EXECUTIVE SUMMARY

GREEN DIGITAL TRANSFORMATION

How to Sustainably Close the Digital Divide and Harness Digital Tools for Climate Action
Governments across the world are looking for solutions that match the urgency and scale of the climate crisis—digital technologies are a key tool in this effort. Advances in digital technology are changing the way people interact, work, and live. They are also creating new ways to manage climate change. At the country level, digital technologies are increasingly powering adaptation efforts and supporting low carbon development pathways. A more strategic approach is needed, however, to develop, enable, and scale solutions and ensure they reach the most climate vulnerable populations.

From drought to floods, climate change is affecting populations across the world. Although no country is spared, climate change disproportionately affects the poorest and most vulnerable populations, threatening to push as many as 130 million people into poverty by 2030 and 200 million into migrating by 2050. Unchecked, climate change poses huge risks to countries’ long-term development, growth, and stability.

A green and digital twin transition is imperative. Digitalization can help nations fight climate change by enabling novel solutions and greater efficiency in a wide range of practices, processes, and services. Digital technologies, however, carry climate costs as well as benefits stemming from the use of energy and resources to build, power, and dispose of digital infrastructure, devices, and components. A twin transition approach seeks to pair digital transformation with climate action. This means ensuring inclusive and sustainable digital foundations and applications are in place to accelerate mitigation and adaptation efforts, while also reaping wider benefits of digital transformation for growth, job creation, and better lives.

This report proposes a path toward low-emission applications of digital technologies to help countries mitigate and adapt to climate change, while simultaneously meeting their digital transformation goals. It examines how to increase the synergies among socioeconomic development goals, climate change policies, and digital technologies, offering guidance on how government institutions and private organizations in the digital field can catalyze green digitalization. The guidance includes strategies for greening the digital sector itself, as well as leveraging digital technologies for climate action across sectors (figure ES.1).
Executive Summary

The Digital–Climate Change Nexus

The links between the digital sector and climate change are less well understood than those with other sectors. This report proposes a conceptual framework with two channels—direct and indirect—to illustrate how digitalization interacts with climate change:

- **Direct channel.** The production, use, and disposal of digital technology contribute directly to GHG emissions. Digital infrastructure is also directly exposed to significant climate change–induced risks, including rising temperatures and sea levels, water scarcity, and extreme events such as drought, cyclones, and flooding.

- **Indirect channel.** As digital technologies become pervasive in social and economic activities, they also have an indirect impact on climate change at the macroeconomic level and across sectors. At the macro level, digital technologies increase productivity, thereby increasing total consumption and pushing up emissions. Decoupling economic growth from emissions—that is, ensuring that the growth rate of GHG emissions is less than that of its economic driving forces—becomes essential to achieving a sustainable growth trajectory. The fact that both production and consumption across sectors are being “dematerialized” thanks to the rapid development of digital technologies provides opportunities to achieve decoupling.

Climate action and digital transformation are core policy priorities for many governments, but most often these efforts are carried out in isolation. There are, however, modest signs of convergence. Many LMICs are already incorporating technology—including digital technology—into their plans to combat climate change.
and adapt to climate change. Overall, 84 percent of countries mention “technology” in the mitigation provisions and 63 percent mention it in the adaptation provisions of their Nationally Determined Contributions (NDCs). NDCs reflect the efforts by each country to reduce national emissions and adapt to the impacts of climate change (figure ES.2). Although the role of technology is often mentioned, it is rarely addressed strategically in the NDCs, and the proposed applications are narrow (mainly disaster risk management technology and smart consumption solutions), indicating a need for a greater awareness of digital technologies for climate action.

At the policy level, integration of green and digital policies cuts across governments and stakeholders, calling for a whole-of-government approach. Digital ministries need to understand how to integrate climate considerations into their sector policies, such as through strategies that promote climate-resilient digital infrastructure, and encourage investments in low-carbon digital infrastructure. Digital ministries also need to ensure that the digital fundamentals such as connectivity and data infrastructure are in place to enable use for climate action. Other ministries, institutions, and organizations that grapple with climate change should focus on identifying digital applications for combating climate change, weighing the factors that may limit the scale and scope of implementation.

![Figure ES.2](source.png)

**FIGURE ES.2** Mentions of Technology in Mitigation and Adaptation Provisions of Nationally Determined Contributions (NDCs)


*Note: Digital tech: a country mentioned one or more technological initiatives heavily underpinned by digital technologies; other tech: a country mentioned one or more technological initiatives that do not necessarily involve digital technologies for connectivity or analytics; no tech: a country did not explicitly mention technology in their NDCs. The analysis covered 197 countries, including 138 low- and middle-income economies.*
Decarbonizing the Digital Sector

Current estimates of the sector’s share of global carbon dioxide (CO₂) emissions range from 1.5 to 4 percent—or roughly equal to the footprints of commercial aviation or maritime transportation. The booming digital economy relies on devices and networks that consume energy and electricity, creating carbon footprints. Country-level emissions vary considerably and depend on a country’s level of digitalization, patterns in the consumption of digital technologies, and sources of the energy used.

Data centers are a large source of emissions, but so are digital devices and telecom networks. Although much attention has been paid to the energy consumption—and thus the emissions—of data centers, emissions from digital devices and networks are similar (figure ES.3). It is heartening that as data consumption has skyrocketed in recent years, data centers’ energy consumption and emissions have not grown apace, a result traceable to efficiency gains and greater use of renewable energy. Overall, however, without a sharper change in direction, expansion of the information and communication technology (ICT) sector will continue to push up emissions, calling for substantially greater investments in innovation, energy-efficient technology, and renewable energy as digitalization increases. Technologies tailored to low- and middle-income economies must not be overlooked in the process.

FIGURE ES.3 Emissions from Subsectors of the ICT Sector

Source: Adapted from WIK-Consult and Ramboll (2021) to include estimates by Minges, Mudgal, and Decoster (forthcoming) based on analysis of reported emissions by more than 150 international digital companies.

Note: The midpoint of the range of the subsector’s contribution to total emissions in the sector is reflected in the size of the boxes. Televisions (including smart TVs) are excluded from the sector breakdown. “Other” includes routers and connected devices. Mobile network operations account for more than 50 percent of the emissions of connectivity network operations. Deployment and decommissioning account for 10 percent of total connectivity network emissions. ICT = information and communication technology.
The sphere of influence for governments will depend on their country’s position in the digital value chain. For example, devices, which emit most during manufacture, are manufactured 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 can have a strong effect on global digital emissions. With shifts to edge infrastructure, data center emissions may become more disbursed globally.

Multinational digital firms lead in the use of renewable energy. In line with corporate commitments, the ICT sector is the largest purchaser of renewable energy globally. This sector is therefore an important and potentially underestimated part of the overall transition to renewable energy, with multinational corporations emerging as significant drivers of demand for renewable power in some LMICs. Governments play a critical role through renewable energy policies, investments, and the enabling of direct power purchase agreements by firms.

From artificial intelligence (AI) to emails, it is the sum that counts. New technologies can expand the use of digital and data infrastructure, generating ever more emissions such as from blockchain, fifth-generation (5G) technology, and AI. Although AI algorithms can be energy-intensive to run, the same is true of the millions of emails, video calls, and bytes of stored data. Greening digital requires big and small actions across multiple use cases and stakeholders, including individual users. As the ICT sector grows across countries at all income levels, every country and every sector will have to consider how the digital transformation can be made more sustainable.

Making the Digital Sector More Resilient

Digital infrastructure is increasingly susceptible to climate risks. Digital disruption means social and economic disruption. Among these hazards are flooding (both coastal and riverine), landslides, tsunamis, cyclones, powerful storms and winds, water scarcity, and extreme heat. Damage to digital infrastructure disrupts connectivity and access to linked data and digital systems. Even localized damage can affect entire networks. Because of economywide digitalization, interruptions can cause failures of the associated critical infrastructure, such as communication services, banking, power grids, railways, and government services. Digital infrastructure is, therefore, critical infrastructure that must be climate proofed.

Digital Technologies for Mitigation

Digital technologies are creating new opportunities to cut emissions and fight climate change across sectors. In this report, energy, transportation, agrifood systems,
Executive Summary

and urban centers are identified as high-emitting sectors in which digital technologies can be leveraged for mitigation:

- In the energy sector, digital technologies can advance the transition to renewable energy. Examples range from pay-as-you-go solutions for solar devices to satellite imagery that helps identify the best locations for geothermal and hydro sites. Digital solutions can also enhance energy efficiency and enable demand-side flexibility (smart grids, meters, and devices/appliances/machines), as well as support implementation of decentralized distributed energy systems powered by renewables.

- In the transportation sector, digital technologies can accelerate the transition to electric vehicles and to modal shifts in passenger transport, public transport, and shared mobility. They can also optimize traffic flows and contribute to digitally enabled logistics systems that enhance freight management and reduce transport needs.

- In the agrifood system, digital technologies can lower emissions systemwide (energy, fertilizer, transportation, processing, and sales) through direct, enabling, and behavioral effects that improve food production, reduce waste, and lead to better use of natural resources.

- In the urban sector, digital technologies can mitigate climate change in urban planning and waste management. They can also improve the carbon footprint and energy efficiency of buildings. Applications can be deployed as well to precisely identify, measure, and manage key sources of pollution (air, waste, water, and noise) in urban areas.

Achieving mitigation at scale will require building digital foundations and promoting widespread adoption. Many climate technologies are never scaled up. The cost of adoption, the lack of adoption incentives, and the failure to tailor solutions to local contexts too often limit demand. On the supply side, the need for digital foundations as prerequisites and enablers of climate action is often underestimated. These foundations include investments in universal broadband coverage and uptake; digital literacy and advanced digital/data skills; and public digital infrastructure to allow governments to generate, share, analyze, and utilize data. Early consideration of cyber resilience and data protection in the design of digitally enabled systems is also vital to minimize risks.

Digital technologies are not a panacea for climate action. Digitalization does not by default shrink the carbon footprint of any sector. Some solutions may reduce unit-level emissions while boosting overall usage, producing a rebound effect. For example, although 5G technology—which can be used for Internet of Things solutions—is more energy efficient per unit of data, increases in data volume and in use of the underlying network infrastructure can result in higher total emissions. Because these effects are not always foreseeable at the outset, constant attention should be paid to measuring and balancing the climate-friendly effects of an innovation and its possible rebound effects. Substantial research is needed to clarify these relationships and
guide climate action. In the meantime, the transition to renewable energy is the surest way to minimize the adverse effects of any digital advance.

**Digital Technologies for Resilience**

Countries must cope with climate shocks as well as the gradual effects of climate change. Eight of the 10 countries most affected by extreme weather events in 2019 were low- and middle-income economies. Half were in the least-developed category. Geographically, many of these countries are exposed to direct effects from rising temperatures and flooding because they lie at low elevations and have densely populated coastlines or riverine zones.

**Digital technologies can contribute to resilience to both long-term climate risks and climate shocks.** At the macro level, development of the digital sector and economywide digitalization can strengthen the resilience of an economy, for example, by diversification to less climate vulnerable sectors and jobs, and virtualization of transactions and communications. Digital technologies can also help policy makers adapt to climate change by providing the tools and data needed to sharpen predictions, enhance decision-making, and better prepare for disasters. Digital infrastructure and applications can enhance resilience before, during, and after climate shocks:

- Before climate shocks, digital solutions can enhance disaster preparedness by identifying high-risk areas and informing investments in, for example, flood protection measures. Digital financial and insurance services can also serve as a safety net against potential income losses.
- During climate shocks, early warning solutions can be critical to protecting vulnerable populations. Advanced technologies using AI and satellites are pushing the boundaries of disaster risk management, while simple technologies such as WhatsApp-based early warning systems are proving equally important.
- After a climate shock, the availability of digital identification systems and digital financial services can allow rapid, targeted, and effective outreach to affected populations through cash transfers, remote access to services, and information. As countries mounted a response, those that used digital databases and data sharing platforms reached more than three times the beneficiaries with social protection payments and services than countries that had to collect new recipient information.

**Both strong digital foundations and advanced digital applications are needed for resilience.** Areas for investment include connectivity, digital skills, and safeguards (cybersecurity and data protection). Global and local investments are needed as well in digital public goods requiring data access, management, and governance. A key concern is whether solutions and digital investments reach the most climate vulnerable people, regions, and countries. Rural areas are a particular challenge because population density and connectivity costs can reduce commercial viability.
Policy Recommendations

Governments, private companies, the broad community of nongovernmental and scientific organizations, and the public at large share the burden and challenge of taking action to combat climate change. Governments, in particular, have a stake in clearing the way for and actively encouraging the ICT sector and other actors to use the full power of digital technology to advance mitigation and adaptation, while mitigating the climate impacts of increased digitalization.

Key principles to inform green digitalization strategies include the following:

- **Complete a risk and emissions profile.** Each country must determine its green digitalization priorities around its climate risk profile and carbon footprint. LMICs are particularly exposed to climate change and need to find cost-effective ways to adapt. High- and low-tech solutions alike can play a key role, but both require investments in digital foundations. Governments must also encourage the ICT sector to build its own climate resilience and set a good example by climate proofing public digital infrastructure to ensure continuity of critical operations, communications, and services.

- **Decouple digitalization from emissions.** Growth of the ICT sector is going one way: up. With nearly 3 billion people remaining offline across the globe, fostering digital inclusion is of great importance. But the climate change impact cannot be neglected during digital transformation. According to International Telecommunication Union estimates, to contribute proportionally to the reduction of global warming, emissions from the sector must be cut in half by 2030. Doing so will require all countries to accelerate the adoption of smarter, more energy-efficient equipment, devices, and processes; expand the use of renewable energy in the digital sector; and apply digital technologies effectively to reduce GHG emissions from other sectors. Policies are needed across the digital value chain. Some examples include the following:
  - **Telecom networks:** policies to promote infrastructure sharing, as well as incentives and investments to promote renewable energy across the value chain (including off-grid, last-mile connectivity).
  - **Data infrastructure:** data infrastructure strategies that factor in energy and water resources, including the reuse of heat; regulations to limit the use of problematic refrigerants; investments in technological innovation and capacity building of the workforce (sustainable data center planning and operations).
  - **Devices:** policies and investments to promote durable and repairable devices, e-waste management, and the circular economy; a push for global standards, as well as regulation and incentives in countries that manufacture devices.
Executive Summary

- **Data**: investments in climate data platforms and data policies for the trustworthy collection, use, and reuse of data, as well as a focus on interoperability, data standards, digital skills, safeguards, and open data access.

- **Ensure resilience of critical digital infrastructure.** Climate events inevitably have an impact on digital infrastructure. Nevertheless, governments can improve the resilience of digital infrastructure by incentivizing adoption of resilient technology choices; requiring consideration of climate risks in the design, deployment, and upgrade processes; and ensuring adequate redundancy while maximizing infrastructure sharing.

- **Calculate costs and benefits in a local context.** Most energy efficiency measures and green technology choices are cost-effective over the life of the asset. However, costs and benefits should be assessed considering a country’s development profile and weighed against other development priorities such as digital inclusion. For resiliency investments, a paradigm shift is needed to move from corrective to preventive measures that are much cheaper and more effective.

- **Leverage position in the value chain.** Because of the global nature of the ICT sector, emissions from some parts of the value chain are concentrated in a few countries (such as those where digital manufacturing takes place or where large data centers operate). Governments in these countries have an opportunity and a responsibility to engage internationally to set enhanced standards—and to apply those standards at home.

- **Break policy silos.** Green digitalization calls for whole-of-government approaches. Digital ministries must consider national climate risks and ambitions and engage with stakeholders to leverage digital technologies effectively. Other sector ministries and implementing agencies may require capacity building to apply digital technologies effectively to climate action and to recognize digital risks.

- **Engage multiple stakeholders.** Private companies play a key role in green digitalization. They have a natural interest in reducing energy consumption and its associated costs, as demonstrated by changes in the telecommunication value chain and data center industry. Meanwhile, multinationals in the ICT sector have set the bar higher by embarking on net zero carbon strategies. Governments should create a strong enabling environment for these efforts and partner with the private sector in, for example, encouraging renewable energy power purchase agreements to power digital infrastructure and leverage the sector to drive demand for the local renewable energy sector.

- **Apply agile regulation principles.** The green–digital policy nexus is uncharted territory for most governments. Agile policy principles can help governments create a responsive enabling environment for green digitalization. So-called regulatory sandboxes and support for innovation test beds can enable novel approaches to data use and testing of climate-friendly digital technologies.
Executive Summary

For the global community, important tasks are at hand:

- **Improve research, standards, and innovation.** The ICT sector lags other sectors when it comes to understanding its links with climate change. Despite digitalizing rapidly, very few countries are able to report emissions from the ICT sector. Stronger methodologies and country-level capacity are needed. In the data center industry, efforts toward greening are common, but internationally recognized standards are lacking. The country-level or regional codes of conduct that are emerging are important for setting a common direction. For cross-sectoral technologies, the focus is moving from uncritical optimism to tough but necessary exploration of the positive and negative drivers of emissions. The multistakeholder partnerships leading the way will be critical in determining which solutions and approaches deserve to be scaled up through investments.

- **Introduce digital climate financing.** The adoption of digital technologies to fight climate change requires investment in digital foundations: networks, devices, applications, capabilities, and services. This investment calls for a new mindset when allocating climate financing. Currently, the ICT sector and digital foundations are largely ignored in climate financing. To unleash the power of digital solutions across sectors, financing should not be limited to sector-specific interventions. Similarly, digital technologies can help solve some of the fundamental challenges of wider climate financing, for example, by improving data collection, verification, and aggregation to create a more transparent and accountable carbon marketplace. The international community, including development banks, has a role to play on both fronts.

The Next Steps to Using and Greening Digitalization to Combat Climate Change

This report aims to provide policy makers in low- and middle-income countries with information about the opportunities and risks digitalization can bring to combating climate change. Climate action and digitalization are already policy priorities across many governments, providing the underpinnings for the transition to green digitalization. For the digital development community, two main challenges remain: (1) closing the digital divide in a sustainable way and (2) developing and scaling digital solutions in a way that ensures that climate dividends dwarf digital emissions.

As the climate and digital transformation agenda evolves, more research is needed to monitor and quantify the enabling effects of digital technologies and the carbon footprint of the ICT sector at both the country and global levels. The World Bank welcomes cross-sectoral collaboration and partnerships in moving this important agenda forward. This effort includes developing the guidance needed to help countries translate green digital ambitions into policies, investments, and innovations, as well as to leverage climate finance to catalyze digital technologies for climate action.
Note

1. Also called the information and communication technology (ICT) sector in this report.

References


Climate change is unfolding amid the greatest information and communication revolution in human history. From e-commerce and social media to smart manufacturing and precision farming, digital technologies have become prevalent in all aspects of economic and social life.

Digital technologies also have the potential to shape climate change action. Green digital transformation can help countries adapt effectively to the impacts of climate change and create greener growth pathways. Doing this means combining a focus on digital transformation and inclusion with a strategic and sustainable use of digital technologies to address climate change.

*Green Digital Transformation: How to Sustainably Close the Digital Divide and Harness Digital Tools for Climate Action* illuminates the channels through which digital technologies intersect with climate change, and it proposes a path to low-emissions applications of digital technologies to help countries mitigate and adapt to climate change.