporation name of the company of interest, as well as being aware of mergers or acquisitions. Timeliness of the data can also be an issue with companies having a year to file their reports. Five companies of relevance had not filed their fiscal year 2022 reports as of October 2023 and one was overdue and had not yet filed its 2021 report. In addition to telecommunications operators, reports are also available for colocation data center companies.

The SECR regulation, coupled with publicly available annual reports, allows for creating a comprehensive picture of GHG emissions and electricity consumption of the UK telecommunications, colocation data center, and cloud computing subsectors, the only country in the world for which this is available at a disaggregated level. Total emissions of the ICT sector were 1.6 million tCO_2e in 2021, representing 0.5 percent of the UK's total emissions from energy use. Electricity consumption was 6.4 TWh, 2.2 percent of the country total, and grew 4.9 percent in 2021. The telecommunications industry accounted for 69 percent of ICT sector emissions in 2021. Telecommunications is the least carbon intensive at 23 tCO_2e per one million US$ of revenue, while colocation data centers are the most intensive with a figure almost eight times more.

[83] Companies must report Scope 1 and Scope 2 location-based emissions as well as energy use. See: HM Government. 2019. *Environmental Reporting Guidelines: Including streamlined energy and carbon reporting guidance*. https://assets.publishing.service.gov.uk/media/5de6acc4e5274a65dc12a33a/Env-reporting-guidance_inc_SECR_31March.pdf

[84] "Government conversion factors for company reporting of greenhouse gas emissions" at: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

[85] Covering companies incorporated in England and Wales. See: https://www.gov.uk/government/organisations/companies-house

Despite the availability of data, data consistency remains a concern, particularly for colocation data centers whose emissions and energy use appear low. Industry boundaries are often not clear cut, including the fact that some telecommunications operators also may provide data center services. Colocation data center operators are not always consistent in terms of emissions allocation; sometimes they attribute all emissions and electricity use to themselves, while in other cases they may be allocating them to customers (that is, Scope 3, Category 8, Upstream Leased Assets). Conversely, one UK data center operator claimed that it had no operational emissions because "The company leases office space, which is managed by the landlord... There were no direct Scope 1 or 2 emissions for the year ended 31 December, 2021 ...Emissions relating to electricity and heating for the company's office are exempt from energy and carbon reporting because these fall into Scope 3 as these services are provided by the landlord."[86] This reporting problem could be remedied if SECR were to be modified to require Scope 3 emissions disclosure along with category breakdowns.

Table 3.2: ICT sector emissions and electricity consumption, UK

	Scope 1+2 emissions (million tCO_2e)			Electricity (TWh)			GHG emissions / million $ revenue		
Company	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
BT Group	0.71	0.67	0.62	2.3	2.3	2.3	30	26	28
Virgin Media	0.13	0.25	0.24	0.4	1.0	1.1	31	17	19
VMED O2	0.14			0.6			18		
Hutch. 3G	0.08	0.08		0.3	0.4		28	27	26
Vodafone	0.16	0.14		0.6	0.6		23	18	19
Telecom	**1.2**	**1.1**		**4.3**	**4.3**		**27**	**23**	
Telehouse	0.04	0.04		0.2	0.2		148	137	
Interxion	0.01	0.01		0.1	0.1		250	203	
Equinix	0.12	0.12		0.5	0.6		219	201	
Others	*0.07*	*0.07*		*0.3*	*0.3*				
Data centers	***0.2***	***0.2***		***1.0***	***1.1***		**200**	**183**	
Amazon Data Svc.	0.06	0.08	0.10	0.3	0.4	0.5	197	169	167
MSFT NCIO	0.05	0.06	0.09	0.2	0.3	0.5	84	115	132
Others	*0.1*	*0.1*	*0.1*	*0.2*	*0.3*	*0.5*			
Cloud	**0.2**	**0.2**	**0.3**	**0.7**	**0.9**	**1.5**	**124**	**141**	**148**
TOTAL	**1.6**	**1.6**		**6.0**	**6.4**		**32**	**28**	
% country total	0.5%	0.5%		2.1%	2.2%				

Note: Virgin Media and 02 combined their mobile assets in 2021. Scope 2 emissions are location-based. Data centers refers to colocation. Company names refer to filing name used in the annual report.
Source: Annual Reports filed with Companies House.

[86] Global Switch Limited. 2022. *Annual Report and Financial Statements.* https://find-and-update.company-information.service.gov.uk/company/06238341

RWANDA

This landlocked East African country is the only known developing country where the ICT regulator publishes electricity consumption of telecom tower companies and data centers.[87] This is primarily due to the fact that the regulator—Rwanda Utilities Regulatory Authority (RURA)—covers not only ICT but also electricity as well as postal services, water, sanitation, and transport. As seen in Table 3.3, GHG emissions and energy consumption reported by the country's operators is limited (see Annex for details on reporting). According to the PeeringDB database, three data center-like "facilities" operate in Rwanda:[88] None of the three data centers listed in Table 3.3 disclose any climate or energy data.

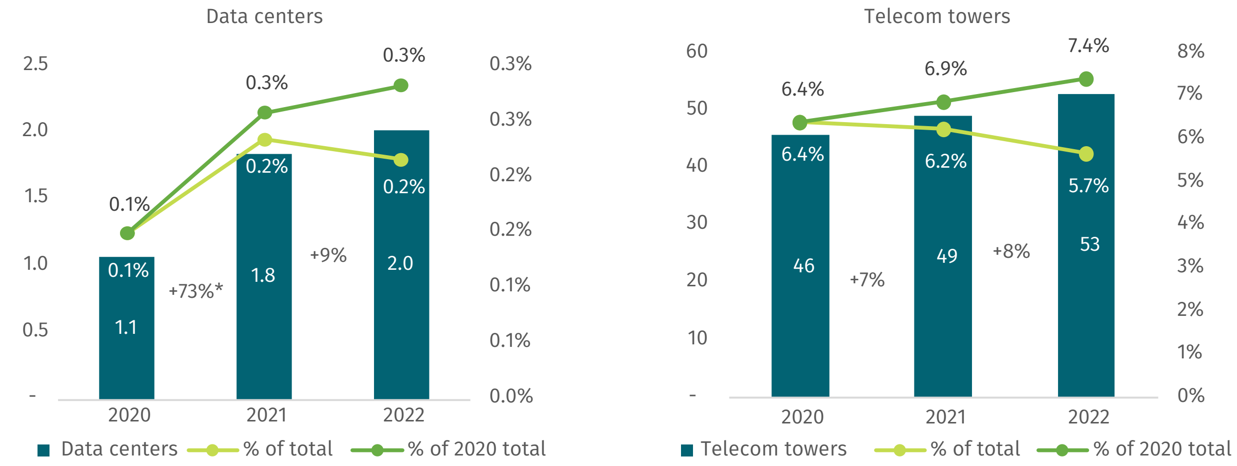
Table 3.3: Disclosure of climate and energy data by main telecom operators, Rwanda

	Scope 1 (tCO_2e)			Scope 2 (tCO_2e)			Scope 1+2 (tCO_2e)			Electricity (MWh)		
Company	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
MTN	1,276	916		2,620	2,613		3,896	3,529		7,060		
Airtel												
Liquid Telecom												841

Note: MTN's 2021 Scope 2 figure is market-based.
Source: Company reports.

RURA compilation of electricity consumption data for towers and data centers is straightforward since they are charged special tariff for usage. Electricity consumption in data centers and telecom towers increased by 89 and 16 percent, respectively, from 2020 to 2022. However, the electricity share of telecom towers and data centers in total consumption has declined, due to Rwanda generating more electricity over the last three years. If using the 2020 figure for electricity, towers would be consuming 7.4 percent of the country total instead of 5.7 percent.

Figure 3.4: Electricity consumption of data centers and telecom towers (GWh), Rwanda



Note: * Two quarters of 2020.
Source: RURA.

[87] RURA. 2023. *Electricity Statistics Report as of the Fourth Quarter (October-December) of the Year 2022.* https://rura.rw/fileadmin/Documents/Energy/Statistics/Electricity_Statistics_Report_as_of_the_Fourth_Quarter_2022.pdf
[88] https://www.peeringdb.com/search?q=rwanda

Rwanda exhibits the characteristics of many developing countries in respect to measuring their ICT carbon footprint. Operators do not directly disclose data (although if part of a group there may be data) and there is generally no legal requirement to do so (that is, either no stock market or no stock market requirement). Given that RURA publishes electricity consumption for towers and data centers, as well as subscription data, for the telecommunications sector,[89] it would appear to be straightforward to collect emissions data.

BRAZIL

In Latin America and the Caribbean (LAC), advancements in aligning ICT and environmental agendas have lacked consistency, coordination, and scale. Brazil is notable for being one of the few countries with a voluntary GHG emissions disclosure scheme for companies and for making them available in a public registry. The Brazilian Greenhouse Gas Protocol Program (PBGHG),[90] coordinated by the Fundação Getúlio Vargas (FGVces),[91] has been developed in partnership with a number of organizations.[92]

Over 1,000 companies from a variety of sectors participate, including three of the four main telecom operators. Companies report on all three emissions scopes (Box 2.1) in a standard format, and a time series is available. Companies also provide a detailed report each year on their GHG emissions, including emission factors used, voluntary offsets purchased, and other relevant information. The program builds capacity on GHG accounting and reporting and provides assistance to stakeholders through development of standards and tools, including guidance on corporate GHG inventory development, third-party verification, and a cross-sectoral calculation tool adapted to the Brazilian context.

Incentives for companies to participate include capacity building and technical advice, as well as reputation, with bronze, silver, and gold seals awarded based on the quality of the reporting. Many companies already disclose similar information in ESG reports, so it would not involve significant additional effort to disseminate the information for a public registry.

[89] RURA. 2023. *Statistics Report for Telecom, Media and Broadcasting Sector as of the Fourth Quarter (October-December) of The Year 2022.* https://rura.rw/fileadmin/Documents/ICT/statistics/Statistics_Report_for_Telecom__Media_and_Broadcasting_Sector_as_of_the_Fourth_Quarter_of_the_Year_2022.pdf

[90] https://registropublicodeemissoes.fgv.br

[91] https://portal.fgv.br/en/institutional

[92] World Resources Institute (WRI), the Ministry of the Environment, the Brazilian Business Council for Sustainable Development (Cebds), the World Business Council for Sustainable Development (WBCSD) and companies

Table 3.4: Information and Communications emissions, 2021, Brazil

Company	tCO_2e		
	Scope 1	Scope 2	Scope 3
Vivo	26,550	230,945	346,715
TIM	4,395	51,355	8,199
Oi	56,783	174,747	17,592
Claro*	34,837	382,632	
Telecom	**122,566**	**839,678**	
Algar Tech	249	4,170	152.03
Algar Telecom	1,090	2,699	383
Ascenty	2,396	67,834	51
Blueshift		0.8	6
Finnet	18	10.52	9
GLOBO	3,109	14,362	8,915
Grupo Nexxees	10		
Others	**6,872**	**89,077**	
TOTAL	**129,438**	**928,755**	

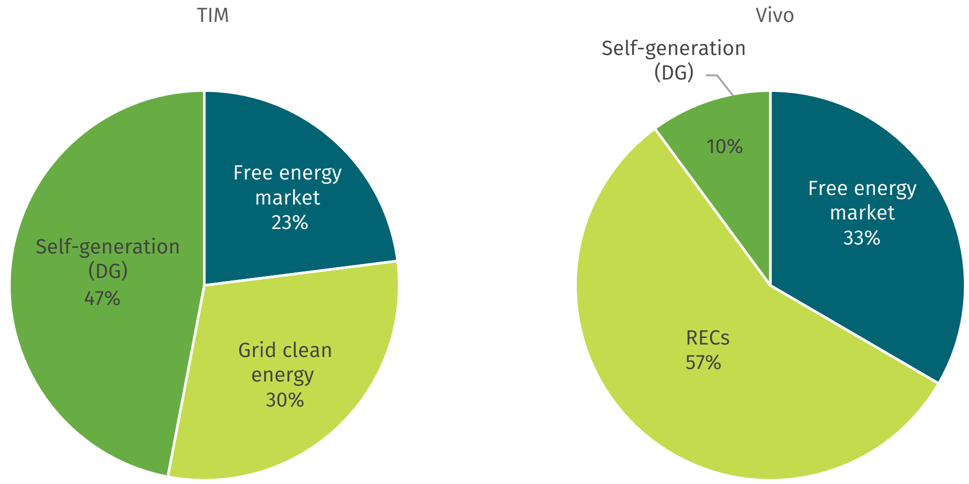
Source: Brazilian Greenhouse Gas Protocol Program (PBGHG) and America Movil.
Note: Scope 2 emissions are location-based. * Does not report to the registry; data from its sustainability report.

An April 2012 regulation allowed the installation of generation units (up to 5 MW) connected to the local power utility using their local grid ("Distributed Generation, DG").[93] Net-metering was allowed, meaning excess electricity generated could be fed back to the distribution network and used to offset purchased electricity. By June 2020, some 245,000 generators with more than 3 GW of capacity were serving over 300,000 consumers. The regulation requires only the use of renewables, with solar accounting for 99 percent of the generators. In addition to DG, Brazilian consumers can also purchase renewable energy from the so-called “free market” where sellers and purchasers trade electric energy freely among themselves.[94]

Brazil's telecom operators have been quick to seize on the DG scheme for powering their networks either by establishing their own generators or partnering with suppliers close to where they need the electricity. TIM and Vivo have been particularly active in this area. By the end of 2022, TIM had 53 renewable energy plants producing 47 percent of its electricity while Vivo had 48 plants generating 10 percent of its renewable energy. The DG system has contributed to the companies using 100 percent renewable energy, essential for meeting their emissions reductions targets and fulfilling requirements related to sustainability-linked bonds.

93 Alex Sandro Feil. 2020. "Incentives for distributed generation in Brazil." FSR Global, 20 July. https://fsr.eui.eu/incentives-for-distributed-generation-in-brazil/
94 See "Learn About the Free Energy Market" at: https://www.engie.com.br/en/solutions/our-expertise/free-energy-market/learn-about-the-free-energy-market/

Figure 3.5: Sources of renewable energy, TIM and Vivo, Brazil, 2022



Source: Company reports.
Note: Self-generation is the use of Distribution Generation plants. Free energy market refers to renewable energy suppliers separate than the grid operator. Clean grid energy refers to the proportion of the Brazilian grid that is generated by renewables adjusted for its use in the company's total renewable energy consumption. RECs refers to Renewable Energy Certificates.

4. KEY TAKEAWAYS: ADDRESSING THE CARBON FOOTPRINT AND ENERGY NEEDS OF THE ICT SECTOR

KEY TAKEAWAY: *Access to data on emissions and energy usage, reported using a common approach and format, equips governments to make informed policy decisions. A data-driven approach is instrumental to establish realistic targets – nationally and globally, for emissions reduction, formulate effective regulations, and closely monitor progress. Collaboration across government entities responsible for ICT, energy, and the environment is important to maximize benefits from these efforts.*

Governments play a fundamental role in upholding environmental responsibility. Oversight of the environmental repercussions of the ICT sector helps demonstrate their commitment to climate change mitigation, as shown, for instance, through endorsement of international accords such at the Paris Agreement. Even though the ICT sector may not be a formal part of national emissions reporting, the ICT sector is increasingly important in many countries' goals to curtail GHGs. Therefore, it is important for governments to engage with the ICT sector to ensure both accurate emissions reporting and effective reduction measures.

Also, high-level recognition of the importance of this data is also important for necessary policies and regulations to be implemented. Collaboration between the ICT sector regulator, the energy regulator, and the national environment agency is important to formulate and enforce these policies and regulations. The Green Digital Action Track[95] at COP28 included a "call for action" for industry to report annually on Scope 1, 2, and 3 emissions. If widely adopted, this practice could significantly increase data availability.

KEY TAKEAWAY: *Addressing emissions from the ICT sector requires data disclosure, aggregation, and assessment to facilitate timely, informed decision making. The ICT regulator can play an important role in this process given their knowledge of the sector and the industry players. Capacity building will be needed to support this process given the lack of experience in collecting, aggregating, and assessing the data.*

As the report notes, substantial disparities in ICT sector energy consumption exist between countries. For instance, Ireland stands out due to significant energy usage by data centers, which eventually prompted introduction of regulatory measures. In contrast, many LMICs have low total ICT emissions and energy use relative to global totals, but these can still represent significant amounts within the country. In Rwanda, telecommunications towers already account for 6 percent of the country's electricity consumption. Despite differences in how emissions are reported, ICT emissions and electricity use are increasing globally.

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[95] See "Green Digital Action at COP28" at: https://www.itu.int/initiatives/green-digital-action-atcop28/

Therefore, data disclosure, aggregation, and assessment is critical. While there is some available ICT data at the company level, very little data is aggregated at the national level. In France, the telecom sector regulator ARCEP requires telecom operators to report their Scope 1 and 2 emissions, electricity use, handset sales, and recycling rate. Ireland's national statistical office collects electricity use by data centers, from which Scope 2 emissions can be calculated. Rwanda's energy regulator collects electricity consumption by data centers and telecommunication towers.

Given the limited data collected currently, training will be critical to develop a global database on ICT sector emissions and energy use. In particular, ICT regulators can play a pivotal role in data aggregation and assessment since they understand the industry and market players. In many LMICs, ICT sector regulators already compile telecom statistics, providing a basis for extending this to include emissions and energy data. For instance, all but one member country in the East African Community already compile telecommunications statistics.

KEY TAKEAWAY: *Technology transitions in the ICT sector have the potential to reduce sector emissions. However, these transitions need to be carefully planned to ensure inclusion and that no population segments, particularly the poor and most vulnerable, are left behind.*

Planning is important to balance ICT sector growth while reducing emissions. Transitioning from legacy networks, both fixed and mobile, is one example where older infrastructure is less energy efficient and hence generates higher emissions. Another is using data proactively to make decisions in anticipation of how digitalization will affect a country's electricity and GHG emissions.

As shown in the report, evidence from the UAE found that 4G and 5G networks were considerably more energy efficient than 2G and 3G. Analysis from France found that while shutting down the country's 2G and 3G networks would increase embedded emissions in the short term due to the need to purchase new devices, this would be offset within six months. Another reason to decommission older mobile networks is to regain spectrum to redeploy for 4G and 5G. It is important for governments to have a strategy for 2G and 3G shutdowns to avoid disruption,[96] including signaling its intentions far enough in advance for network operators and users to adapt.

However, it is critical that countries develop an inclusive transition plan that considers key issues such as coverage, cost of new devices, and conversion of machine-to-machine (M2M) devices, such as Automatic Teller Machines (ATMs), point of sale terminals, and utility meters to the IoT. Energy efficiency gains from technology transitions need to be balanced with ensuring access to services, including for the most vulnerable people.

In addition, technology transition in fixed networks is also important to reduce energy consumption and hence emissions. In France, the regulator found that copper networks use four times more energy than fiber optic. Therefore, transitions from legacy digital infrastructure can present opportunities to deploy technologies that offer both better performance and greater energy efficiency.

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[96] Ofcom. 2023. *3G and 2G switch-off: Our expectations of mobile providers.* https://www.ofcom.org.uk/__data/assets/pdf_file/0025/252592/3G-and-2G-switch-off.pdf

KEY TAKEAWAY: *Regulatory modifications, coupled with incentives and collaboration between the ICT and energy sectors, can help reduce emissions and support sustainable energy access.*

Regulations coupled with financial incentives can help reduce ICT sector emissions.[97] Emissions from the sector reflects the digital maturity and the local energy mix. While the sector's emissions are relatively low in many developing countries the current and future strain on energy resources can be high. Enhancing data collection related to the sector is important for energy resource management. Energy efficiency within the ICT sector, particularly for data centers—given their high electricity consumption—is critical. Liberalization of the South African energy market opened the way for Amazon to invest in one the country's largest solar farms to supply renewables for its data center. In Brazil, distributed generation (DG) regulation has enlivened the country's renewable industry with telecom firms, in particular, taking advantage to the extent that some now completely operate their networks on clean energy. More broadly there are other policy and regulatory options available that can support the scale up of renewable energy for the ICT sector, such as electricity market reform, facilitation of corporate power purchase agreements and guarantee of origin frameworks.[98]

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[97] Policies for Enabling Corporate Sourcing of Renewable Energy Internationally: A 21st Century Power Partnership Report by Lori Bird, Jenny Heeter, Eric O'Shaughnessy, Bethany Speer, Christina Volpi, and Ella Zhou, National Renewable Energy Laboratory (2017)

[98] European Commission. 2022. *COMMISSION RECOMMENDATION of 18.5.2022 on speeding up permit-granting procedures for renewable energy projects and facilitating Power Purchase Agreements.* https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=PI_COM:C(2022)3219

5. ANNEX. METHODOLOGY FOR GHG EMISSIONS AND ELECTRICITY CONSUMPTION ESTIMATES

This section describes the methodologies used in this report to estimate ICT sector emissions and electricity consumption.

A growing number of companies, including those in the ICT sector, publish emissions data in Environmental, Social, and Governance (ESG) reports. Some multinational ICT companies also disseminate country breakdowns. These reports form the basis of the estimates here. Almost all companies follow the *GHG Protocol Corporate Accounting and Reporting Standard* for compiling emissions.[99] The framework breaks emissions down into operations (Scope 1 and 2) and upstream and downstream activities (Scope 3 with 15 categories). Many use the Global Reporting Initiative (GRI) framework for reporting their emissions and energy use (disclosure 302 for energy[100] and 305 for emissions).[101]

World and country totals for GHG emissions from energy use are sourced from the Energy Institute.[102] World and country totals for electricity consumption are sourced from the Energy Information Administration (EIA).[103] At the time the report was written, 2022 electricity consumption was not available.

5.1 TELECOMMUNICATIONS

The boundaries and scope of telecommunication operators' data are important to ensure data accuracy and comparability. Relevant telecommunications operators to include were identified by reviewing national regulatory agency websites for list of licensed facility-based operators. The includes companies that provide mobile and/or fixed telecommunications services as well as tower companies. For operators with operations in more than one country, this includes only assessing the relevant country through review of the reports of the relevant subsidiary if available; when not available, we consulted the breakdown of country emissions by the group. Note that the GHG Protocol calls for companies to report total emissions for subsidiaries that they have operational control or financial control over (i.e., emissions are the total for the subsidiary and not prorated according the ownership share. Equity share reporting is another option offered by the GHG Protocol but is much less used. The scope of telecommunications services provided affects emissions. Some operators provide only mobile services, others fixed, and some both. Further, most operators have data centers for their own use, while some also make them available for hosting client data. Emissions disaggregation by the telecommunication service provided (for example, mobile, fixed, data center) is rarely provided, though there are exceptions (Box 5.1).

99 https://ghgprotocol.org/corporate-standard
100 https://www.globalreporting.org/standards/media/1009/gri-302-energy-2016.pdf
101 https://www.globalreporting.org/standards/media/1012/gri-305-emissions-2016.pdf
102 Energy Institute. 2023. Statistical Review of World Energy. https://www.energyinst.org/statistical-review
103 https://www.eia.gov/international/data/world

BOX 5.1: BREAKING DOWN EMISSIONS AND ENERGY DATA

PLDT is a telecommunications operator headquartered in the Philippines. The company's annual Sustainability Report provides detailed climate and energy data disaggregated by its three main business lines: fixed, mobile, and data centers.[104] Analysis is enhanced by including a three-year time series that allows for adjustments to previous years' data. The company uses the data to identify mitigation measures and refinements in its practices.

PLDT adheres to international reporting standards, including the Global Reporting Initiative (GRI) and Task Force on Climate-related Financial Disclosures (TCFD), both of which call for using the GHG Protocol for compiling GHG emissions data.[105] The data have been assured by a third party.

Non-renewable energy use generates GHG emissions. PLDT discloses the emissions factors used for converting fuel and electricity consumption to GHG emissions. For electricity, two figures are used since the grid emissions vary between major island groups (Luzon and Visayas; and Mindanao).

For Scope 1 emissions, liters of diesel and gasoline used for vehicles, mobile base stations, and back-up generators are converted to gigajoules, a standard measurement of energy. Appropriate emissions factors are applied to obtain the corresponding emissions.

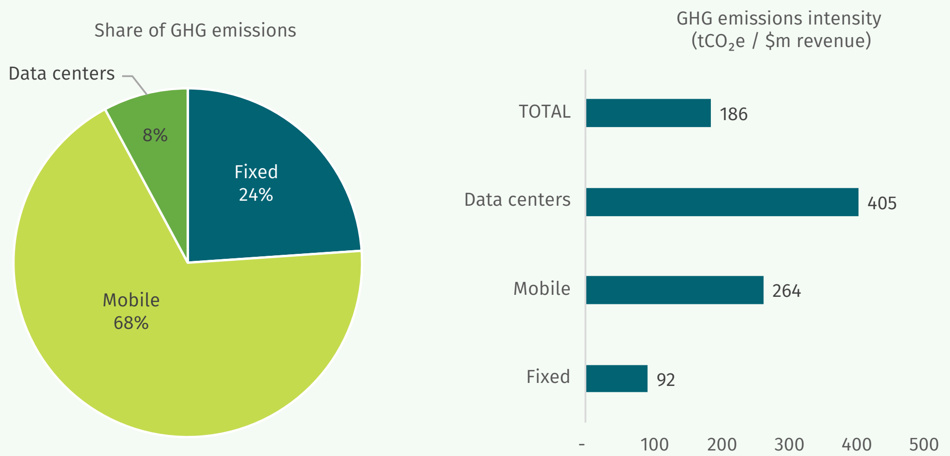
Scope 2 emissions are location-based. Electricity consumption is obtained from utility bills as well as purchased renewable energy using emission factors provided by the vendor.

PLDT reports four categories of upstream and downstream Scope 3 emissions:

- Category 1: Purchased Goods and Services (3 percent of total Scope 3);
- Category 2: Capital Goods (62 percent);
- Category 3: Fuel and Energy Related Activities (7 Percent);
- Category 11: Use of Sold Products (28 percent).

Mobile networks accounted for over two-thirds of PLDT's emissions in 2022 (Figure 5.1, left). However, data centers are the most carbon intense of its operations based on emissions per unit of revenue, whereas mobile networks are the least (Box Figure 5.1, right).

Figure 5.1: PLDT GHG emissions and intensity factor by service, 2022



Source: PLDT. 2023. Sustainability Report 2022.
https://main.pldt.com/investor-relations/annual-and-sustainability-reports

[104] PLDT. 2023. *Sustainability Report 2022.* https://main.pldt.com/investor-relations/annual-and-sustainability-reports

[105] Relevant GRI disclosures include 302 ENERGY (https://www.globalreporting.org/standards/media/1009/gri-302-energy-2016.pdf) and 305 EMISSIONS which states "...The reporting requirements for GHG emissions in this Standard are based on the requirements of the 'GHG Protocol Corporate Accounting and Reporting Standard' ('GHG Protocol Corporate Standard')" (https://www.globalreporting.org/standards/media/1012/gri-305-emissions-2016.pdf). TCFD notes "GHG emissions should be calculated in line with the GHG Protocol methodology to allow for aggregation and comparability across organizations and jurisdictions." (https://assets.bbhub.io/company/sites/60/2021/07/2021-TCFD-Implementing_Guidance.pdf)

Some operators providing mobile services make use of tower companies to host their mobile base stations. Emissions attribution varies affecting comparability. In some cases the operators are charged for their energy use and report the consequent emissions as their own, in Scope 2. In other cases, the operators report tower emissions as either Scope 3 purchase of services or Scope 3 upstream leased assets and the tower companies are responsible for the emissions (reported in the tower companies operational Scope and 2 emissions). Data have been adjusted accordingly by including the emissions of tower companies where relevant.

Telecommunication operators from the 30 largest countries in terms of GHG from energy emissions were considered.[106] These operators accounted for 95 percent of global telecommunication revenues in 2022.[107] The operators are the largest in each country considered and typically account for all telecommunications revenue and/or mobile subscriptions. We consulted ESG reports with emissions data for 95 operators, while estimating data for another 10 operators based on revenue.[108]

Table 5.1: Emissions and electricity use reported by telecommunications operators

		Scope 1 (million tCO_2e)			Scope 2 Location-based (million tCO_2e)			Electricity (TWh)		
Economy	**Operators**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
China	3	0.65	1.05	0.56	61.46	61.2	63.03	94.97	103.31	108.05
United States	6	2.23	2.34	2.04	14.37	15.3	13.5	41.21	41.39	37.43
India	5	1.71	1.7	1.62	10.24	11.22	10.83	12.86	17.06	15.5
Japan	3	0.17	0.18	0.1	4.94	5.08	4.51	11.55	12.76	10.98
Indonesia	3	0.07	0.06	0.06	3.8	3.35	3.64	4.61	4.08	4.44
Germany	3	0.15	0.14	0.14	1.81	1.5	1.41	4.55	4.28	4.26
Saudi Arabia	3	0.27	0.26	0.29	1.25	1.13	1.1	2.13	1.88	1.84
Korea, Rep.	3	0.05	0.05	0.05	3.27	3.47	3.61	7.49	8.13	8.47
Canada	5	0.26	0.25	0.24	0.56	0.5	0.44	4.37	4.28	4.36
Mexico	3	0.15	0.15	0.14	1.36	1.18	1.15	2.95	2.99	2.88
Brazil	4	0.17	0.16	0.11	0.69	0.84	0.42	5.26	5.19	5.19
South Africa	4	0.1	0.13	0.17	1.81	2.21	1.83	1.83	2.18	1.76
Türkiye	3	0.16	0.15	0.16	1.38	1.18	1.23	3.02	2.72	2.59
Australia	3	0.04	0.04	0.04	1.81	1.74	1.68	5.9	5.7	5.69
United Kingdom	5	0.23	0.22	0.22	1	0.92	0.86	4.31	4.44	4.45
Italy	5	0.16	0.14	0.12	0.87	0.85	0.83	3.08	3.29	3.31
Poland	5	0.03	0.05	0.04	0.8	0.79	0.73	1.14	1.36	1.34
United Arab Emirates	2	0.62	0.09	0.09	0.59	0.41	0.44	1.14	0.8	0.83
Thailand	3	0.03	0.03	0.03	1.44	1.52	1.56	2.75	3.03	3.15

106 The Russian Federation, Iran, Vietnam and Pakistan were excluded due to a lack of data.
107 https://www.idc.com/getdoc.jsp?containerId=prUS50644723
108 Revenue as an intensity indicator avoids the challenge of subscription data where some operators provide only mobile services, some only fixed services, some both and others outside the telecom sector do not have subscribers.

		Scope 1 (million tCO_2e)			Scope 2 Location-based (million tCO_2e)			Electricity (TWh)		
Economy	**Operators**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
Malaysia	4	0.04	0.07	0.07	0.81	0.97	1.05	1.19	1.51	1.56
Taiwan, China	3	0.03	0.03	0.03	1.25	1.26	1.26	2.52	2.58	2.58
France	4	0.13	0.14	0.1	0.25	0.25	0.25	4.46	4.44	5.05
Spain	4	0.04	0.04	0.03	0.58	0.71	0.36	2.76	2.76	2.5
Egypt, Arab Rep.	4	0.3	0.28	0.28	0.63	0.65	0.63	1.3	1.29	1.57
Kazakhstan	2	0.04	0.04	0.04	0.27	0.36	0.3	0.29	0.36	0.34
Singapore	3	0.01	0.01	0.01	0.2	0.19	0.18	0.47	0.48	0.44
Argentina	3	0.09	0.08	0.09	0.61	0.45	0.4	1.67	1.53	1.41
Netherlands	3	0.03	0.02	0.02	0.45	0.4	0.34	1.04	0.96	0.91
Iraq	2	0.3	0.32	0.28	0.24	0.17	0.16	0.23	0.24	0.24
Philippines	2	0.07	0.09	0.09	0.94	1.06	1.18	1.33	1.57	1.67
	105	**8**	**8**	**7**	**120**	**121**	**119**	**232**	**247**	**245**

Note: Ranked in order of total GHG emissions from energy use.
Source: Company reports and ITU/World Bank estimates.

5.2 COLOCATION DATA CENTERS

Colocation data centers are often connected to the internet providing hosted organizations and internet service providers a facility to exchange data and access cloud computing facilities. There were 3,831 connected colocation data centers in 2022.[109] Market size by revenues was US$64.9 billion in 2022[110] of which the top eight accounted for around a third (Table 5.2). While the top 10 consists of companies headquartered in just two countries (China and the United States), they have operations across the globe.

Table 5.2: Colocation data centers GHG emissions and electricity use, world estimate

	Scope 1 +2 (millions tCO_2e)			Electricity (TWh)		
Company	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
Equinix	2.3	2.4	2.5	6.4	7.1	7.8
Digital Realty	3.0	3.2	3.5	8.3	9.3	10.3
GDS	1.5	2.4	2.7	2.8	4.2	4.7
CyrusOne	1.0	1.1	1.2	2.8	3.2	3.4
VNET	0.5	0.7	0.9	0.5	0.9	1.2

[109] Extrapolated from https://www.peeringdb.com/.
[110] https://structureresearch.net/product/2023-global-data-centre-colocation-interconnection-report-copy/

	Scope 1 +2 (millions tCO_2e)			Electricity (TWh)		
Company	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
Flexential	*0.3*	*0.3*	*0.3*	*0.7*	*0.7*	0.8
CoreSite	0.3	0.3	0.3	1.0	1.1	1.2
Cyxtera	*0.3*	*0.3*	*0.3*	*1.1*	1.1	1.2
Above	**9.2**	**10.6**	**11.7**	**23.6**	**27.6**	**30.5**
TOTAL	**35**	**39**	**42**	**89**	**102**	**110**

Note: Companies listed by order of revenue. Scope 2 is location based. Figures in italics are estimates. World estimate derived from revenue market share of companies shown. Data centers operated by telecommunications operators excluded.
Source: Company reports.

5.3 CLOUD AND CONTENT DATA CENTERS

Cloud companies offer access to databases, AI algorithms and other computational services. Customers can also store their data on the cloud but unlike collocation data centers, they are not tenants. Therefore, emissions are fully allocated to the cloud providers Scope 1 and 2 and the clients Scope 3. Large social media companies also have their own hyperscale data centers. Global estimates are based on revenue market share.

Table 5.3: GHG emissions and electricity use, cloud services and content

	Scope 1+2 (million tCO_2e)				Electricity (TWh)				GHG / $ million revenue		
Company	**2020**	**2021**	**2022**	**Change 2022/2020**	**2020**	**2021**	**2022**	**Change 2022/2020**	**2020**	**2021**	**2022**
AWS	4.8	5.7	6.5	36%	12.0	15.4	17.7	47%	106	92	81
Azure	4.4	5.1	6.5	47%	10.8	13.6	18.2	69%	92	85	87
Google Cloud	*1.3*	*1.7*	*2.2*	71%	*3.3*	*4.7*	*6.0*	80%	99	89	84
3 Above	**9.2**	**10.9**	**13.0**	**41%**	**22.8**	**29.1**	**35.8**	**57%**	**87**	**77**	**72**
CLOUD	***14***	***16***	***19***		***33***	***43***	***53***				
Google	4.6	4.9	5.9	29%	11.8	13.5	15.8	34%	27	21	23
Meta	2.7	3.1	4.0	45%	7.2	9.4	11.5	61%	32	27	34
Tencent	0.9	2.5	2.8	203%	1.7	4.4	5.0	194%	13	29	34
Content	**8**	**11**	**13**	**54%**	**21**	**27**	**32**	**86%**	**25**	**24**	**28**
TOTAL	**22**	**27**	**32**	**46%**	**54**	**70**	**85**	**63%**	**41**	**37**	**40**

Note: Emissions are location-based. GHG / $ million revenue for AWS, Azure and Google is based on cloud computing revenue.
Source: Company reports.

5.4 ICT EQUIPMENT EMISSIONS

Embedded (that is, from the manufacturing process) and product use emissions from the use of ICT equipment (for example, servers, mobile phones, computers, and others) form part of the ICT sector footprint. Supply chain and product use emissions (Scope 3, Category 1 and Category 11, respectively) of the leading computer and network gear operators form the basis to estimate embedded and product use emissions globally. Note that embedded emissions represent an alternative to determining the sectoral emissions of the ICT manufacturing industry. Life Cycle Assessment (LCA) usually considers the materials goods are made of, the manufacturing process, transportation, use and end of life, but transportation and end-of-life emissions are excluded from the analysis.

Vendors of branded ICT equipment design and sell products but outsource much of their manufacturing and assembly. As a result, they have low operational emissions (that is, Scope 1 and 2).[111] Their Scope 3, Category 1 emissions (purchased goods and services) reflect their supply chain footprint. Branded equipment manufacturers rarely supply products and services among themselves so the impact of double counting is limited. However supply chain emissions are first degree meaning they omit the supply chain emissions of the vendor's suppliers.

5.4.1 PERSONAL COMPUTERS (PCS)

The top six vendors of personal computers (PCs) accounted for 85 percent of the market in 2022, selling 243 million of a world total of 286 million units.[112] All of the leading PC vendors disclose their own Scope 1 and 2, supply chain and product use emissions. This report estimates the remainder for other vendors from market share. Vendors of ICT equipment report their product use emissions (Scope 3, Category 11, Use of Sold Products) for products manufactured that year, so it does not include PCs still in use. Therefore, it is necessary to estimate how many years a PC is in use, on average, and add up the product use emissions for those years to obtain emissions for a specific year. Apple reports an average product use of four years for a PC,[113] therefore product use for 2022 is the sum of product use for 2019-2022. Although the majority of emissions come from PC production and use, these vendors sell related equipment such as printers, wearables, and others. Since they do not provide detailed emissions breakdowns, these are included in the totals.

[111] For instance Apple iPhone chips are manufactured by Qualcomm, Broadcom and TSMC, camera by Sony, etc. See: https://www.lifewire.com/where-is-the-iphone-made-1999503

[112] "Gartner Says Worldwide PC Shipments Declined 28.5% in Fourth Quarter of 2022 and 16.2% for the Year." Press Release, 11 January 2023. https://www.gartner.com/en/newsroom/press-releases/2023-01-11-gartner-says-worldwide-pc-shipments-declined-28-percent-in-fourth-quarter-of-2022-and-16-percent-for-the-year

[113] https://www.apple.com/in/environment/pdf/products/desktops/Mac_Pro_PER_June2023.pdf

Table 5.4: PC embedded and product use emissions

Company	Shipments (millions)			Emissions (million tCO_2e)											
				Own use			Supply chain			Embedded			Product use		
	2020	2021	2022	2020	2021	2022	2020	2021	2022	2020	2021	2022	2020	2021	2022
Lenovo	71.8	83.4	69.0	0.2	0.2	0.2	6.5	7.8	8.7	6.7	8.0	8.9	54	50	46
HP	67.8	74.2	55.6	0.3	0.2	0.2	17.1	18.2	16.1	17.3	18.5	16.4	52	48	43
Dell	50.3	59.6	50.0	0.4	0.4	0.4	8.8	13.7	13.7	9.2	14.1	14.1	51	54	57
Apple	22.8	26.9	27.9	0.6	0.7	0.7	10.5	10.5	8.4	11.1	11.1	9.1	16	15	13
Acer	21.0	24.3	18.7	0.02	0.02	0.02	6.6	7.1	5.6	6.6	7.1	5.6	7	7	6
ASUS	17.8	21.6	20.7	0.02	0.02	0.02	0.9	1.1	1.1	0.9	1.1	1.1	1	1	2
Sub-total	**251**	**290**	**242**	**1**	**2**	**2**	**50**	**58**	**53**	**52**	**60**	**55**	**182**	**176**	**167**
Others	52	52	*44*	*0.3*	*0.3*	*0.3*	*10*	*10*	*10*	*11*	*11*	*10*	*21*	*21*	*20*
TOTAL	**304**	**342**	**286**	**2**	**2**	**2**	**61**	**69**	**63**	**62**	**71**	**65**	**203**	**197**	**187**

Note: Figures in italics are estimates. Apple also sells smartphones and wearables; therefore, its emissions have been prorated using Mac revenue share. Embedded is the sum of the vendors own emissions (Scope 1 and 2 location-based) and their supply chain emissions (Scope 3 Category 1). Transportation and end of life emissions are not included.
Source: Company reports and Gartner.

5.4.1.1 Smartphones

Estimating smartphone production emissions is not straightforward due to several factors. Emissions data are available for the top three vendors,[114] but Samsung and Apple also sell other products (televisions and other home products in the case of Samsung, and computers and wearables in the case of Apple). These two companies do not provide disaggregated emissions data for their smartphone segment. Therefore, this report estimates manufacturing emissions based on the life cycle emissions published by Apple and Samsung for their popular selling smartphones and applied to the other companies in this group. Smartphone manufacturing (that is, embedded) emissions are estimated at 57million tCO_2e and electricity use at 119 TWh in 2022.

Table 5.5: Smartphone production (embedded) emissions and electricity consumption

	2020	2021	2022
Supply chain emissions (million tCO_2e)			
Samsung	10	10	10
Apple	12	14	13
Others	38	40	34
Total	60	64	57
Electricity consumption (TWh)	116	131	119

[114] https://www.idc.com/getdoc.jsp?containerId=prUS51088223

Product use emissions and electricity use have been estimated based on the smartphone daily charging electricity factor from the United States EPA.[115] There were 5.2 billion smartphones in 2022 according to shipment data over the last four years, assuming a smartphone is in service for an average of four years.

Table 5.6: Smartphone product use emissions and electricity consumption

	2020	2021	2022
Estimated smartphones in use (millions)	5,520	5414.6	5217.5
Product use emissions (million tCO_2e)	19	18	18
Product use electricity (TWh)	24	24	23

Note: Estimated based on US EPA data for daily smartphone charging (0.012 kWh/smartphone charged). Number of smartphones based on sales over the four previous years. Emissions derived from global grid emissions factor.

[115] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

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