caspera.lab

# The Green Signal: A Comprehensive Study on Sustainability, Decarbonization, and the Future of Telecommunications

a caspera.lab research paper

Sept2025

## The Environmental Footprint of the ICT Sector: Scope, Scale, and the Data-Driven Challenge

### 1.1. The Global Picture: From Niche to Major Contributor

The information and communication technology (ICT) sector has evolved from a nascent industry into a pervasive global utility, now connecting two-thirds of the world's population[1]. This rapid digitalization, however, carries a significant environmental footprint, primarily driven by increasing energy demands and associated greenhouse gas (GHG) emissions[2]. Estimates of the sector's share of global carbon emissions vary widely across the literature, ranging from 1.5% to 4%[3]. A recent report from the World Bank and the International Telecommunication Union (ITU) places this figure at a **minimum of 1.7% of global emissions** as of 2022, representing 567 million metric tons of carbon dioxide equivalent ($tCO_2e$)[4]. This places the ICT sector's environmental impact in a comparable class to the global aviation and shipping industries, which are responsible for 1.9% and 1.7% of global emissions, respectively[5].

The broad range in emission estimates is not an indication of a lack of rigorous analysis, but rather a symptom of the inherent complexity and a notable absence of standardized global metrics for measuring the sector's true environmental impact[6]. The ICT ecosystem is vast and fragmented, encompassing everything from network infrastructure and data centers to a multitude of consumer devices[7]. This lack of a unified measurement framework creates a data gap that can obscure the full scale of the industry's environmental responsibilities[8]. In response, global organizations like the GSMA and ITU are actively working to address this issue by developing a common set of indicators and key performance indicators (KPIs) to better measure and compare energy efficiency across different networks and regions[9].

Despite its substantial footprint, the ICT sector also serves as a critical enabler of decarbonization for other industries, a concept often referred to as the industry's **"handprint"**[10]. Mobile and digital technologies, such as smart cities, smart grids, and smart manufacturing, are estimated to enable carbon reductions that are up to

**10 times larger** than the mobile industry's own carbon footprint[11]. This dual role positions the sector as both a source of environmental challenge and a vital catalyst for the broader global green transition[12].

## 1.2. Breakdown of the Footprint: A Look Inside the Network

A detailed analysis of the ICT sector's footprint reveals that its impact is not uniform across its various subsectors[13]. The primary source of energy consumption for a telecommunications operator is its
**Radio Access Network (RAN)**, which is responsible for approximately **73% of the network's total energy use**[14]. This concentration of energy use in the RAN is a direct consequence of the extensive infrastructure required to deliver wired and wireless connectivity to billions of users, from cell towers to base stations[15].
Other significant contributors to the sector's overall footprint include data centers and the manufacturing and use of ICT equipment[16]. In the European Union, for instance, data centers consumed an estimated 45–65 terawatt-hours (TWh) of electricity in 2022, accounting for 1.8–2.6% of total EU electricity use, while telecommunication networks consumed 25–30 TWh, or 1–1.2% of the total[17].
The high energy consumption of network infrastructure translates directly into a significant financial burden for operators[18]. Energy costs are typically the third most important operational expenditure (OpEx) for network operators, often accounting for **20-40% of their total OpEx**[19]. This substantial financial outlay provides a compelling business case for pursuing sustainability initiatives, transforming environmental stewardship from a corporate social responsibility (CSR) exercise into a core, cost-saving business strategy[20].

## 1.3. Today's Figures and Tomorrow's Projections

The ICT sector's environmental impact is growing, but not in a simple, linear fashion[21]. The sector's total electricity consumption rose by 8.2% from 2020 to 2022, reaching 1,183 TWh[22]. However, a more granular analysis reveals a complex and often paradoxical trend[23]. As mobile data traffic has quadrupled, the mobile industry's operational emissions have **fallen by 8% between 2019 and 2023**[24]. This is due to a simultaneous and impressive improvement in energy efficiency, where each new generation of technology, such as 5G, is vastly more energy-efficient per bit of data transferred than its predecessors[25]. For example, 5G is specified to use **90% less energy** to transfer each bit of data[26].

Despite these remarkable efficiency gains, the sector's overall energy consumption continues to increase due to a phenomenon known as the **"rebound effect"**[27]. As the cost and energy required to transfer data decrease, it fuels an exponential surge in data traffic, driven by new services, higher-definition content, and a constant influx of new users and devices[28]. Ericsson projects a compound annual growth rate (CAGR) of 21% for mobile data per smartphone from 2022 to 2028[29].

Table 1: ICT Sector Global Emissions & Energy Footprint (2022)

caspera.lab

| ICT Subsector | Total Emissions (tCO_2e) in 2022 | % Change from 2020 | Total Electricity Consumption (TWh) in 2022 | % Change from 2020 |
|---|---|---|---|---|
| :--- | :--- | :--- | :--- | :--- |
| Total ICT Sector | 567 million 30 | -0.2% 31 | 1183 32 | 8.2% 33 |
| Telecommunications Operators | 133 million 34 | -1% 35 | 258 36 | 8% 37 |
| Data Centers (Cloud & Content) | 32 million 38 | 46% 39 | 85 40 | 63% 41 |
| Data Centers (Colocation) | 43 million 42 | 20% 43 | 109 44 | 22% 45 |
| ICT Equipment (Embedded) | 154 million 46 | 0.5% 47 | N/A 48 | N/A 49 |
| ICT Equipment (Use Emissions) | 205 million 50 | -7.5% 51 | N/A 52 | N/A 53 |

caspera.lab

# 2: Strategic Pillars of Telecom Sustainability: Actions and Innovations

## 2.1. Energy Efficiency and Network Optimization

Energy efficiency is a central pillar of the telecom industry's sustainability strategy, driven by both environmental commitments and the financial imperative of reducing operational costs[54]. One of the most impactful and accelerating actions is the **decommissioning of older, less efficient network technologies**[55]. For example, shutting down legacy 3G wireless networks, which now have few users but consume a disproportionate amount of power, can reduce energy costs by up to 15%[56]. This strategy, known as "refarming," also frees up valuable spectrum for more efficient and higher-capacity 4G and 5G networks[57].

Beyond decommissioning, a host of innovations are being deployed to optimize network performance and energy use[58]. The shift from outdated copper infrastructure to modern **"green" fiber optics** offers a significant opportunity for energy savings, with some analyses suggesting a potential reduction of 45-65% in overall energy costs[59].

Furthermore, the industry is increasingly leveraging intelligent technologies to manage power dynamically[60]. Advanced software solutions, often powered by artificial intelligence (AI) and machine learning (ML), can dynamically adjust the power consumption of network elements based on real-time traffic conditions[61].

## 2.2. The Shift to Renewable Energy

While efficiency measures are crucial for reducing consumption, the transition to renewable energy is vital for decarbonizing the remaining energy use[62]. This shift addresses **Scope 2 emissions**, which are indirect emissions from purchased electricity and often constitute the largest portion of an operator's operational footprint[63]. In 2023, operators that disclosed to the CDP purchased **37% of their electricity from renewables**, a substantial increase from just 14% in 2019[64].

Major telecom companies are setting and actively working toward ambitious renewable energy goals[65].

- **Verizon** has set a target to source 100% of the energy for its networks from renewables by 2030[66].
- **United Group** has already achieved a significant milestone, with 61% of its electricity coming from renewable sources in 2024, and it is on track to increase this to over 65% by 2027[67].

This transition is a dual-benefit strategy[68]. It not only directly lowers a company's carbon footprint but also provides a critical hedge against the volatility of energy prices, enhancing a company's financial resilience[69].

## 2.3. The Circular Economy: Beyond Recycling

The telecom industry faces a significant challenge in managing the massive volume of electronic waste (e-waste) it generates, which totals over 53 million metric tons globally

each year[70]. A **"circular economy"** model offers a fundamental shift from the traditional "take, make, and dispose" linear model to one that maximizes the value and lifespan of products and materials[71].
Leading operators are actively embedding circularity into their core business strategies[72].

- **Telefónica's "Zero Network Waste" plan** aims to reuse, sell refurbished equipment, and recycle 100% of its network equipment by 2025[73]. In 2023, the company reused over 313,000 pieces of network equipment, a 36% increase from the previous year[74].
- **United Group**, for instance, refurbished 25% of all installed CPE in 2024 and recovered over 2,300 kg of e-waste and 1,500 smartphones through customer take-back programs[75].

The strategic importance of this approach is underscored by a case study of an international carrier that, by reselling its decommissioned network equipment, turned a potential recycling expense into a substantial **€6 million in revenue** over two years[76].

caspera.lab

# 3: The Data Center: A Critical Nexus for Sustainability

## 3.1. The Power and Water Paradox

The data center industry is a critical component of the ICT sector, and its environmental footprint is escalating at an exponential rate[77]. The surge in power consumption is a direct result of the global digital acceleration, which has been massively amplified by the rise of artificial intelligence (AI)[78]. In the U.S., data centers consumed approximately **4.4% of total electricity in 2023**, a figure that is projected to double or triple to **6.7-12% by 2028**[79].

However, the challenge of data centers extends beyond electricity consumption to a critical and often-overlooked resource: **water**[80]. A single data center can consume **millions of gallons of potable (drinking) water per day**, an amount equivalent to the daily water needs of thousands of households[81]. This creates a "water-power" nexus that is generating significant public scrutiny and regulatory pushback[82].

Table 2: Data Center Energy & Water Consumption Projections (US and Global)

| Metric | U.S. Projections |
|---|---|
| Electricity Consumption (2023) | 176 TWh, or 4.4% of total U.S. electricity 83 |
| Electricity Consumption (2028) | 325-580 TWh, or 6.7-12% of total U.S. electricity 85 |
| Water Consumption | A single data center can consume up to 5 million gallons of potable water per day 87 |

## 3.2. Innovations in Cooling and Infrastructure

The growing energy and water demands of data centers, particularly those driven by high-density AI workloads, have spurred a wave of innovation in cooling and infrastructure design[89]. Traditional air cooling, which can account for up to 40% of a data center's total energy consumption, is increasingly being replaced or supplemented by more efficient methods[90].

**Liquid cooling**, including direct-to-chip and immersion cooling, is gaining significant momentum[91]. A study by Microsoft found that switching from air cooling to cold plates can reduce energy demand by 15-20% and water consumption by 31-52%[92]. Beyond cooling, other strategic initiatives are essential to greening data centers[93]. The **reuse of waste heat**, for example, is an innovative approach that enhances sustainability by capturing and repurposing heat to generate electricity or provide heating for other processes[94].

## 3.3. Case Study: The Tucson Water Ordinance

The local and political dimensions of data center sustainability are best exemplified by the case of **Tucson, Arizona**[95]. The Tucson City Council unanimously **rejected a proposed data center**, known as "Project Blue," following a period of intense public debate and community outrage[96]. The public's concern was driven by the project's potential to consume hundreds of millions of gallons of water annually, which was seen as a direct threat to the region's already fragile water supply[97].

In the wake of the rejection, the city council passed a landmark ordinance to regulate "large quantity water users"[98]. The new rules require any large user to submit a comprehensive water conservation plan, agree to use recycled water to offset at least 30% of their consumption, and prove that water will not be wasted[99]. This case study provides a clear warning that the future of data center siting and operation will be heavily influenced by public and regulatory approval, demanding more robust and transparent conservation plans from the industry[100].

caspera.lab

# 4: The Ecosystem of Change: Actors, Leaders, and Collaborations

## 4.1. The Leaders: Company Profiles and Concrete Actions

A select group of telecommunications operators are pioneering the industry's sustainability transformation by adopting ambitious goals and implementing comprehensive, holistic strategies that extend beyond their direct operations[101].

- **AT&T**: The company has set a goal to achieve carbon neutrality for its Scope 1 and Scope 2 emissions by 2035[102]. It also has a strategic focus on its "handprint," with a commitment to help business customers reduce a gigaton of GHG emissions by 2035[103].
- **United Group**: This regional leader has set a Net Zero target for 2040 and has already made significant progress[104]. In 2024, the company reduced its Scope 1 and 2 emissions by 52% compared to its 2020 baseline[105].
- **Vodafone**: The company's sustainability strategy is underpinned by its "Digital for Green" services, which help corporate customers in sectors like logistics and agriculture to reduce their carbon emissions[106].
- **Telefónica**: As a leader in the circular economy, Telefónica has committed to a "Zero Network Waste" goal by 2025 and has a broader circular economy plan to achieve zero waste by 2030[107].
-

## 4.2. The Role of Regulators and Collaborative Bodies

The industry's collective sustainability journey is being guided and accelerated by a variety of collaborative and regulatory bodies[108]. A pivotal actor is the **GSMA**, which in 2019 committed the mobile industry as a whole to a collective goal of achieving **Net Zero emissions by 2050**[109]. While collaboration provides the vision, national and regional regulatory bodies provide the necessary enforcement and standardization[110]. France's electronic communications regulator,
**ARCEP**, stands out as a global leader, being the only regulator to mandate and publish climate data from companies[111].

## 4.3. The Supply Chain and Strategic Partnerships

The decarbonization of the telecom industry is not a solo effort but a value-chain-wide initiative that requires deep and strategic partnerships[112]. Companies are actively working with a wide range of external partners to achieve their sustainability goals, including hardware manufacturers, e-waste partners, and energy providers[113]. Leaders like United Group are using their purchasing power to influence their entire supply chain, directing spending toward suppliers that have committed to ethical compliance and science-based climate targets[114].

caspera.lab

Table 3: Select Telecommunications Operator Sustainability Goals & Progress

| Company | Key Goals & Targets |
| --- | --- |
| :--- | :--- |
| AT&T | Achieve carbon neutrality (Scope 1 & 2) by 2035; Enable business customers to reduce a Gigaton (1 billion metric tons) of GHG emissions by 2035 115 |
| United Group | Achieve Net Zero emissions by 2040 117 |
| Verizon | Source 100% of network energy from renewables by 2030; Plant 20 million trees by 2030 119 |
| Telefónica | Zero Network Waste by 2025; Zero waste by 2030 121 |
| Deutsche Telekom | Net Zero target by 2040; Reduce global emissions by up to 95% 123 |

caspera.lab

# 5: The Financial Imperative and the Path to 2050

## 5.1. Sustainability as a Financial Strategy

The adoption of robust sustainability initiatives is no longer a discretionary activity for the telecommunications industry; it has become a fundamental financial strategy for navigating a challenging economic environment[125]. As a significant portion of a mobile operator's OpEx, ranging from 20% to 40%, energy costs represent a major financial burden that can be directly mitigated through sustainability efforts[126]. GSMA Intelligence estimates that a **20% reduction in power costs** for an average operator could **increase EBITDA by approximately 3.8%**[127]. Beyond cost savings, sustainability is also emerging as a source of new revenue opportunities[128].

Table 4: The Financial Case for Sustainability: OpEx & Revenue Impacts

| Financial Metric | Impact of Sustainability Initiatives | Source |
| --- | --- | --- |
| Operational Expenditure (OpEx) | Energy efficiency and renewable energy procurement can reduce energy costs, which account for 20-40% of a mobile operator's OpEx, leading to significant savings 129 | 130 |
| EBITDA | A 20% reduction in power costs is estimated to increase EBITDA by 3.8% for an average operator 131 | 132 |
| Revenue | Circular economy initiatives (resale of refurbished equipment) and energy efficiency can create new revenue streams 133 | |
| Reputation & Investment | Strong ESG performance is rewarded by investors and enhances brand loyalty among consumers 134 | 135 |

## 5.2. The 2050 Vision: Goals and Milestones

The commitment to **Net Zero by 2050**, as set forth by the GSMA and embraced by a third of the industry, is more than a distant, aspirational target; it is a foundational framework that is driving urgent, near-term action[136]. The goal aligns with the global scientific consensus on limiting temperature rise to 1.5°C, providing a clear and non-negotiable

directive for the entire sector[137]. Achieving this vision necessitates a fundamental shift in business models, moving away from a linear, "take, make, and dispose" economy to a **fully circular one** where products and materials are continuously reused and repurposed[138].

## 5.3. Recommendations for a Sustainable Future

Based on the comprehensive analysis of the telecom industry's environmental footprint, strategic initiatives, and key drivers, a multi-stakeholder roadmap is essential to accelerate progress toward a sustainable future[139].

*For Telecommunications Operators:*

- **Accelerate Network Modernization**: Prioritize and expedite the decommissioning of legacy networks, such as 3G, to realize immediate energy savings and free up spectrum for more efficient 4G and 5G technologies[140].
- **Invest in Green Infrastructure**: Transition to "green" fiber optic networks over legacy copper infrastructure to achieve significant energy savings and build a future-proof, high-capacity network[141].
- **Expand Circular Economy Programs**: Extend equipment refurbishment and take-back programs, both for network infrastructure and consumer devices, to reduce e-waste and create new revenue streams from reselling refurbished assets[142].
- **Integrate Sustainability into the Supply Chain**: Require suppliers to meet stringent ESG standards and incentivize them to set science-based climate targets[143].

*For Policymakers and Regulators:*

- **Standardize Reporting Metrics**: Implement mandatory, standardized reporting frameworks for emissions and energy consumption, similar to France's ARCEP model[144].
- **Provide Regulatory Incentives**: Offer financial incentives and streamlined permitting processes for the deployment of green infrastructure, such as solar-powered towers and energy-efficient data centers[145].
- **Address the Water-Power Nexus**: Develop and enforce regulations that address the significant water consumption of data centers, especially in water-stressed regions[146].

*For Investors and Financial Markets:*

- **Prioritize ESG Performance**: Integrate a company's ESG performance, particularly its progress on emissions reduction and circular economy initiatives, as a core metric in investment decisions[147].
- **Recognize the Financial Case**: Acknowledge that sustainability initiatives are not just about environmental compliance but are key drivers of cost reduction, financial resilience, and new revenue streams in a competitive market[148].
- **Support Collaborative Platforms**: Provide capital and support to industry-wide initiatives, such as those led by the GSMA, that are working to create standardized metrics and accelerate the sector's collective transition to Net Zero by 2050[149].