GREEN IT STRATEGIES:

INNOVATING FOR A SUSTAINABLE DIGITAL FUTURE

An artificial intelligence program was used to reformat the image that illustrates this text.

IDB

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The TechReports are an initiative of the Emerging Technologies Laboratory of the IDB's IT department, known as TechLab, which is in charge of exploring, experimenting, and disseminating information about new technologies to learn about their impact on the IDB Group and the LAC region.

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EXECUTIVE SUMMARY

In a global context where digitalization is advancing rapidly, the environmental impact of the technology sector has taken on renewed relevance.

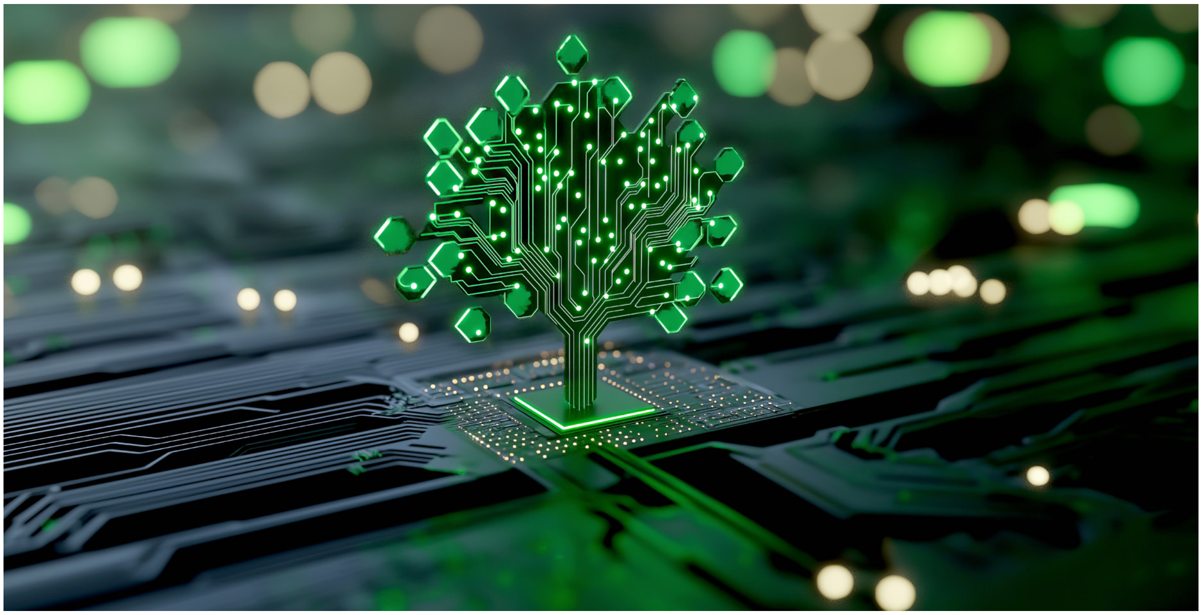
The increase in the use of electronic devices, the intensification of data traffic and the proliferation of digital services have increased the sector's carbon footprint, which already represents up to 4% of total global emissions. Against this backdrop, sustainable computing – or Green IT – emerges as a strategic approach that seeks to reduce the negative effects of information and communication technologies (ICTs) through practices aimed at energy efficiency, the circular economy and responsible waste management.

This report explores the main areas of intervention of Green IT, such as the mapping of carbon emissions throughout the value chain, the virtualization of physical resources, the adoption of cloud computing services, and the design of green data centers that include sustainability criteria. Risks and consequences associated with greater digitalization are also identified, such as the rebound effect and the growth in the volume of data stored, even those without real use ("dark data"), as well as the ambivalent role of emerging technologies such as artificial intelligence and blockchain, whose potential to generate greater efficiency and lower environmental impact coexists with a high demand for energy and resources.

The Latin American and Caribbean region faces particular challenges in this area, linked to high e-waste versus limited infrastructure for recycling, dependence on global supply chains, and pressure on fragile and vulnerable ecosystems. In this regard, the IDB has been promoting initiatives that strengthen the sustainability of the digital ecosystem through technical assistance, green investments, and the articulation of public policies aimed at improving waste management, fostering circular innovation, and accelerating the sector's energy transition.

Green IT not only mitigates the impact of the technology sector, but also represents an opportunity to generate economic and competitive value, improve institutional reputation and strengthen regulatory compliance. Aligning with this vision implies rethinking the use of scarce resources, incorporating environmental metrics into decision-making, and harnessing the enabling potential of ICTs in the transition to a more sustainable development model.

INTRODUCTION



In an increasingly digital world, where every technological component, from tiny microchips to giant data centers, has environmental implications, sustainability emerges as an inescapable challenge. At the same time, technology has established itself as a strategic priority for governments, businesses, and organizations, evolving at a breakneck pace while offering new ways to pave the way to an eco-digital age.[1]

The exponential growth of Internet access illustrates this evolution. The number of users went from 413 million in 2000 to almost 4,000 million in 2020. Between 2020 and 2023, according to estimates by the International Telecommunication Union (ITU), the figure increased by another 35%, reaching 5,400 million people, or 67% of the world's population. This increase in connectivity has expanded the sector's environmental footprint, putting increasing pressure on energy resources, especially in countries with limited infrastructure. Although the total effect is difficult to pin down, various studies estimate that Information and Communication Technologies (ICTs) are responsible for between 1.5% and 4% of global carbon emissions, with direct consequences for the environment and climate.[2]

This often underestimated impact is compounded by the rebound effect, a phenomenon in which improvements in energy efficiency, rather than reducing the total environmental footprint, stimulate greater use of technological products and services, thus negating the initial efficiency benefits.[3] If this trend continues without remedial action, it is estimated that ICT could account for up to a third of global emissions by 2050, which highlights the need for a structural transformation towards a more sustainable model.[45]

In this context, Green IT, also known as sustainable computing, proposes a comprehensive vision that covers the entire life cycle of technological products: from their design and manufacture to their use, recycling and final disposal.6 This approach seeks to reduce emissions, optimize energy consumption and promote responsible practices in each link of the technological chain.[3] Its importance lies not only in its ability to respond to environmental challenges, but also in its potential to generate economic and social benefits aligned with the commitments and targets of multilateral agendas such as the 2030 Agenda for Sustainable Development[7] and the Paris Agreement.[8]

Far from being limited to mitigating damage, digital technologies also act as catalysts for solutions that reduce emissions in other sectors through smart solutions.[9] In this sense, Green IT not only represents a way to improve operational efficiency and reduce costs, but also promotes a culture of environmental awareness with effects at the individual, organizational and global levels.[10]

SUSTAINABILITY AND TECHNOLOGY LANDSCAPE

Technological advances in conjunction with new digital habits, especially those derived from the confinements of the pandemic, have redefined the way we live, work and relate to each other.[11] Currently, there are more mobile subscriptions than people in the world, which shows the magnitude of the phenomenon.[12] The expansion of wearable devices, the increased use of social media,[13] the rise of big data, and the growing access to AI models, especially generative AI since its massive irruption in 2022,[14] have expanded the reach of ICT to an unprecedented scale.

In this context, the enabling power of emerging technologies offers new opportunities for countries and organizations to build resilience to threats, diversify their economies, and move towards development trajectories with a lower burden on the environment.[15] Private sector companies, the main drivers of innovation, have begun to respond to sustainability challenges. Globally, the ICT sector accounted for 60% of corporate purchases of renewable energy in 2021, and six of the top ten renewable energy buyers were in the technology sector in 2022.[16]

However, while technology has the potential to contribute to climate change mitigation, many of the solutions developed in recent decades have failed to reverse environmental damage. In some cases, they have even added an additional burden. For example, much of the electricity used in data centers goes to idle or obsolete servers that continue to consume energy without adding value.[17] There are also other less visible, but equally significant impacts, such as the intensive use of water and the generation of waste during manufacturing and operation linked to technological production. While much of the debate has focused on processing infrastructures, individual physical devices represent a very significant contributor to the problem.[18] In this sense, e-waste management remains a pending issue, and as the costs of storing information and producing devices are reduced, the accumulation of data and frequent replacement generates waste at a rate that exceeds current efforts to contain it.[19][20]

This duality leads to the need to leverage technology as a positive force that contributes to a healthier, safer, and more sustainable environment.[21] The UN has warned that current commitments to reduce emissions by 2030 are far from being met.[22] In 2020, the sectors with the highest GHG emissions were energy (34%), materials (21%) and mobility (19%). It is estimated that, with proper integration, digital solutions could reduce emissions in these three sectors by up to 20% by 2050.[23] Taking advantage of ICTs responsibly is one of the keys to facing environmental challenges, mitigating the effects of climate change and ensuring the well-being of the planet and future generations. The transformation needed to achieve global sustainability will not be possible without seizing the opportunities offered by digital technologies, underscoring the importance of incorporating them into green strategies.[24]

Some global figures

The effects of electronic devices begin before use.

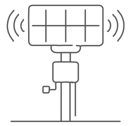
The manufacturing process of a smartphone accounts for 83% of its carbon footprint,[25] with an average emission of 55 kg of CO_2.[26]

In countries like the U.S., one of the largest consumers of technology globally, an average household has 11 connected devices[27] and replacement cycles are short: 2.5 years for cell phones and between 3 and 5 years for tablets or laptops.[28]

Data centers contribute to global energy consumption. Currently, they use up to 1.5% of the world's electricity and are responsible for about 1% of global emissions. According to the International Energy Agency (IEA), this proportion could double by 2030.[29] About half of that energy goes exclusively to cooling and backup systems.[30] One of the factors that has driven this increase is the expansion of AI. In 2022, servers for tasks related to this technology accounted for about 24% of the total electricity demand of data centers.[31]

Electronic waste (WEEE) is constantly increasing. In 2022, 62 million tons were generated, a record figure that could reach 82 million by 2030.[32] Only 20% of this waste was properly collected and recycled, while the rest was managed in a non-compliant manner or disposed of in landfills.[33] This implies the loss of valuable resources that reach about 12 million tons of unrecovered metals due to inefficiency in recycling or improper management.[34]

Semiconductor production is also highly environmentally charged.



Semiconductors are found in almost every everyday device, from phones and computers to cars. 80% of its emissions come from the direct use of energy and gases in the manufacturing process.[35] LAC plays a leading role, since the “lithium triangle”, formed by Bolivia, Argentina and Chile, more than half of the world’s reserves of this mineral, critical in the manufacture of semiconductors. Demand is expected to increase 40-fold in the coming years.[36]

DIGITAL POLLUTION

Digital pollution refers to the negative impact that the massive use of digital technologies has on the environment. [37][38] The most common online activities, such as music or video streaming and video calls, require a constantly functioning resource infrastructure. It is estimated that these actions could occupy up to 40% of the per capita carbon budget compatible with the 1.5°C target proposed by the United Nations.[39] At the same time, 55% of the share of mineral and metal resources, 20% of access to fresh water and generate more than 10% of air pollution and fossil fuel consumption.[40][41]

Within this problem, a new risk for sustainability arises: the so-called “dark data”. This is information that organizations collect and keep, but is rarely reused.[42] Their retention is usually motivated by regulatory requirements or by the ease provided by cloud storage systems.[43] However, preserving this data entails more costs and risks than benefits, in addition to increasing the energy demand for its maintenance. The electricity consumed by this inactive information becomes an additional burden on the grid, diverting in many cases the use of renewable energies towards the support of content with no practical use.[44][45]

The growth of big data has boosted the accumulation of dark data. Many companies, especially technology companies, instead of classifying and debugging their databases, choose to store them preventively, without evaluating their relevance.[46] The lack of effective records management policies aligned with sustainable goals has led to estimates that up to 88% of the data safeguarded by companies is redundant, obsolete or trivial. Addressing this overhead requires a transformation in the way information is managed, promoting efficient storage practices, elimination of unnecessary files, and active coordination among the responsible teams.[47]

There are free public tools that can support organizations in their transition to carbon neutrality. For example, Loughborough University and The London Data Company have developed solutions such as interactive dashboards and forecasting tools that allow the carbon cost of data requirements in new projects to be assessed. It should be noted that open source tools play a fundamental role in offering accessible frameworks to make informed decisions about the creation, use, storage and exchange of data, thus contributing to a more sustainable management of information.[48]

Daily digital activities generate micro-emissions that seem insignificant but are cumulative:

- Each Google search emits up to 1.45 grams of CO_2.[49]
- Visiting an average website generates 1.76 grams of CO_2.[50]
- Sending an email produces 4 grams of CO_2, and keeping it stored on a server, 10 grams per year.[51]
- Browsing for a minute on social media can emit up to 3 grams of CO_2, and posting a photo on Instagram generates about 0.15 grams of CO_2.[52]
- An hour of playback on YouTube emits about 28 grams of CO_2, and an hour of streaming on Netflix between 56 and 114 grams of CO_2.[53]
- A Zoom call produces up to 1 kg of CO_2 and requires up to 12 liters of water in the process.[54]

THE DOUBLE-EDGED SWORD OF EMERGING TECHNOLOGIES

Emerging technologies play an ambivalent role in the field of sustainability. On the one hand, they enable innovative solutions that reduce emissions, optimize resources and improve the efficiency of critical systems; on the other, their accelerated adoption and growing demand for infrastructure generate new pressures on the environment, especially in terms of energy consumption, use of critical materials and associated emissions.

The case of AI is illustrative of this tension. Its ability to transform productive sectors, predict weather patterns and optimize agricultural practices positions it as a valuable tool to face climate change.[55] However, the dizzying and exponential advance of generative AI, particularly since models such as ChatGPT and Gemini gained importance, has highlighted its high environmental cost. Training and running these algorithms require large volumes of electricity, which has raised concerns about their sustainability in the medium term.[56]

The growth of AI has also intensified the demand for semiconductors, essential components for the operation of these technologies. It is estimated that one of the major manufacturers could deploy up to 1.5 million AI servers per year by 2027. If they were operating at full capacity, they would consume around 85 TWh annually, a figure higher than the total electricity consumption of several small countries.[57] Even so, semiconductors are also fundamental pieces for a cleaner economy, as they enable technologies such as solar panels, electric vehicles and intelligent energy management systems through IoT, promoting a more efficient use of electricity in everyday devices.[58]

This same logic is observed in other technologies. Blockchain, for example, can strengthen the transparency and traceability of emissions along value chains,[59] support real-time monitoring systems by integrating with sensors and drones, and lay the groundwork for more reliable and scalable voluntary carbon markets.[60] However, certain applications, such as proof-of-work (PoW)-based cryptocurrency mining, have generated controversy due to their high electricity and water consumption, along with social factors such as informal work and noise pollution in surrounding populations.[61] Bitcoin mining, in particular, has been noted for its potential to exceed emissions targets defined in the Paris Agreement on its own, as well as contributing to environmental degradation through deforestation and intensive land use.[62]

NET ZERO COMMITMENT

More and more countries and companies are adopting strategies aimed at reducing their pressure on the environment.[63] [64] A more ambitious step is the concept of "net zero", which goes beyond simple compensation. Its aim is to minimise emissions to residual levels, so that any remaining amount can be permanently absorbed by natural sinks or disposal technologies, thus achieving a neutral atmospheric balance.[65] This vision is aligned with the goals of the Paris Agreement and charts a concrete path towards global decarbonization.[66]

In recent years, the technology sector has taken a more active role, especially among large companies in the field, which have announced public commitments to reach net zero. However, the pace of progress in the sector as a whole is still slow and uneven.[67] Part of the difficulty lies in the fact that the sector faces particular challenges in achieving zero emissions, such as the accelerated expansion of demand for digital services, the complexity of its supply chains, and the difficulty of decarbonizing certain operational processes. Still, the technology's potential to scale rapidly means that even incremental changes can translate into amplified effects on millions of users.[68]

To guide and validate these efforts, different initiatives have emerged. The Science Based Targets initiative (SBTi) provides a framework for aligning business objectives with scenarios compatible with a maximum 1.5°C increase in global temperature in the near term.[69] Other proposals such as Breakthrough Energy[70] and the Climate Innovation Fund[71] are aimed at developing solutions with negative emissions. These actions are strengthened by multisectoral alliances, such as Transform to Net Zero, which seek to consolidate a common roadmap to achieve these objectives collaboratively.[72]

IT SUSTAINABILITY PRACTICES

The Green IT approach has evolved in recent years, shifting attention from domestic energy saving strategies to solutions applied in business systems, especially in client and server machines. This transition has led to the development of practices that align technology processes and operations with the fundamental principles of sustainability: reduce, reuse, and recycle.

In addition, it promotes the innovative use of technology within corporate operations, generating benefits both at the organizational level and in its broader ecosystem. Common practices include end-to-end emissions mapping, virtualization, cloud computing, sustainable data centers, and device lifecycle extension.[73]

MAPPING CARBON EMISSIONS

One of the main challenges on the road to sustainability is the management of indirect emissions, generated by secondary actors in the value chain, such as suppliers, logistics operators or the end users themselves. Although they are beyond the direct control of organizations, they are the result of their operational decisions and, in many sectors, constitute the largest percentage of their environmental footprint, especially those activities linked to logistics and supply processes.[74] An additional obstacle is the lack of reliable data on these. Unlike other intensive sectors, such as transport, energy or agriculture, which have consolidated measurement systems, ICT emissions have historically been less monitored. This scarcity of information makes it difficult to accurately analyze and implement effective mitigation strategies.[75]

To address this challenge, the first step is to carry out a complete mapping of emissions in order to identify the most critical links and target interventions towards areas with the greatest potential for improvement.51 In this sense, the Corporate Standard of the Greenhouse Gas Protocol, developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), is a guidance tool that classifies a company's GHG emissions into three scopes:[76]

Scope 1	Direct emissions from sources owned or controlled by the company. These mainly result from activities such as electricity, heat or steam generation; physical or chemical processes; transportation of materials, products, waste and employees; and fugitive emissions, such as leaks in equipment through gaskets and valves.
Scope 2	Indirect emissions from electricity generation, heating and cooling purchased by the company.
Scope 3	All other indirect emissions that occur along the value chain. This includes those related to the purchase and use of goods, services, energy, and capital in the production process, as well as those primarily related to the transportation, processing, use, and disposal of the products sold. It also includes those associated with services such as leased assets, franchises and investments.

The latter group presents the greatest complexity, but encompasses the broader impact of business operations.[77] Its measurement is especially relevant in sectors where the effects do not come so much from the direct use of resources as from the energy consumed by data centers or from the components purchased. In the case of ICT products and services, the assessment involves particular challenges due to extensive hardware supply chains, the diversity of services offered and the sharing of infrastructure.

To move forward, organizations such as the ITU and the Global Enabling Sustainability Initiative (GeSI) have developed technical guidelines based on Scope 3 of the GHG protocol, which could reduce emissions from the sector by up to 45% by 2030.[78] These methodological tools are complemented by regulations such as ISO 14040 and ISO 14044, aimed at life cycle analysis; PAS 2050 of the British Standards Institution, focused on GHG quantification; and ISO 14067, specialized in the carbon footprint of products. Likewise, the ITU L.1410 methodology provides criteria for assessing the environmental impact of ICT goods, networks and services, while the report of the International Electrotechnical Commission (IEC TR 62725) details the measurement in all its stages.[79] Together, these measurement systems make it possible to move towards a more rigorous and transparent accounting of emissions, facilitating decisions aimed at the effective decarbonisation of the value chains of the IT sector.

VIRTUALIZATION

Virtualization is a solution that allows the same computer to share its hardware resources between different digital environments through specific software known as a hypervisor.[80] Unlike conventional servers, which require physical space and constant maintenance, virtualization abstracts the functionality of the hardware, facilitating some scalability of the infrastructure comparable to that of a web application.[81] Thanks to these advantages, it has established itself as a standard in IT architectures and integrates seamlessly with cloud computing solutions.[82] In this sense, by reducing the need for physical servers, virtualization not only improves flexibility in resource management, but also reduces energy consumption and carbon footprint.[83]

Among the benefits of its application are:

- **Resource optimization:** Allows multiple virtual machines to be hosted on a single physical computer, freeing up space and reducing power and cooling costs.[84]
- **Service automation:** Simplifies software management, enables automated workflows, and improves operational efficiency.[85]
- **Accelerated recovery:** Shortens response times to failures, favoring almost immediate recovery and greater operational continuity.[86]

CLOUD COMPUTING AND SUSTAINABLE DATA CENTERS

Cloud computing is a model for providing digital services that offers, via the internet, scalable, flexible and on-demand computing resources.[87] This ecosystem is supported by a vast network of data centers (cloud data centers) generally operated by global providers, known as hyperscalers, including Amazon Web Services (AWS), Google Cloud, Microsoft Azure, IBM and Oracle, which provide computing power and storage without companies having to acquire or maintain local hardware.88 With pay-as-you-go and the ability to scale automatically, organizations can optimize their energy consumption, as well as reduce upfront investments and maintenance costs.[89]

Beyond operational efficiency, the cloud environment has shown great potential to drive sustainability initiatives. A McKinsey report indicates that the migration to cloud services could accelerate almost half of the actions needed to limit global warming to 1.5 °C by 2050 and avoid up to 32 gigatons of carbon, about half of the total required to reach net-zero emissions. In some cases, it also makes decarbonisation efforts cheaper by up to 10%.[90] However, data centers continue to demand significant volumes of electricity and water, and rely on complex physical infrastructures with redundant systems to ensure continuous availability.[91] Although they incorporate techniques such as virtualization, load consolidation and resource optimization, it is estimated that these facilities can consume up to 50 times more energy than a conventional building, according to the United States Department of Energy,[92] and are among the largest users of water for cooling, which represents a risk in regions with water stress.[93] They can also generate noise pollution, affecting the quality of life of nearby communities.[94]

In this context, green data centers have begun to become popular, structures conceived from the design to integrate sustainability criteria in each component: high-efficiency air conditioning systems, renewable sources, reuse of waste heat, recycling of equipment and waste reduction.[95] The choice of sites with access to robust electricity grids and the incorporation of on-site generation and storage also allow them to make energy management more flexible.[96]

To measure and improve their environmental performance, standardized metrics are used, such as Power Usage Effectiveness (PUE), which relates the total energy consumed to that intended exclusively for IT equipment[97], and Carbon Usage Effectiveness (CUE), which quantifies CO_2 emissions per unit of energy used.[98] In addition, the ANSI/TIA-942 specification, originally designed to define infrastructure, design and security requirements in data centers, has incorporated new criteria for environmental efficiency, AI adoption and management of large volumes of data, configuring itself as a comprehensive framework for the certification of sustainable facilities.[99]

CIRCULAR ECONOMY

In the face of increasing volatility in the price of raw materials, their scarcity, and more stringent environmental regulations, the linear make-use-dispose model has proven to be unsustainable. In response, the circular economy proposes a restorative and regenerative production system that seeks to prolong the value of products, components and materials through technical and biological cycles.[100]

This approach goes further than traditional recycling techniques, which only intervene at the end of the product's life, by integrating all phases, from responsible design and production, to marketing, use, refurbishment, refurbishment and recycling.101 In this way, organizations reduce their dependence on natural resources, strengthen the resilience of their supply chains, and pave the way for business models such as servitization (product-as-a-service, or PaaS).[102]

Circular economy models are based on three fundamental pillars: minimising waste and emissions, extending the useful life of assets and regenerating ecosystems. These objectives not only contribute to curbing climate change and protecting biodiversity, but also to improving the competitiveness and profitability of companies by optimizing the use of materials and reducing operating costs.[103]

In this context, digital technologies function as enablers by providing visibility, traceability, and optimization capacity throughout the entire life cycle of a product.[104] In the data capture phase, tools such as RFID and the Internet of Things (IoT) make it possible to track the movement of materials in real time, facilitating their reuse, repair or remanufacturing. That data is then unified into integrated platforms such as ERP or

CRM, creating a single repository that supports decisions aligned with circular principles. Finally, the advanced analysis of large volumes of data, through techniques such as big data or advanced AI models, it is possible to anticipate demands, optimize industrial processes and design simulations to maximize the recovery of resources.[105]

Moving towards circularity in the technology sector involves adopting modular designs that facilitate upgrades and repairs for end consumers, incorporating sustainability criteria in all areas (R+D, manufacturing and operations), exploring new materials and processes, and establishing strategic alliances along the value chain.[106]

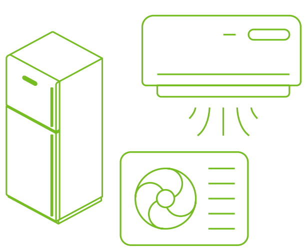
E-WASTE MANAGEMENT

Waste electrical and electronic equipment (WEEE), commonly referred to as e-waste, is generated when devices are discarded with no intention of being reused. This category includes a wide range of products that rely on electricity or batteries to function—such as computers, mobile phones, household appliances, power tools, servers, toys, and medical equipment, among others.[107] The volume of WEEE has grown rapidly, driven by accelerating technological advancement, rising global consumption, and increasingly shorter product lifecycles due to planned obsolescence. Beyond their widespread use in homes and offices, these devices are now deeply embedded in emerging sectors such as electric transportation, renewable energy, and smart cities. As a result, the steady increase in e-waste has brought with it a more complex material composition—combining both valuable resources and hazardous substances—which demands specialized processes for proper handling and safe disposal.[108]

FIGURA 1. **CATEGORÍAS DE APARATOS**

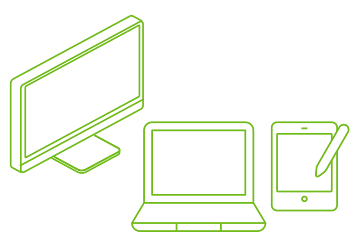
1. APARATOS DE INTERCAMBIO TÉRMICO:

Habitualmente denominados aparatos de refrigeración o congelación, esta categoría comprende frigoríficos, congeladores, aparatos de aire acondicionado y bombas de calor, entre otros.



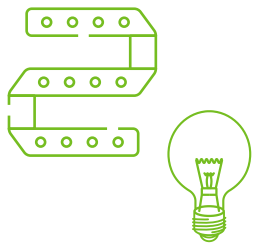
2. PANTALLAS Y MONITORES:

Esta categoría incluye habitualmente teñevisores, monitores, ordenadores portátiles o móviles y tabletas.



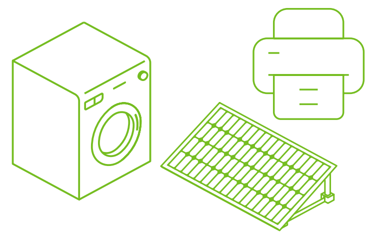
3. LÁMPARAS:

Habitualmente denominados aparatos de refrigeración o congelación, esta categoría comprende frigoríficos, congeladores, aparatos de aire acondicionado y bombas de calor, entre otros.



4. APARATOS DE GREAN TAMAÑO:

Esta categoría incluye habitualmente teñevisores, monitores, ordenadores portátiles o móviles y tabletas.

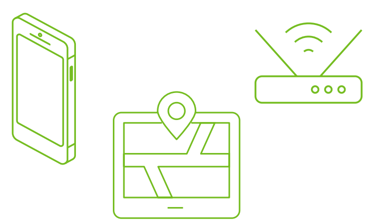


5. APARATOS DE PEQUEÑO TAMAÑO:

Esta categoría incluye habitualmente aspiradoras, hornos microondas, tostadoras, hervidores eléctricos, afeitadoras eléctricas, balanzas electrónicas, calculadoras, dispositivos radiofónicos, cámaras de vídeo, juguetes eléctricos o electrónicos, pequeás herramientas eléctricas o electrónicas, dispositivos médicos de pequeño tamaño, instrumentos de vigilancia y control de pequeño tamaño y cigarrilos electrónicos.

6. PEQUEÑOS EQUIPOS INFORMÁTICOS Y DE TELECOMUNICACIONES:

Esta categoría comprende teléfonos móviles o de otro tipo, computadores personales, dispositivos GPS, encaminadores de red e impresoras, entre otros aspectos.



Source: [The global E-waste Monitor 2024]

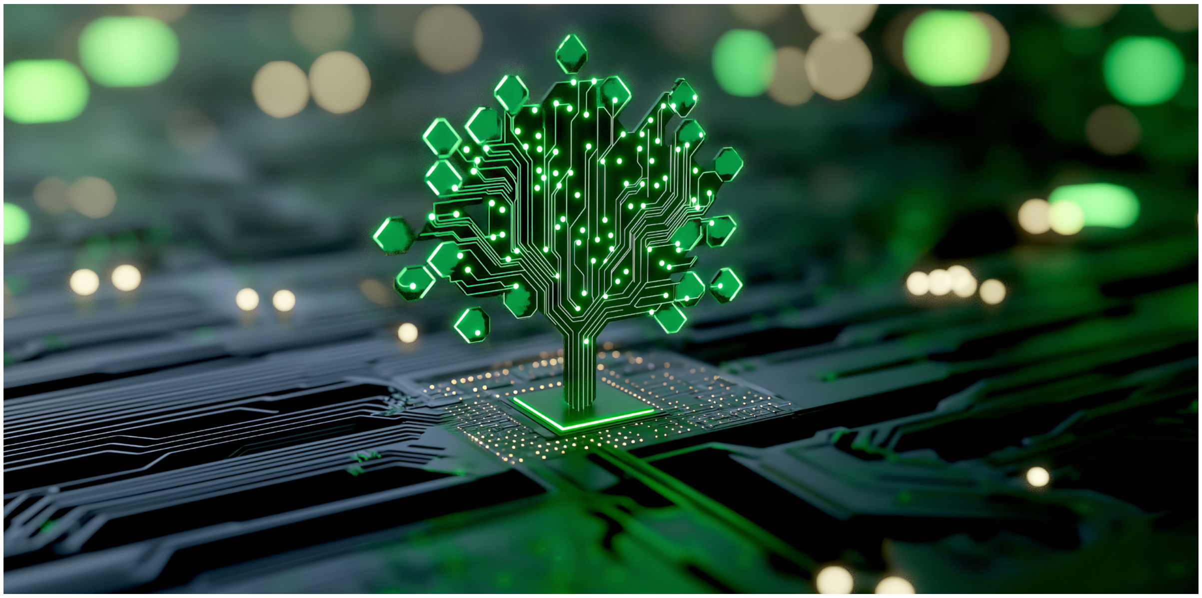
Despite the volume that is generated, only a fraction of it is formally recycled under appropriate environmental standards. The rest is usually disposed of in landfills or treated through informal channels, causing the loss of recoverable resources and the release of pollutants into the environment. In contexts with limited infrastructure, this represents a worrying risk to public health and surrounding ecosystems. Part of this risk relates to persistent organic pollutants (POPs), i.e. toxic, bioaccumulative and degradation-resistant compounds capable of being transported over long distances through air or water.[109]

Another problematic aspect is metal processing, which represents a major source of GHG emissions and is often complex. In this context, recycling is presented as a priority strategy, since it reduces pollution and the footprint compared to primary production.[110] For example, secondary production of aluminum is estimated to generate up to 25 times fewer emissions than initial extraction and processing.[111] These differences reinforce the need to conserve existing resources and design processes that maximize their use.[112] Added to this dimension is the need to manage increasing volumes of equipment that stores sensitive information. The implementation of formal protocols is one of the pillars that guarantees both the secure disposal of devices and the protection of the data they contain.[113]

Effective and responsible management of WEEE requires clear and specific regulatory frameworks, accessible collection systems and policies that encourage the repair, reuse and reduction of waste designed from the design of products. However, in most countries, regulations are still in an incipient stage and tend to focus mainly on final disposal, without addressing prevention or circularity strategies in sufficient depth. According to ITU's Global E-Waste Monitor, the development of legal frameworks has slowed down in recent years. Globally, only 42% of countries had WEEE policies, legislation or regulations in place in 2023, a figure below the 50% target set for that year.[114]

In this scenario, mechanisms such as extended producer responsibility (ERP), which assigns manufacturers responsibility for the management of the waste generated by their products at the end of their useful life, take on a central role. In conjunction with adherence to international agreements such as the Basel and Rotterdam Conventions, these tools not only promote safer and more traceable management of e-waste, but also reinforce a logic of shared co-responsibility throughout the value chain, in line with the principles of the circular economy.

THE POTENTIAL OF **GREEN IT**



The impact of Green IT manifests itself in various ways, and each company must have a sustainable plan adapted to its particular context.[115] By integrating responsible practices, organizations not only promote a healthier environment, but also strengthen their reputation and relationship with their customers. This approach opens up spaces for innovation and transforms the way they operate and compete in the marketplace.

Gartner's Hype Cycle for Environmental Sustainability 2024 identifies some emerging technologies that could redefine organizations' approach to current environmental challenges. Some, such as the adoption of the Scope 3 Standard, green data centers, and the circular economy in the IT space, are still in the early stages of implementation, indicating that their adoption is in the process of consolidation. While energy efficiency is at a more advanced stage of implementation, many practical initiatives, such as the acquisition of refurbished IT equipment or the improvement of the sustainable user experience,[116][117]moving forward requires companies to be able to balance short-term performance expectations and their long-term sustainability commitments. Integrating sustainability metrics into decision-making will allow aligning environmental outcomes with financial targets, addressing climate challenges without compromising viability.[118]

BENEFITS OF GREEN IT

The application of Green IT provides a series of environmental, social and economic aspects that have a positive impact on organizations and society in general, among which are:[119]

Environmental: Seeks to reduce the ecological footprint of operations.

Reducing emissions: Reducing carbon emissions is the key point of environmental impact strategies. According to the United Nations, to limit global warming, global emissions need to be reduced by 7.6% each year until 2030.[120]

Less e-waste: Reusing and refurbishing IT equipment is a more sustainable and often cheaper alternative to purchasing new products.[121] At the same time, minimizing e-waste helps create a cleaner environment and reduces exposure to harmful materials.

Social: Emphasizing the effect of technology on society, addressing ethical concerns, and striving to improve people's quality of life..

Responsabilidad social empresaria (RSE): By implementing Green IT practices and communicating their use, companies become role models in their industries, encouraging CSR and decisions based on financial gain and profitability, and the consequences of their actions on their communities and the world at large.[122]

Customer loyalty: Many consumers prefer socially responsible companies. This not only attracts customers, but also fosters their long-term loyalty.[123]

Corporate culture: Green IT demonstrates to employees that they work for an ethical company, which can improve morale and increase staff retention. Sustainability also offers opportunities for productivity and overall engagement.[124]

Economic: Among the advantages of Green IT is the possibility of creating financial benefits and ensuring long-term economic sustainability within IT operations in different organizations.

Ahorro de costos: Organizations that adopt green IT solutions, such as sustainable hardware and green coding, can reduce their energy consumption and generate savings.[125] In addition, the reuse of devices decreases the cost of raw materials in production.[126] Technologies such as cloud and virtualization also reduce the need for hardware, contributing to lower power consumption and maintenance costs.

Extended maintenance: Eco-friendly, reusable computing products allow for longer maintenance cycles and reduce the need for frequent replacement, which is key in organizations with large structures.[127]

Competitiveness: When companies strive to improve their green governance practices, they usually need to find new and creative solutions to complex challenges. This approach can lead to the development of innovative products, services, and processes that contribute to sustainability and provide new avenues for growth and profitability.[128]

Regulatory compliance: Regulations on e-waste disposal and energy consumption are becoming more stringent. Establishing a Green IT strategy helps to comply with environmental regulations.[129]

SUSTAINABILITY & TECHNOLOGY IN LATIN AMERICA & THE CARIBBEAN

Latin America and the Caribbean (LAC) is at a decisive moment, in which sustainability and technology converge to shape new possibilities for development. The region has natural and energy wealth, along with an expanding innovation ecosystem, which strategically position it to move towards more sustainable models. However, it coexists with structural vulnerabilities and urgent environmental challenges, which require a comprehensive look at how to implement solutions that respond to the local context without reproducing inequities or deepening ecological damage.

One of the axes of this transition is the use of renewable sources. In the last decade, the installed capacity of clean energy has grown by about 70%, representing more than half of the regional electricity generation by the end of 2021. Initiatives such as RELAC (REnewables in Latin America and the Caribbean) promoted by the IDB, and the United Nations Net Zero 2050 coalition reflect a firm regional commitment to the transition, with goals of raising the share of renewables to 70% and moving towards a chain free of net emissions. Despite advances in technological adoption and renewable energies, obstacles persist such as variability in photovoltaic and wind generation, along with requirements for optimization in efficiency and profitability of emerging alternatives such as hydrogen. Also, storage and distribution systems face difficulties in making energy storage technologies cheaper and implementing smart grids that comply with global parameters.[130 131]

In this scenario, lithium is presented as an opportunity to reduce dependence on fossil fuels.[132] The growing demand for lithium-ion batteries, driven by the expansion of renewables, electronic devices and electric vehicles, places LAC in a strategic position, as the region is home to almost 70% of the world's lithium-ion reserves.[133] However, its extraction poses serious environmental challenges, such as the intensive use of water in areas with high levels of water stress[134] and the possible degradation of vulnerable ecosystems, such as those located in the Salar de Atacama and the Salar de Uyuni.[135] In addition, the value chain is currently still dominated by Asian countries, which limits the ability of Latin American countries to capture added value from battery production to improve their participation and connectivity.[136]

The recent technological expansion in LAC has generated a critical collateral effect, where the uncontrolled increase in e-waste has positioned the region among the largest global contributors of e-waste. In 2022 alone, 5 million metric tons (8.2% of the global total) were recorded, revealing a management crisis when 97% of this waste lacks adequate treatment. This infrastructure failure not only threatens ecosystems, but wastes valuable resources. It is estimated that the recoverable materials in this waste exceeded USD 1,700 million in 2019.[137] The regional distribution of e-waste reveals contrasts, and while Brazil, Mexico and Argentina generate the highest absolute volumes, countries such as Aruba, the Dominican Republic and Puerto Rico have the highest per capita rates. This situation is exacerbated by the lack of specific regulation, as only some countries have extended producer responsibility systems to manage this waste, which slows down the effective implementation of circular economy models in the region.[138]

Still, there are encouraging signs. Projects led by international organizations have contributed significantly to improving institutional capacities, strengthening recycling infrastructures, and fostering public-private partnerships. An example of this is the UNIDO-coordinated and GEF-funded project, which concluded after six years of work with 13 countries in the region. This initiative managed to strengthen public policies, improve recycling infrastructures, develop technical tools such as the first regional E-Waste Monitor and promote awareness-raising activities. In addition, approximately 700,000 pieces of electronic equipment were processed and 230 metric tons of waste were managed.[139]

On the other hand, the private sector is also making a difference. Startups such as the Colombian BATx are dedicated to the diagnosis, reconditioning and reuse of batteries from electric vehicles, with the aim of extending their useful life and reducing the impacts derived from their disposal. Through services such as repair, assembly of storage systems and technical training, this company promotes a circular economy, and has made it possible to mitigate 221,000 kg of CO_2 emissions, revalue 9,000 kg of hazardous materials and optimize 72,000 kWh of energy consumption.[140] Similarly, Recicli in Brazil applies advanced biotechnology for mineral recovery with 85% efficiency. Its clean process extracts valuable metals (gold, silver, lithium, nickel, copper and palladium) from industrial waste, without generating secondary pollutants. This solution especially benefits sectors with a high environmental footprint such as mining, automotive and electronic manufacturing through reverse logistics schemes.[141][142]

SUSTAINABILITY INITIATIVES

IDB GROUP EFFORTS

The IDB has placed climate action at the center of its institutional strategy, with a comprehensive approach that encompasses the protection of key ecosystems for the region, such as the Amazon, the reduction of emissions and the conservation of biodiversity.[143] In 2016, the Group adopted the "Bahamas Resolution," committing to allocate at least 30% of its approvals to climate-related projects in LAC. This commitment is reflected in its Climate Change Action Plan, which promotes the integration of adaptation measures into project planning and the acceleration of cross-cutting solutions aimed at sustainability.[144]

In line with these commitments, the Information Technology Department (ITE) began its Green IT program in 2023, focused on reducing the environmental impact of its digital operations. One of the actions was to establish a baseline to measure GHG gas emissions attributable to the operation of technological solutions and services, both at headquarters and in country offices. This measurement will make it possible to monitor progress towards emission reduction targets and guide future operational decisions towards sustainability criteria.

During the same year, efforts to reduce e-waste through a strategy of more efficient use of technology were intensified. This included the decommissioning of outdated equipment, the consolidation of computing resources, and increased adoption of cloud services. At the same time, in partnership with the community relations program, an initiative was implemented to refurbish and donate devices that retained potential for use. This equipment was delivered to schools and social organizations, promoting equitable access to technology and extending the useful life of the devices.

Consumo de energía inteligente

Initiative to support BIA, a Colombian company that seeks to reduce energy consumption and CO2 emissions. It does this through a technological solution that combines smart meters with ML algorithms to analyze companies' energy consumption and offer them valuable information to optimize it.[145]

Residuos convertidos en recursos

Waste turned into resources: Project to support GAIA Vitare, a Colombian company that seeks to expand its recycling plant and automate its processes to manage e-waste, including engineering plastics. With this project, it is expected to reduce CO2 emissions, contributing to the circular economy and sustainable development in Colombia.[146]

Facilitando el acceso a D-RECs

Facilitating access to D-RECs: Prototype to incentivize solar energy generation and reduce GHG emissions through a solution that facilitates access to Distributed Renewable Energy Certificates (D-RECs) for small generators. The proposal focuses on the development of a platform that will connect small generators with investors, automating the issuance of D-REC certificates via blockchain and using AI to optimize the performance of the systems.[147]

Gestión de e-waste

E-waste management: Technical cooperation that collects data on the generation and composition of WEEE in Trinidad and Tobago, Suriname and Guyana. It includes identifying stakeholders, current disposal routes, and market conditions for the recovery of recyclable materials. With the analysis surveyed, evaluation reports will be prepared, a WEEE management proposal will be designed with a subregional approach and training modules will be developed for the personnel who will implement the solution, and a business plan that supports its sustainable execution.[148]

OTHER GENERAL INITIATIVES

WIPO GREEN

This platform, developed by the World Intellectual Property Organization (WIPO), facilitates the exchange of environmentally friendly technologies, connecting suppliers and applicants seeking sustainable solutions. By encouraging collaboration in the creation and adoption of green technologies, it contributes to the advancement of sustainability, allowing companies to access new opportunities and accelerate the transition to low-carbon solutions.[149]

EnvironmentGPT

This application uses large language models (LLMs) specifically trained to address environmental issues. The data used in its development come from data sources validated by the United Nations Environment Programme (UNEP), to ensure the integrity, quality and reliability of the information.[150]

ML for energy efficiency: A Chilean startup specializing in CleanTech solutions, uses ML algorithms to optimize energy efficiency and air quality in industrial and commercial environments. Its focus is on the automation of HVAC (heating, ventilation and air conditioning) systems, which reduces energy consumption and carbon emissions. In addition, it offers a platform for the monitoring of environmental pollutants, making it easier for companies to manage and reduce their ecological impact, supporting the transition to more sustainable and environmentally responsible business models.[151]

Recycling of copper cables This global initiative, with an approach in LAC, promotes the responsible recycling of copper cables. The process includes the delivery of bags for the collection of the material, which is then processed in a certified manner to ensure compliance with environmental standards. As an incentive, participating companies receive a “Green Check” that they can redeem for new products, reinforcing the circular economy and the reuse of valuable materials.[152]

ULIB Modular Recycling A Colombian company has developed its own technology for the recycling of lithium-ion batteries (ULIB) using an electromechanical process in an inert atmosphere, without the use of chemical reagents. This approach allows for the efficient recovery of valuable materials for the manufacture of new batteries, as well as copper, aluminum, and lithium salts. The process is tailored to the specific chemical characteristics of each batch of batteries, ensuring high performance in the recovery of essential minerals.[153]

Sustainable electronics A startup specializing in the manufacture of sustainable electronic devices, such as headphones, chargers, and speakers, uses recycled e-waste with a focus on eco-design. It also promotes the circular economy through partnerships with recycling companies and programs such as collaboration with Recicla Electrónicos México (REMSA) and the Junta, Entrega y Recicla (JER) program, which offers free collection. In addition, it uses certified recycled plastics and works to reduce the carbon footprint of its products, contributing to sustainability and the minimization of electronic waste in LAC.[154]

FINAL COMMENTS

The urgency of addressing the externalities of the technology sector has placed Green IT as a strategy to direct digital transformation towards a more sustainable model. As the use of digital devices, data, and services grows, so do the spillovers and environmental footprint. In this scenario, Green IT allows us to rethink the relationship between technology and sustainability through practices that not only mitigate environmental impact, but also offer operational, economic, and social benefits for both organizations and nations.

The potential of these strategies lies in their ability to be integrated throughout the entire technology value chain. From the design of more durable and repairable modular hardware, to the adoption of efficient software, virtualization, consolidation of loads in cloud ecosystems and the design of sustainable data centers, Green IT seeks to redefine the traditional parameters of efficiency linked to ICT. It also encourages the circular economy through the refurbishment and reuse of equipment, and promotes e-waste management by sharing responsibility among the different actors involved. These actions not only decrease carbon emissions and resource use, but extend the life of products, improve organizational resilience, and open up new opportunities for innovation.

However, there are still obstacles to its adoption on a larger scale. The necessary infrastructure is limited and the costs of implementation and training for these practices can be high, especially in less developed regions such as Latin America and the Caribbean. The lack of specific policies, low investment in R+D, and the absence of incentives to adopt sustainable models also restrict its progress at a faster rate. Added to this are the contradictions inherent in the use of technologies that, although they offer powerful tools to face multiple sustainability challenges, also present intensive energy and natural resource requirements for their development and operation that often go unnoticed. Therefore, it is extremely important to integrate sustainability metrics from decision-making, the promotion of a responsible organizational culture and the prioritization of the use of responsible digital tools, to monitor and optimize the use of resources, as well as to guarantee transparency in value chains.

Faced with this panorama, the role of multilateral organizations is fundamental. The Inter-American Development Bank (IDB) has begun to integrate sustainability principles into its technology operations through initiatives such as emissions mapping, the donation of refurbished equipment, and support for startups working in energy efficiency or electronic recycling. These efforts contribute to laying the foundations for a green agenda in the digital sphere and position the IDB as a strategic partner in the promotion of Green IT in the region.

In conclusion, moving towards a sustainable digital transformation requires an effort to change the way technology is produced, used, and disposed of without considering its ultimate impact. Green IT offers a concrete way to align technological innovation with environmental commitments, strengthening the capacity to respond to the climate crisis without renouncing the evolution of the digital age.

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